A driver textural warning 23, such as the conventional textural warning "objects in mirror are closer than they appear", may be included in the outermost more curved portion 55 of an electrochromic multi-radius exterior mirror according to this invention. (See FIG. 13.) Alternatively, a driver textural warning may be included in the innermost less curved region 65. Heretofore, such warnings have been established through sandblasting or as described in O'Farrell. Alternatively, textural warnings may be applied by silkscreening onto a surface of one of the substrates 2,3 of the mirror assembly or by other suitable techniques, such as laser etching, onto the reflective element of the mirror which is coated onto a surface of substrate 3.

On demand displays 14 may be positioned behind the reflective element of the mirror (see FIGS. 9 and 10) and become activated by user input or by input from a sensor, such as a supplementary vision device (e.g., camera, sensor, proximity detector, blind-spot detector, infrared and microwave detector), temperature sensor, fuel sensor, fault detector, compass sensor, global positioning satellite detector, hazard detector or the like. In addition, a vehicle function (such as a turn signal, hand brake, foot brake, high beam selection, gear change, memory feature selection and the like) may activate the on demand display. The on demand display may also be activated by a function such as a compass, clock, a message center, a speedometer, an engine revolution per unit meter and the like. In the context of their use in conjunction with rearview mirrors for motor vehicles, an on demand display, when not active or activated, should desirably remain at least substantially unobservable or undetectable by the driver and/or passengers. Similarly, in other applications with which these on demand displays may be desirably used, they should remain at least substantially unobservable or undetectable when not activated.

On demand displays 14 should be an emitting electronic display, such as a vacuum fluorescent display, a light emitting diode, a gas discharge display, a plasma display, a cathode ray tube, an electroluminescent display and the like.

Conventionally, the reflective element in electrochromic mirrors is constructed by coating the rearmost (non-inward) surface of the second substrate 3, with a reflective element using a wet chemical silver line mirror coating. This rearmost surface is typically coated with a layer of silver 8, and then protected with a thin film layer of copper 19 which itself is overcoated with a protective material 20, typically a paint such as a lead-based paint. In this construction, the light transmissivity through the mirror is substantially opaque—i.e., substantially less than about 0.01%. To place a display, camera, sensor or the like behind such a conventional mirror, a "window" 13 through which light may pass must be created as described hereinafter.

With reference to FIGS. 8, 9 and 10, it may be seen that on demand display capability may be introduced to a mirror through the window 13 that has been previously created therein [typically, by sand blasting, mechanical erosion (e.g., with a spinning rubber), laser etching, chemical etching and the like] by coating a layer of reflective material, such as a thin film of a metal 16 (e.g., a medium reflector, such as chromium, titanium, stainless steel and the like, having a thickness preferably less than about 750 Å), onto the rearmost (non-inward) surface of substrate 3 at the portion of the substrate where the window 13 exists. (See FIG. 10.) It may be preferable to use a medium reflector, such as chromium, titanium, stainless steel and the like, because such medium reflectors are durable, scratch resistant and resistant to environmental degradation without the need for additional overcoat layers like paints, lacquers, or other oxide coatings. Nevertheless, such overcoat layers may, of course, be used. Also, a high reflector such as silver or aluminum may be used, if desired. The window 13, now being only partially opaque in light transmissivity, is substantially light reflecting.

This partially transmitting/substantially reflecting window may be established through evaporating or sputtering (using vacuum deposition techniques) chromium metal over the window to a thickness of up to about 750 Å. By so doing, light transmittance within the range of about 1% to about 10% may be achieved, while also achieving light reflectance within the range of about 40% to about 65%. This method, however, introduces increased manufacturing costs (e.g., by first creating the window in the silver line-coated rearmost surface of substrate 3 and then vacuum depositing thereover the thin film of chromium). Also, the differences in reflectivity between the higher reflectance off the silver reflective element and the lower reflectance off the partially transmitting, lesser reflecting window may be detectable by or noticeable to an observer.

An alternative method involves the use of a partially transmitting (i.e., light transmission within the range of at least about 1% to about 20%), substantially reflecting (i.e., light reflectance within the range of 10 least about 40% to greater than about 70%) metal foil or reflector-coated polymer sheet or film 15, such as metalized polymer sheet or film, like aluminum or chromium coated acrylic sheet or polyester "MYLAR" film (commercially available from Du Pont). Such a foil, or sheet or film 15, reflector coated with a thin film of metal 16 may be contacted with, or adhered to using an optical adhesive 18, preferably an index matching adhesive such as described hereinafter, the window 13 in the layer of reflective material on substrate 3.

Likewise, an appropriately sized glass cover sheet 15 (or a polymer cover sheet) which is coated with a thin film of metal 16 that is partially light transmitting (preferably, about 1% to about 20%), and yet substantially light reflecting (preferably, at least about 40% to greater than about 70%) may be contacted with, or adhered to using an optical adhesive 18 as described herein, the window 13 in the layer of reflective material on substrate 3. (See FIG. 9.)The glass cover sheet 15 may be any desired shape and should be sufficiently large to at least cover the entire window 13 created in the silver-coated, rearmost surface of substrate 3 (which may be suitable to accommodate, for example, compass displays, like the compass displays described in O'Farrell and Larson).

It may be convenient to coat glass lites with a high reflector, such as a thin film coating of aluminum or silver, to a thickness that achieves the desired partial light transmittance and substantial light reflectance. Alternatively, a medium reflector, such as a thin film coating of chromium, stainless steel, titanium or the like, may be used to coat the glass lites.

An inorganic oxide coating, such as silicon dioxide, titanium dioxide, zinc oxide or the like, may also be overcoated onto the thin film metal reflector coating to impart resilience, resistance against environmental degradation, enhance scratch resistance and enhance optical performance. Likewise, a thin film of magnesium fluoride, or a combination of thin films of dielectric materials such as described supra, may be used to overcoat the thin film metal reflector coating. A clear coat of a lacquer, such as an acrylic- or a urethane-based lacquer or the like, is still another choice which may be used to overcoat the thin film metal reflector coating.

Once formed, the partially transmitting/substantially reflecting glass lites may be subdivided into a multitude of smaller sized cover sheets to cover the window in the reflector on the rearmost (non-inward) surface of substrate 3. More specifically, a square, circle or rectangle may be cut to dimensions of about 1 to about 6 mm or larger than the dimensions of the window for the display. The square- or rectangular-shaped glass cover sheets may then be contacted with, or adhered to, the rearmost (non-inward) surface of substrate 3 to cover the previously established window for the display.

An optical adhesive 18 that is index matched to the refractive index of glass (i.e., about 1.52) may be used to adhere the glass cover sheet 15 to the rearmost (non-inward) surface of substrate 3. Such optical adhesives maximize optical quality and optical index matching, and minimize interfacial reflection, and include plasticized polyvinyl butyral, various silicones, polyurethanes such as "NORLAND NOA 65" and "NORLAND NOA 68", and acrylics such as "DYMAX LIGHT-WELD 478". The glass cover sheet 15 may be positioned with its semitransparent metal reflector coating 16 closest to the rearmost (non-inward) surface of substrate 3 so that the mirror construction comprises an assembled stack of the glass cover sheet 15/semitransparent reflector metal coating 16/optical adhesive 18/rearmost (non-inward) surface of substrate 3. In this construction, the optical adhesive is used as both an adhesive and as a protectant for the semitransparent metal reflector-coating 16 of the glass cover sheet 15. Such a use of semitransparent reflector-coated glass cover sheets 15/16 lends itself to economical and automated assembly. Also, the cover sheet may be made from glass that is coated with a dichroic mirror or made from polymer reflector material ("PRM"), as described hereinafter.

As an alternative to localized reflector coating with a thin metal film as shown in FIG. 10, or localized use of cover sheets, foils, films, and the like as shown in FIG. 9, at the non-inward surface of substrate 3 at window 13, similar localized reflector means can be employed at the inward facing surface of substrate 3 at the location of window 13.

An emitting display 14 may also be positioned behind the rearmost (non-inward) surface of the glass cover sheet 15 (which itself is positioned behind substrate 3 of the electrochromic mirror assembly). In this regard, it may be desirable to use a thin glass for the cover sheet 15 to minimize multiple imaging and/or double imaging. The thickness of the cover sheet need not be thicker than about 0.063", with suitable thicknesses being about 0.063"; about 0.043"; about 0.028"; about 0.016" and about 0.008". However, if desired the thickness of the cover sheet 15 may be greater than about 0.063".

Again with reference to FIG. 5, where the layer of reflective material is coated onto the inward surface of substrate 3, improved optical performance may be observed without reducing the thickness of substrate 3. In such constructions, a relatively thick glass (having a thickness of greater than about 0.063") may be used for substrate 3 with a thin glass (having a thickness of about 0.063" or less) used for substrate 2 while maintaining good mechanical properties due to the relatively greater stiffness of substrate 3. Improved optical performance may also be observed due to the relative closeness of the layer of reflective material (coated onto the inward surface of substrate 3) and the frontmost (non-inward) surface of substrate 2.

An illustration of this aspect of the present invention may be seen where substrate 3 is fabricated from "TEC 10" glass (having a sheet resistance of about 10 ohms per square), with a thickness of about 3 mm, and substrate 2 is fabricated from soda-lime glass (coated with HW-ITO having a sheet resistance of about 12 ohms per square as a substantially transparent conductive electrode coating 4), with a thickness of about 0.043". In this construction, the fluorine-doped tin oxide surface of the substrate 3 fabricated from "TEC 10" glass is positioned inward (and overcoated with a metal reflector/conductive electrode coating 4') and the HW-ITO coated surface of substrate 2 is also positioned inward so that the coated substrates 2,3 face one another.

A silicon or similar elemental semiconductor material may also be used as a reflective element 8 coated onto either the rearmost (non-inward) surface or the inward surface of substrate 3. Methods for making elemental semiconductor mirrors for motor vehicles are taught by and described in commonly assigned co-pending U.S. patent application Ser. No. 07/700,760, filed May 15, 1991 ("the '760 application"), the disclosure of which is hereby incorporated herein by reference. Where it is desired that the high reflectance off the elemental semiconductor reflector be within the range of at least about 60% to greater than about 70%, an undercoat of a thin film layer of silicon dioxide between a thin film layer of silicon and the surface of the substrate onto which it is coated may be used to enhance reflectivity performance [see e.g., the '760 application, and U.S. Pat. No. 4,377,613 (Gordon) and U.S. Pat. No. 4,419,386 (Gordon), the disclosures of each of which are hereby incorporated herein by reference].

In addition, the layer of silicon and/or an undercoat of silicon dioxide may be deposited using techniques such as vacuum deposition, spray deposition, CVD, pyrolysis and the like. For example, in-line deposition on a float glass line, and preferably in-bath, in-line deposition on a float glass line (as known in the glass manufacturing art) using CVD may be employed to deposit silicon layers and silicon/silicon dioxide thin film stacks onto float glass to provide a reflector for substrate 3 that is both highly reflecting and partially transmitting. A further advantage of these elemental semiconductor coatings is that they are bendable.

For example, a glass coated with a reflective element may be constructed by depositing onto a glass substrate a first layer of elemental silicon at an optical thickness of about 6,950 Å, followed by deposition of a second layer of silicon dioxide at an optical thickness of about 1,050 Å, which in turn is followed by deposition of a third layer of elemental silicon at an optical thickness of about 1,600 Å. Such a construction has a luminous reflectance of about 69% before heating and bending; and a luminous reflectance of about 74% after heating and bending. A substantially transparent conductive electrode coating, such as doped tin oxide (e.g., fluorine-doped tin oxide) and the like, may be coated over the third layer of elemental silicon to construct a highly reflecting, electrically conducting glass substrate suitable for use in electrochromic mirrors and electrochromic devices where the coated substrate may be bent without unacceptable deterioration in its optical and electrical properties. Preferably, reflector-coated substrates constructed using multi-layer stacks, such as a glass/silicon/silicon dioxide/silicon stack (with or without additional undercoating or overcoating stack layers), may be deposited in-bath, on-line onto glass being manufactured on a float glass line.

It may also be advantageous to employ bendable reflector-coated substrates and techniques for manufacturing the same as taught by and described in the '760 application, and multi-layer stacks, such as the glass/silicon/silicon dioxide/silicon stack as described supra, with or without an additional overcoating of a substantially transparent conductive electrode coating such as fluorine-doped tin oxide and the like. Bendable coatings may be advantageous in minimizing manufacturing requirements since depositing a thin film of metal generally requires the steps of first bending the non-reflector coated substrate and then coating the bent substrate with the layer of reflective material.

As described supra, it may be advantageous to construct electrochromic mirrors whose reflective element 8 is located within the laminate assembly. This may be achieved by coating the inward surface of substrate 3 with a layer of reflective material 8, such as silver, so that the silver coating (along with any adhesion promoter layers 11) is protected from the outside environment. For example, a layer of reflective material 8 may be vacuum deposited onto the inward surface of substrate 3 in one and the same process step as the subsequent deposition of the electrochromic solid film 7 onto substrate 3. This construction and process for producing the same not only becomes more economical from a manufacturing standpoint, but also achieves high optical performance since uniformity of reflectance across the entire surface area of the mirror is enhanced. The thin film stack [which comprises the electrochromic solid film 7 (e.g., tungsten oxide), the layer of reflective material 8 (e.g., silver or aluminum) and any undercoat layers between the layer of reflective material 8 and substrate 3] should have a light reflectance within the range of at least about 70% to greater than about 80%, with a light transmission within the range of about 1% to about 20%. Preferably, the light transmission is within the range of about 3% to about 20%, and more preferably within the range of about 4% to about 8%, with a light reflectance greater than about 80%. The inward facing surface of substrate 3 may be coated with a multi-layer partially transmitting/substantially reflecting conductor comprising a partially transmitting (preferably, in the range of about 1% to about 20%)/substantially reflecting (preferably, greater than about 70% reflectance, and more preferably, greater than about 80% reflectance) metal layer (preferably, a silver or aluminum coating) that is overcoated with an at least partially conducting transparent conductor metal oxide layer [comprising a doped or undoped tin oxide layer, a doped or undoped indium oxide layer (such as indium tin oxide) or the like]. Optionally, an undercoating metal oxide (or another at least partially transmitting metal compound layer, such as a metal nitride like titanium nitride) may be included in the stack which comprises the multi-layer conductor. This multi-layer conductor functions as reflective element 8, and can be overcoated with electrochromic solid film 7 during fabrication of an electrochromic mirror incorporating on demand displays. Alternatively, the multi-layer conductor described supra may be used on the inward surface of substrate 3, with the electrochromic solid film 7 coated onto the inward surface of substrate 2.

A light reflectance of at least 70% (preferably, at least 80%) for the reflective element to be used in an electrochromic mirror incorporating on demand displays is desirable so that the bleached (unpowered) reflectivity of the electrochromic mirror can be at least 55% (preferably, at least 65%) as measured using SAE J964a, which is the recommended procedure for measuring reflectivity of rearview mirrors for automobiles. Likewise, a transmission through the reflective element of, preferably, between about 1% to 20% transmission, but not much more than about 30% transmission (measured using Illuminant A, a photopic detector, and at near normal incidence) is desirable so that emitting displays disposed behind the reflective element of the electrochromic mirror are adequately visible when powered, even by day but, when unpowered and not emitting, the displays (along with any other components, circuitry, backing members, case structures, wiring and the like) are not substantially distinguishable or visible to the driver and vehicle occupants.

With reference to FIGS. 9 and 10, emitting displays 14, such as vacuum fluorescent displays, light emitting diodes, gas discharge displays, plasma displays, cathode ray tubes, electroluminescent displays and the like may also be placed in contact with, or adhered to using an adhesive 17, 18 such as an epoxy, the rear of substrate 3. Generally, such emitting displays may only be observable when powered so as to emit light.

A variety of emitting displays 14 may be used in this connection including, but not limited to, double heterojunction AlGaAs very high intensity red LED lamps, such as those solid state light emitting display LED lamps which use double heterojunction Al/GaAs/GaAs material technology [commercially available from Hewlett Packard Corporation, Palo Alto, Calif. under the designation "T-1¾ (5 mm) HLMP-4100-4101"].

Alternatively, vacuum fluorescent displays, such as 12V battery driven high luminance color vacuum fluorescent displays may be advantageously used [commercially available from Futaba Corporation of America, Schaumburg, Ill. under the designations S-2425G, S-24-24G, S-2396G and S2397G]. It may also be advantageous to use displays 14 that operate efficiently at about 12V or lower since these voltages are particularly amenable to motor vehicles. Also, ultrahigh luminance vacuum fluorescent displays, suitable for heads-up-display applications in motor vehicles may be used with appropriate circuitry, such as Type 3-LT-10GX [commercially available from Futaba Corporation]. Suitable vacuum fluorescent displays are also commercially available from NEC Electronics Incorporated, Mountain View, Calif., such as under the designation Part No. FIP2QM8S.

It may also be desirable, particularly where the reflective element is at least partially light transmitting, to use a light absorbing means, such as a black-, brown- or blue-colored or other suitably colored absorbing coating, tape, paint, lacquer and the like, on portions of the rearmost (non-inward) surface of substrate 3 where displays are not mounted. It may be desirable to use substantially opaque, and preferably dark colored tape or plastic film and the like, across the surface of substrate 3, such as by adhering to protective material 20, preferably across substantially the entire rear surface, except where any displays are to be positioned. By so doing, any secondary images or aesthetically non-appealing mirror case illumination due to stray light emittance from the display may be reduced.

Placement of apertures or cutouts in a tape or film backing may expedite the assembly of such mirrors by guiding the assembler to the point where the desired display or displays is to be mounted. The tape or film backing may also serve as an anti-scatter means to enhance safety and prevent injury by retaining any glass shards which may result due to mirror breakage, for example caused by impact from an accident.

Suitably colored paints, inks, plastic films or the like may be applied to the surface of substrate 3 where the display 14 is to be placed to change or effect the color of the display. Also, the display 14 may be adhered to a surface of the substrate using an adhesive 18, such as an index matching adhesive 17, 18, that may be dyed to effect color and/or contrast enhancement in the display [see e.g., Larson, the disclosure of which is hereby incorporated herein by reference].

Generally, and particularly when the electrochromic element is in its bleached, uncolored state, it may be desirable for the image of the display—e.g., an information display, such as a compass display, a clock display, a hazard warning display or the like—to have a luminance within the range of at least about 30 foot lamberts to about 80 foot lamberts (preferably, within the range of at least about 40 foot lamberts to about 60 foot lamberts), as measured with the display placed behind, and emitting through, the electrochromic mirror and with the electrochromic element in its fully transmitting, bleached state. With this level of luminance, such a display may be read easily even with bright ambient levels of light. Also, the electronic circuitry taught by and described in Larson may be used to appropriately dim the display to suit nighttime driving conditions and/or to compensate for any dimming of the electrochromic element. Generally, at night the luminance of the display is about 15–40%, preferably about 20–35%, that of the daytime value.

During daytime lighting conditions, drivers of motor vehicles mounted with an electrochromic mirror (interior, exterior or both) benefit from relatively high reflectance (at least about 55%, with at least about 65% typically being preferred) when in the bleached "day" state. Any display positioned behind the electrochromic mirror should have a sufficiently high luminance to permit the display (which may be digital, alpha-numeric, analog or combinations thereof) to emit therethrough and be readable. The display 14 should be readable even when ambient conditions within the cabin of a motor vehicle (or outside, where electrochromic exterior rearview mirrors are used or where the electrochromic interior rearview mirror is mounted in a convertible with its top down) are bright, such as midday on a sunny, cloudless day. The mirrors of the present invention may achieve a light reflectance of at least about 55% for the high reflectance state where a high reflector in the form of a thin film metal coating is used with a sufficient thickness to allow for light to transmit through the electrochromic element 1, preferably within the range of about 1% to about 15% transmission, but not exceeding about 30% (as measured using Illuminant A and a photopic detector, with near normal incidence). More specifically, where silver is used as a high reflector, the mirrors of the present invention may achieve a light reflectance of at least about 65% for the high reflectance state with a light transmission therethrough within the range of about 1% to about 20% transmission (measured as described supra). The thin film metal coating may have a thickness within the range of about 200 Å to about 1,500 Å, preferably within the range of about 200 Å to about 750 Å.

It may also be desirable, particularly when used in conjunction with highly spectrally selective light emitting diodes and the like, to use PRM as a reflector placed between the display 14 and the rearmost (non-inward) surface of substrate 3. PRM is a spectrally selective, substantially reflecting (greater than about 50%) and significantly transparent polymer reflector material [see T. Alfrey, Jr. et al., "Physical Optics of Iridescent Multilayered Plastic Films", *Polym. Eng'g. & Sci.*, 9(6), 400–04 (1969); W. Schrenk et al., "Coextruded Elastomeric Optical Interference Film", *ANTEC* '88, 1703–07 (1988); and see generally U.S. Pat. No. 3,711,176 (Alfrey, Jr.); U.S. Pat. No. 3,557,265 (Chisolm) and U.S. Pat. No. 3,565,985 (Schrenk). PRM is commercially available from Dow Chemical Co., Midland, Mich., such as under the designation PRM HU75218.03L, which is a 0.125" thick sheeting made of multiple polymer layers (e.g., 1305 layers), having differing refractive indices and transparent/transparent CAP layers. This PRM exhibits a light reflectance of about 58% and a generally neutral light transmittance. Another PRM, designated as PRM HU75218.08L, also is a 0.125" thick sheeting, made from multiple polymer layers (e.g., 1305 layers), with a light reflectance of about 58%. However, this PRM has transparent/red CAP layers which results in a transmission which has a distinctly red tint. As such, it may be particularly well-suited for use in conjunction with the mirrors of the present invention that employ in their construction red light emitting diodes, such as those typically employed in hazard warning devices.

An array of light emitting diodes may be positioned behind a window 13 in a mirror with an appropriately sized piece of PRM positioned between the emitting displays 14 and the rearmost (non-inward) surface of the substrate 3. By choosing a PRM with a selective transmission which permits the passage of the bandwidth of light emitted by the emitter but that substantially attenuates other wavelengths not within that bandpass of light, optical efficiency may be enhanced. Indeed, PRM itself may be an appropriate reflective element behind which display emitters may be disposed. While PRM may be vulnerable to scratching and susceptible to degradation from environmental exposure, substrates 2,3 offer desirable protection from such damage. Use of PRM where the piece of PRM is larger than and covers the window created in the reflective element on substrate 3 (but is smaller than the entire surface area of substrate 3) is particularly attractive compared to the use of conventional dichroic mirrors [such as thin film dielectric stack dichroic mirrors (commercially available from Optical Coatings Labs, Santa Rosa, Calif.)] as the reflective element because of economic benefits.

Should it be desirable to use a PRM/emitting display, a substrate with or without a thin film of metal reflector coating that is substantially transmitting may be positioned in front of the PRM. Suitable optical adhesives, preferably index matching adhesives as described supra, may be used to construct a mirror that comprises a light emitting element which emits light through a sheet of PRM, which is positioned behind a glass substrate through which the emitted light also passes. Such a mirror would appear reflective when the light emitting element (e.g., a red LED such as described supra) is unpowered, yet would efficiently display a warning indicia when the light emitting element is powered, strobed or flashed. Also, PRM being a polymer material is relatively easily formed by molding, slumping, bending and similar polymer forming methods, so conformance to a compound curvature or convex curvature is facilitated.

In that aspect of the present invention directed to exterior rearview mirrors for motor vehicles, it may be advantageous to use in conjunction therewith signal lights, security lights, flood lights, remote actuation and combinations thereof as taught by and described in commonly assigned co-pending U.S. patent application Ser. No. 08/011,947, filed Feb. 1, 1993 ("the '947 application"), the disclosure of which is hereby incorporated herein by reference.

The electrochromic mirrors of the present invention may also include an anti-reflective means, such as an anti-reflective coating, on the front (non-inward) surface of the outermost or frontmost substrate as viewed by an observer (see e.g., Lynam V); an anti-static means, such as a conductive coating, particularly a substantially transparent conductive coating, ITO, tis ITO, tin oxide and the like; index matching means to reduce internal and interfacial reflections, such as thin films of an appropriately selected optical path length; and/or light absorbing glass, such as glass tinted to a neutral density, such as "GRAYLITE" gray tinted glass (commercially available from Pittsburgh Plate

Glass Industries) and "SUNGLAS" gray tinted glass (commercially available from Ford Glass Co., Detroit, Mich.), which assists in augmenting contrast enhancement. Moreover, polymer interlayers, which may be tinted gray, such as those used in electrochromic devices as taught by and described in Lynam I. may be incorporated into the electrochromic mirrors described herein.

The mirrors of this present invention, particularly rearview mirrors intended for use on the exterior motor vehicles, may also benefit from an auxiliary heating means used in connection therewith such as those taught by and described in U.S. Pat. No. 5,151,824 (O'Farrell) and U.S. patent application Ser. No. 07/971,676, filed Nov. 4, 1992 ("the '676 application"), the disclosures of each of which are hereby incorporated herein by reference. Preferred among such heating means are positive temperature coefficient ("PTC") heater pads such as those commercially available from ITW Chromomatic, Chicago, Ill. These heater pads employ conductive polymers, such as a crystalline organic polymer or blend within which is dispersed a conductive filler like carbon black, graphite, a metal and a metal oxide, [see e.g., U.S. Pat. No. 4,882,466 (Friel)]. The heater pads exhibit a positive temperature coefficient; that is, their resistance increases when the surrounding temperature increases. Thus, the heater pads may be used as a self-regulating heating element.

As an alternative to a heater pad, a heater means, such as a resistance layer or heating film, may be deposited (such as through vacuum deposition, thick film printing, screen printing, dispensing, contact printing, flow coating and the like) onto the outward facing surface of substrate 3 (i.e., onto the rearmost surface of an electrochromic mirror assembly). Suitable heater means include a PTC material, a metal thin film layer (such, chromium, molybdenum, a nickel-based alloy like Inconel and Hastelloy, stainless steel, titanium and the like), and a transparent conductor thin film [such as tin oxide (doped or undoped) and indium tin oxide]. Such heater means are disclosed in the '676 application.

The heater means referred to above function both to assure rapid coloration and bleaching of an electrochromic rearview mirror when operated at low temperatures, and to remove any frost or dew which may accumulate on the outward facing surface of substrate 2 (i.e., the outermost surface of the rearview mirror that is contacted by outdoor elements like rain, snow, dew and the like). For example, a convex or multi-radius electrochromic outside mirror for an automobile may be fabricated by forming substrate 3 through bending a fluorine-doped tin oxide coated glass substrate (such as a "TEC-Glass" product like "TEC 20", "TEC 12" or "TEC 10") so that the transparent conductor doped tin oxide thin film coating is located on the concave surface of substrate 3. The opposite, convex surface of substrate 3 is coated with a metal reflector layer (such as silver, optionally being undercoated with a chromium adhesion promoter layer) and the reflector in turn is contacted with an electrochromic layer, such as tungsten oxide. This convex surface reflector coated/concave surface transparent conductor coated substrate 3 is then mated with an equivalently bent substrate 2 that is coated on its concave (inward facing) surface with a transparent conductor (such as fluorine doped tin oxide), and with an electrolyte between the mated substrates to form an electrochromic exterior rearview mirror. Next, bus bars (e.g., a conductive frit, solder or the like) are formed on opposing sides of the transparent conductor thin film heater on the rearmost, concave surface of substrate 3. When connected to the 12 volt battery/ignition electrical supply of a vehicle, the transparent conductor thin film heater on the rearmost, concave surface of substrate 3 heats the electrochromic medium and defrosts the front, outermost, concave surface of substrate 2.

If a display is to be mounted behind the reflective element, an appropriately sized and shaped aperture through the auxiliary heating means should be used to accommodate the display but not leave portions of the mirror unheated for de-icing or de-misting purposes. Likewise, should a heat distribution pad be used, such as an aluminum or copper foil as described in the '676 application, an appropriately sized and shaped aperture should also be provided therein to accommodate such displays. Where apertures are to be included in a PTC heater pad, a pattern of resistive electrodes which contact the conductive polymer, which may typically be applied by a silk-screening process as described in Friel, should be designed to accommodate the apertures in the pad. In addition, such a pattern may also be useful to thermally compensate for the apertures in the pad. Alternatively, the resistive electrode/conductive polymer combination may be applied, for example, directly onto the rearmost (non-inward) surface of substrate 3, or onto a heat distribution pad that is contacted and/or adhered thereto.

It may also be advantageous to provide mirrors in the form of a module, which module comprises the mirror itself and its electrical connection means (e.g., electrical leads); any heater pad (optionally, including a heat distribution pad) and associated electrical connection means; bezel frames; retaining members (e.g., a one-piece plate) and electrical connection means (see e.g., O'Farrell); actuators [e.g., Model No. H16-49-8001 (right-hand mirror) and Model No. H16-49-8051 (left-hand mirror), commercially available from Matsuyama, Kawoge City, Japan] or planetary-gear actuators [see, U.S. Pat. No. 4,281,899 (Oskamo) and the '947 application, the disclosures of each of which are hereby incorporated herein by reference] or memory actuators that include memory control circuitry such as Small Electrical Actuator #966/001 which includes a 4 ear adjusting ring, 25 degree travel and an add-on memory control and is available from Industrie Koot B. V. (IKU) of Montfort, Netherlands; and brackets for mounting the module within the casing or housing of a mirror assembly such as taught by and described in the '947 application. Electrochromic mirrors may be assembled using these items to provide modules suitable for use with a mirror casing or housing that includes the electrochromic element, which incorporates the reflective element and any associated components such as heater means, bezel means, electrically or manually operable actuation means, mounting means and electrical connection means. These components may be pre-assembled into a module that is substantially sealed from the outside environment through the use of sealants like silicones, epoxies, epoxides, urethanes and the like. These components may also be formed and/or assembled in an integral molding process, such as with those processes described in U.S. Pat. No. 4,139,234 (Morgan) and U.S. Pat. No. 4,561,625 (Weaver), each of which describe suitable molding processes in the context of modular window encapsulation. An added-value electrochromic mirror module, including the actuators which allow adjustment and selection of reflector field of view when mounted within the outside mirror housings attached to the driver-side and passenger-side of a vehicle, may be pre-assembled and supplied to outside vehicular mirror housing manufacturers to facilitate ease and economy of manufacturing.

Many aspects of the present invention, particularly those relating to the use of PRM and emitting displays; glass cover sheets, foils and the like; and thin film metal coatings that are applied locally and that are substantially reflecting and partially transmitting, may of course be employed with non-electrochromic rearview mirrors for motor vehicles, such as conventional prismatic mirrors. For instance, with exterior rearview mirrors for motor vehicles, a driver-side rearview mirror and a passenger-side rearview mirror may be mounted in combination on a motor vehicle to be used to complement one another and enhance the driver's rearward field of view. One of such mirrors may be an electrochromic mirror and the other mirror may be a non-electrochromic mirror, such as a chromed-glass mirror, with both exterior mirrors benefitting from these aspects of the present invention. In addition, these aspects of the present invention may be employed in connection with a display window that has been established in a prismatic mirror.

Substrate 2 may be of a laminate assembly comprising at least two transparent panels affixed to one another by a substantially transparent adhesive material, such as an optical adhesive as described herein. This laminate assembly assists in reducing the scattering of glass shards from substrate 2 should the mirror assembly break due to impact. Likewise, substrates 2,3 may each be of such a laminate assembly in a glazing, window, sun roof, display device, contrast filter and the like.

Also, the outermost surface of substrate 2 (i.e., the surface contacted by the outdoor elements including rain, dew and the like when, for example, substrate 2 forms the outer substrate of an interior or exterior rearview mirror for a motor vehicle constructed such as shown in FIGS. 1 to 13) can be adapted to have an anti-wetting property. For example, the outermost glass surface of an exterior electrochromic rearview mirror can be adapted so as to be hydrophobic. This reduces wetting by water droplets and helps to obviate loss in optical clarity in the reflected image off the exterior mirror when driven during rain and the like, caused by beads of water forming on the outermost surface of the exterior electrochromic mirror assembly. Preferably, the outermost glass surface of the electrochromic mirror assembly is modified, treated or coated so that the contact angle θ (which is the angle that the surface of a drop of liquid water makes with the surface of the solid anti-wetting adapted outermost surface of substrate 2 it contacts) is preferably greater than about 90°, more preferably greater than about 120° and most preferably greater than about 150°. The outermost surface of substrate 2 may be rendered anti-wetting by a variety of means including ion bombardment with high energy, high atomic weight ions, or application thereto of a layer or coating (that itself exhibits an anti-wetting property) comprising an inorganic or organic matrix incorporating organic moieties that increase the contact angle of water contacted thereon. For example, a urethane coating incorporating silicone moieties (such as described in Lynam II, the disclosure of which is hereby incorporated by reference) may be used. Also, to enhance durability, diamond-like carbon coatings, such as are deposited by chemical vapor deposition processes, can be used as an anti-wetting means on, for example, electrochromic mirrors, windows and devices.

It is clear from the teaching herein that should a glazing, window, sun roof, display device, contrast filter and the like be desirably constructed, the reflective element 8 need only be omitted from the assembled construction so that the light which is transmitted through the transparent substrate is not further assisted in reflecting back therethrough.

In the aspects of the present invention concerning electrochromic devices, particularly electrochromic optical attenuating contrast filters, such contrast filters may be an integral part of an electrochromic device or may be affixed to an already constructed device, such as cathode ray tube monitors. For instance, an optical attenuating contrast filter may be manufactured using an electrochromic element as described herein and then affixing it to a device, using a suitable optical adhesive. In such contrast filters, the constituents of the electrochromic element should be chosen so that the contrast filter may color to a suitable level upon the introduction of an applied potential thereto, and no undesirable spectral bias is exhibited.

Also, an electrochromic reflector according to this invention can be used with a refracting means comprising a first refractor and a second refractor. The first refractor diverts incident light towards the electrochromic variably dimmable reflector. The second refractor is positioned so that light from the first refractor is incident thereon and directs light from the electrochromic reflector towards the observer (typically, the driver of a motor vehicle). A refracting means suitable for use in accordance with this invention is described in U.K. Patent GB 2,254,832B for "A Rear View Mirror Unit", the disclosure of which is hereby incorporated herein by reference.

A synchronous manufacturing process, such as the one represented in FIG. 15, may be used for the production of both interior and exterior electrochromic rearview mirrors. For example, uncoated glass shapes (which may be flat shapes, curved shapes or multi-radius shapes) already cut to the desired shape and size of the substrate 2 are loaded into the evaporative coater 1500 and a transparent conductor (such as indium tin oxide) is deposited thereon [such as by electron beam evaporation at a rate of about 3–5 Å/sec using an oxygen backfill pressure within the range of from about 5×10^{-5} torr to about 9×10^{-4} torr oxygen partial pressure and with the substrate heated to a temperature within the range of about 200° C. to about 450° C.]. Synchronous with this deposition, uncoated glass shapes already cut to the desired shape and size of the substrate 3 are loaded into the evaporative coater 1510. An adhesion layer of chromium, followed by a reflector layer of aluminum, followed by an electrochromic solid film layer of tungsten oxide are then deposited thereon. After substrate coating is complete, the substrates 2,3 pass to a seal dispensing station 1520 where a high speed, computer-controlled automatic fluid dispensing system (such as AUTOMOVE 400) is used to dispense a latent cure, one-package epoxy around the edge periphery of the transparent conductor coated surface of the substrate 2. Next, and with the substrates 2,3 held in fixtures, the respective inwardly-facing surfaces are mated, with the weight of the fixture itself providing a temporary hold to keep the mated surfaces in place. The sandwiched parts are then moved to a conveyorized oven or lehr 1530, where the latent curing agent in the latent cure epoxy is activated by exposure to a temperature of at least about 110° C. Upon exiting the conveyorized oven or lehr 1530, the now permanently mated cell is removed from the fixtures (which are themselves reusable) and the cell is filled and finished at the fill/assembly station 1540. Use of such a synchronous manufacturing process, and particularly when a latent cure epoxy is used which is dispensed by an automatic fluid dispenser, with the epoxy cured in a conveyorized oven or lehr, is well-suited for economic, high volume, lean manufacturing of products, such as interior and exterior electrochromic rearview mirrors.

Many aspects of the present invention, especially those concerning mirror construction, use of elemental semiconductor layers or stacks (with or without an additional undercoat of silicon dioxide and/or an overcoat of doped tin oxide), PRM, anti-wetting adaptation, synchronous manufacturing, localized thin film coatings, multi-layer transparent conducting stacks incorporating a thin metal layer overcoated with a conducting metal oxide layer, conducting seals, variable intensity band pass filters, isolation valve vacuum backfilling, cover sheets and on demand displays, may of course be incorporated into electrochromic mirrors and electrochromic devices that employ electrochromic technology for the electrochromic element different from that which is taught and described herein, such as electrochromic solution technology of the electrochemichromic type (e.g., Byker I, Byker II, Varaprasad I and Varaprasad III) and electrochromic solid film technology (e.g., the '675 application, the '557 application and Lynam I), including electrochromic organic thin film technology, in which a thin film of organic electrochromic material such as a polymerized viologen is employed in the electrochromic element [see e.g., U.S. Pat. No. 4,473,693 (Wrighton)].

Also, an electrochromic solid film may be used which is formed of an inorganic metal oxide, such as a semiconductor electrode of transparent polycrystalline titanium dioxide (TiO_2), to which is attached a redox species (such as a viologen) using a chelate (spacer) such as salicylic acid chemiabsorbed to the TiO_2 by chelation to surface Ti^{4+} atoms. When such a solid film [such as is described in Marquerettaz et al., *J. Am. Chem. Soc.*, 116, 2629–30 (1994), the disclosure of which is hereby incorporated herein by reference] is deposited (preferably with a thickness of about 0.1 μm to about 10 μm) upon an electronic conducting layer, such as fluorine-doped tin oxide, an electron donor (TiO_2)—spacer (the salicylic acid bound to the TiO_2)—electron acceptor (the viologen bound to the salicylic acid) heterodyad is formed that is capable of efficient electrochromic activity. Such donor-spacer-acceptor complexes can include multiple acceptors, such as may be formed when a second acceptor (such as a quinone like anthraquinone) is linked to a first acceptor (such as a viologen). Such a donor-spacer-acceptor solid film can function as an electrochromic solid film, and may be advantageously employed in the electrochromic rearview mirrors, windows, sun roofs and other devices of this invention.

The electrochromic medium can comprise a variety of electrochromically active moieties attached, such as by chemical bonding, to an organic or inorganic matrix, and/or included in a polymer structure as electrochromically active sites. For example, an electrochromically active phthalocyanine-based, and/or phthalocyanine-derived, moiety that, preferably, is color-fast and UV stable in both its reduced and oxidized state, can be included in the electrochromic medium, preferably as part of a solid film. Electrochromically active phthalocyanines that can be incorporated in a solid, and/or formed as a solid, include transition metal phthalocyanines such as zirconium phthalocyanines and molybdenum phthalocyanines, such as described in J. Silver et al., *Polyhedron*, 8(13/14), 1163–65 (1989), the disclosure of which is hereby incorporated herein by reference; solid state polymerized phthalocyanines such as are formed by thermal polymerization of dihydroxy(metallo) phthalocyanine compounds of Group IVa elements as disclosed by K. Beltios et al., *J. Polym. Sci.: Part C: Polymer Letters*, 27, 355–59 (1989), the disclosure of which is hereby incorporated herein by reference; silicon phthalocyanine-siloxane polymers such as described in J. Davison et al., *Macromolecules*, 11(1), 186–91 (January–February 1978), the disclosure of which is hereby incorporated herein by reference; and lanthanide diphthalocyanines such as lutetium diphthalocyanine such as described by G. Corker et al., *J. Electrochem. Soc.*, 126, 1339–43 (1979), the disclosure of which is hereby incorporated herein by reference. Such phthalocyanine-based electrochromic media, preferably in solid form and, most preferably, UV stable in both their oxidized and reduced states, may be advantageously employed in the electrochromic rearview mirrors, windows, sunroofs, and other device of this invention.

Once constructed, the electrochromic device, such as an electrochromic mirror, may have a molded casing or housing placed therearound. This molded casing or housing may be pre-formed and then placed about the periphery of the assembly or, for that matter, injection molded therearound using conventional techniques, including injection molding of thermoplastic materials, such as polyvinyl chloride or polypropylene, or reaction injection molding of thermosetting materials, such as polyurethane or other thermosets. These techniques are well-known in the art [see e.g., Morgan and Weaver, respectively].

Also, where it is desirable to dispense a fluid medium, such as a potentially air-sensitive electrolyte, into the cell cavity (or interpane spacing) formed between substrates 2 and 3 in an empty electrochromic cell (such as an empty electrochromic rearview mirror cell), a vacuum backfilling method, such as described in Varaprasad IV, may be used.

For example, a vacuum backfill apparatus can be configured with a first bell-jar chamber capable of receiving an empty electrochromic rearview cell and a second chamber, separate from the first bell-jar chamber. The second chamber includes a container, such as a crucible, which holds the potentially air-sensitive electrolyte to be filled into the empty interpane cavity of the electrochromic mirror cell in the bell-jar chamber. The second chamber is initially maintained at an atmospheric pressure of inert gas (such as nitrogen). An isolation valve (such as a gate valve) separates this second inert gas-filled chamber from the first bell-jar chamber, that itself is initially at an atmospheric pressure of ordinary air. After loading an empty cell into the first bell-jar chamber, a vacuum pump is used to evacuate the air therefrom to create a high vacuum (i.e., a low partial pressure of the components of air such as oxygen, water vapor, carbon dioxide, nitrogen, etc.) within the first bell-jar chamber. A high vacuum is also created within the interpane cavity of the rearview mirror empty cell in the now evacuated first bell-jar chamber. Next, and only when the air within the bell-jar chamber has been substantially removed, the isolation valve between the bell-jar chamber and the electrolyte-containing crucible in the second chamber is opened. The vacuum pump now pumps on the second chamber to pump away the inert gas therein. As a result, both the bell-jar chamber and the second chamber are brought to a high vacuum.

Procedures described in Varaprasad IV for backfilling are now followed. During the venting step, the bell-jar chamber/second chamber is vented to an atmospheric pressure of inert gas (such as nitrogen). The isolation valve is then closed, once again isolating the second chamber (now refilled with inert gas) from the bell-jar chamber. Once the second chamber is again isolated, the bell-jar chamber is opened to an ordinary room air atmosphere and the now-filled mirror cell is removed.

In such a vacuum backfilling technique using an isolation valve means, backfilling occurs using an inert gas but the use of an isolation valve (such as a gate valve, sluice valve, port valve, slit valve or equivalent isolation valve) isolates the potentially air-sensitive electrolyte from the air atmosphere at those times when the empty cell is inserted, and the filled cell is removed, from the bell-jar chamber. Such use of an isolation valve means during vacuum backfilling using an inert gas allows for the bell-jar chamber to be loaded and unloaded in an ordinary room air environment, while protecting the potentially air-sensitive electrolyte from exposure to air. In such an isolation valve vacuum backfilling apparatus, a suitable dispenser can be used to replenish the crucible with electrolyte, with the electrolyte being pumped from an electrolyte reservoir that is maintained under air-tight conditions without being exposed to air. With this arrangement, the electrolyte is replenished without being exposed to air. Also, as an alternative to flooding the second chamber with inert gas when the isolation valve is closed (so as to isolate the electrolyte in the second chamber from contact with air), a vacuum can be established (and/or maintained) in this second chamber when the isolation valve is closed.

Each of the documents cited herein is hereby incorporated by reference to the same extent as if each document had individually been incorporated by reference.

In view of the above description of the instant invention, it is evident that a wide range of practical opportunities is provided by the teaching herein. The following examples of electrochromic mirrors and electrochromic devices are provided to illustrate the utility of the present invention only and are not to be construed so as to limit in any way the teaching herein.

EXAMPLES

Example 1

An electrochromic interior rearview automotive mirror cell having a shape commonly used for interior rearview mirrors was constructed from clear HW-ITO-coated glass as the first substrate (having a sheet resistance of about 12 ohms per square), with a tungsten oxide electrochromic solid film coated over its HW-ITO coating (which is coated onto the inward surface of the substrate). As the second substrate of the mirror cell, a HW-ITO-coated glass substrate (also having a sheet resistance of about 12 ohms per square) with the ITO coated onto its inward surface was used. A reflective element was formed by coating a layer of silver onto the rearmost (opposite, non-inward) surface of the second substrate of the mirror cell. The HW-ITO was coated onto the glass substrates at a thickness of about 1,500 Å; the tungsten oxide electrochromic solid film was coated over the HW-ITO coating of the first substrate at a thickness of about 5,000 Å; and the silver was coated onto the rearmost surface of the second substrate using conventional wet chemical silver line deposition as known in the mirror art. The first substrate was positioned in spaced-apart relationship with the second substrate to form a 88 μm interpane spacing between the coated inward surfaces of the substrates. The first substrate was also laterally displaced from the second substrate to provide a convenient area for bus bar attachment.

We formulated an electrolyte for this mirror cell containing ferrocene (about 0.015M), phenothiazine (about 0.06M), lithium perchlorate (about 0.05M) and "UVINUL" 400 [about 5% (w/v)] in a solvent combination of tetramethylene sulfone and propylene carbonate [in a ratio of about 50:50 (v/v)].

We dispensed the electrolyte described above into the mirror cell by the vacuum backfilling method [as described in Varaprasad IV].

Upon application of about 1.4 volts, we observed that the mirror dimmed uniformly and rapidly to a neutral gray colored state. Specifically, we observed that the mirror dimmed from about 70% reflectance to about 20% reflectance in a response time of about 3.2 seconds. In addition, we observed that the mirror exhibited a high reflectance in the unpowered, bleached state of about 74.7% and a low reflectance in the dimmed state of about 5.9%.

We made and recorded these observations following the standard procedure J964A of the Society of Automotive Engineers, using a reflectometer—set in reflectance mode—equipped with a light source (known in the art as Standard Illuminant A) and a photopic detector assembly.

Spectral scans were recorded using a conventional spectrophotometer operating in reflection mode in both the bleached state [see FIG. 1 and Tables II(a) and II(b)] and the colored state at an applied potential of about 1.5 volts [see FIG. 2 and Tables III(a) and III(b)].

TABLE II(a)

Reflectance Data In The Unpowered, Bleached State

WL (nm)	0	5	10	15	20	25	30	35	40	45
380	14.5	20.4	29.1	38.2	45.9	51.7	56.1	59.5	61.9	64.2
430	65.9	67.7	68.9	70.4	71.6	72.7	73.6	74.8	75.4	76.2
480	77.0	77.7	75.1	75.9	79.5	80.2	80.6	80.7	80.7	80.9
530	80.7	80.6	80.0	80.1	79.4	79.3	78.8	78.5	78.1	77.8
580	77.2	76.9	76.5	75.8	75.1	74.5	74.1	73.5	72.5	71.9
630	71.4	70.6	70.1	69.4	68.7	67.9	67.2	66.5	65.6	64.9
680	64.5	63.6	62.9	62.0	61.3	60.6	60.2	59.6	58.6	57.4
730	57.1	56.6	55.7	55.0	54.6	53.9	52.5	51.6	51.2	50.7
780	50.5									

TABLE II(b)

Color Statistics - C.I.E. Convention Using 2 Degree Eye

Illuminant	x	y	DomWave	Purity	Y
A	0.4422	0.4172	547.0	3.2	77.0
C	0.3097	0.3304	549.7	3.8	77.8

TABLE III(a)

Reflectance In The Colored State at 1.5 Volts										
WL (nm)	0	5	10	15	20	25	30	35	40	45
380	11.4	11.6	11.8	11.5	10.6	9.5	8.6	7.7	6.8	6.1
430	5.5	5.0	5.0	5.1	5.6	5.6	5.8	6.0	6.2	6.3
480	6.5	6.7	6.8	6.9	7.0	7.1	7.2	7.2	7.2	7.3
530	7.4	7.6	7.8	8.0	8.1	8.1	8.0	7.8	7.6	7.4
580	7.3	7.0	6.8	6.6	6.3	6.1	6.0	5.7	5.6	5.4
630	5.4	5.2	5.2	5.1	5.0	4.9	4.9	4.8	4.8	4.8
680	4.8	4.8	4.8	4.7	4.8	4.8	4.8	4.8	4.8	4.8
730	4.9	4.9	4.9	5.0	5.1	5.0	5.1	5.2	5.1	5.2
780	5.4									

TABLE III(b)

Color Statistics - C.I.E. Convention Using 2 Degree Eye at 1.5 Volts					
Illuminant	x	y	DomWave	Purity	Y
A	0.4323	0.4342	545.3	8.5	7.0
C	0.3098	0.3499	549.3	8.9	7.1

We also cycled the mirror as described in Table IV below.

TABLE IV

Number of	Cycle	Color/Bleach	
Cycles	Temperature (°C.)	Cycle (secs)	Voltage
30,000	50	5/5	1.4/0.0
40,000	room temperature	5/5	1.4/0.0
30,000	−30	5/5	1.4/0.0
90,000	50	5/5	1.6/0.0
11,000	80	30/30	1.4/0.0

After subjecting this mirror to such cycling conditions, we observed the reflectance of the mirror to decrease from about 70% to about 20% in a response time of about 3.2 seconds. In addition, we observed the mirror to have a high reflectance in the unpowered, bleached state of about 78.6% and a low reflectance in the dimmed state of about 6.4% when a potential of 1.4 volts was applied thereto. We made and recorded these observations using the SAE procedure referred to supra.

We observed that these mirrors exhibited excellent stability to temperature extremes. For example, after storage at temperatures in the 80° C.–110° C. range, for periods ranging from about 2 hours to in excess of 336 hours, performance remained excellent, and, indeed, in aspects such as transition times from low to high reflectance states performance was even better after heat exposure.

Example 2

In this example, we used the same electrolyte formulation and an electrochromic mirror constructed in the same manner as in Example 1, supra.

We introduced an applied potential of about 1.4 volts to the mirror and observed its center portion to change from a high reflectance of about 75.9% to a low reflectance of about 6.3%, which decreased from about 70% reflectance to about 20% reflectance in a response time of about 3.5 seconds.

We then subjected this mirror to an accelerated simulation of outdoor weathering conditions to investigate its resilience

and stability to ultraviolet light. Specifically, we subjected the mirror to about 1300 KJ/m^2 of ultraviolet exposure in an Atlas Ci35A Xenon Weather-o-meter (Atlas Electric Devices Company, Chicago, Ill.), equipped with a Xenon lamp emitting about 0.55 w/m^2 intensity at about 340 nm. After accelerated outdoor weathering, we observed that the mirror continued to function suitably for use in a motor vehicle. We also observed that the mirror cycled well. In addition, we observed the high reflectance to be about 75.2% and the low reflectance to be about 6.9% when a potential of about 1.4 volts was applied thereto.

We made and recorded these observations using the SAE procedure referred to in Example 1, supra.

Example 3

The electrochromic mirror cell of this example was constructed from clear HW ITO-coated glass as the first substrate as in Example 1, supra. However, the second substrate was constructed of ordinary soda-lime glass. Using electron beam evaporation in a vacuum chamber, a layer of chromium was coated directly onto the inward surface of the second glass substrate as an adhesion promoter. Next, and without breaking vacuum, a thin film of silver was coated onto the layer of chromium as a reflective element, and thereafter (again without breaking vacuum) tungsten oxide was coated over the layer of silver as an electrochromic solid film. The layer of chromium was coated onto the second substrate at a thickness of about 1,000 Å; the thin film of silver was coated over the chromium at a thickness of about 1,000 Å; and the tungsten oxide was coated over the silver at a thickness of about 5,000 Å. The sheet resistance of the silver so undercoated with chromium was about 0.4 to 0.5 ohms per square. As with the mirror cell of Example 1, supra, the first substrate was positioned in spaced-apart relationship with the second substrate to form an 88 μm interpane spacing between the coated inward surfaces of the substrates. The first substrate was laterally displaced from the second substrate to provide a convenient area for bus bar attachment.

We used the electrolyte of Example 1, supra, and dispensed it into the mirror cell using the vacuum backfilling method [as described in Varaprasad IV].

We introduced an applied potential of about 1.4 volts to the mirror and observed the change from a high reflectance of about 81.6% to a low reflectance of about 5.9%, which decreased from about 70% reflectance to about 20% reflectance in a response time of about 1.9 seconds.

We made and recorded these observations using the SAE procedure referred to in Example 1, supra.

We also cycled the mirror as described in Table V below.

TABLE V

Number of	Cycle	Color/Bleach	
Cycles	Temperature (°C.)	Cycle (secs)	Voltage
30,000	50	5/5	1.4/0.0
40,000	room temperature	5/5	1.4/0.0

After subjecting the mirror to such cycling conditions, we observed the reflectance of the mirror in the unpowered, bleached state to be 77.3%, and the mirror dimmed to 6.2% reflectance with 1.4 volts applied thereto.

Example 4

We used an electrochromic mirror cell constructed in the same format and with the same shape and dimensions as in

Example 1, supra, except that a tungsten oxide electrochromic solid film (having a thickness of about 5,000 Å) was coated over the HW-ITO coating on the inward surface of the second substrate.

We formulated an electrolyte containing ferrocene (about 0.025M), phenothiazine (about 0.05M), lithium perchlorate (about 0.05M) and "UVINUL" 400 [about 10% (w/v)] in a solvent combination of tetramethylene sulfone and propylene carbonate [in a ratio of about 25:75 (v/v)]. We dispensed the electrolyte into the mirror cell using the vacuum backfilling method [as described in Varaprasad IV].

Upon introduction of an applied potential of about 1.4 volts, we observed the mirror to dim uniformly and rapidly to a neutral gray colored state. Specifically, we observed the mirror to have a high reflectance in the unpowered, bleached state of about 70.7% and a low reflectance in the dimmed state of about 7.3%. We made and recorded these observations using the SAE procedure referred to in Example 1, supra.

We also cycled the mirror and subjected the mirror to an accelerated simulation of outdoor weathering conditions to investigate its resilience and stability to ultraviolet light as described in Example 2, supra, but at an exposure of about over 2,500 KJ/m^2. We observed that the mirror cycled well, and after accelerated outdoor weathering, we also observed that the mirror continued to function in a manner suitable for use in a motor vehicle.

Example 5

In this example, we fabricated an electrochromic glazing cell of a construction suitable for use as a window or a sun roof for a motor vehicle. The glazing cell was dimensioned to about 15 cm× about 15 cm, with an interpane spacing between the tungsten oxide coating on the inward surface of the second substrate and the HW-ITO coating on the inward surface of the first substrate of about 105 µm.

The glazing cell was constructed using spacers to assist in defining the interpane spacing. The spacers were sprinkled over the tungsten oxide-coated surface of the first substrate and, inward from the peripheral edge of the HW-ITO-coated second substrate, an epoxy was applied using a silk-screening technique. While the epoxy was still uncured, the first substrate and the second substrate were off-set from one another by a lateral displacement and a perpendicular displacement. The epoxy was then cured into a seal for the electrochromic glazing cell using a vacuum bagging technique (as is known in the laminating art) at a reduced atmospheric pressure of about 10" of mercury and a temperature of about 110° C. for a period of time of about 2 hours in order to achieve substantially even pressure while curing the epoxy into a seal.

We formulated an electrolyte containing ferrocene (about 0.015M), phenothiazine (about 0.06M), lithium perchlorate (about 0.05M) and "UVINUL" 400 [about 5% (w/v)] in a solvent combination of tetramethylene sulfone and propylene carbonate [in a ratio of about 50:50 (v/v)]. We dispensed this electrolyte into the electrochromic glazing cell using the vacuum backfilling method [as described in Varaprasad IV].

Upon introduction of an applied potential of about 1.4 volts to the electrochromic glazing, we observed the transmissivity change from a high transmittance of about 78.6% to a low transmittance of about 12.9%.

We made and recorded these observations using the SAE procedure referred to in Example 1, supra, except that the reflectometer was set in transmittance mode.

Example 6

In this example, we constructed an electrochromic mirror suitable for use as an exterior rearview mirror for a motor vehicle.

The mirror was constructed from clear HW-ITO-coated glass as the first substrate as in Example 1, supra.

However, as the second substrate we used ordinary soda-lime glass. Both substrates were sized and shaped to dimensions of 9.5 cm×15 cm. A notch was cut in one edge of the first substrate, and another notch was cut in a different location on one edge of the second substrate. A bus bar was formed along the edges of the first substrate by silk-screening a silver conductive frit material [#7713 (Du Pont)] all around the perimetal region of the HW-ITO-coated surface of the substrate to a width of about 2.5 mm, and then firing the frit at an elevated temperature in a reducing atmosphere to avoid oxidizing the HW-ITO.

A layer of chromium at a thickness of about 1,000 Å was coated directly by vacuum deposition onto the inward surface of the second glass substrate as an adhesion promoter. Thereafter, without breaking vacuum, a thin film of silver at a thickness of about 1,000 Å was coated onto the layer of chromium as a reflective element, and tungsten oxide at a thickness of about 5,000 Å was then coated/again, without breaking vacuum) over the layer of silver as an electrochromic solid film. The first substrate and the second substrate were then positioned in spaced-apart relationship so that the edges of the substrates were flush, and a seal was applied so as to form a cavity between the two substrates. In this flush design, the interpane spacing between the coated inward surfaces of the substrates was 88 µm.

For this exterior mirror, we formulated an electrolyte containing ferrocene (about 0.025M), phenothiazine (about 0.06M), lithium tetrafluoroborate (about 0.05M) and "UVINUL" 400 [about 5% (w/v)] in propylene carbonate. We dispensed this electrolyte into the mirror cell using the vacuum backfilling method [as described in Varaprasad IV].

Electrical leads were then attached to the mirror. The notch on the second substrate permitted an electrical lead to be attached at a point contact on the silver frit bus bar formed around and substantially circumscribing the perimeter of the HW-ITO-coated inward surface of the first substrate. Another electrical lead was attached to the portion of the chromium/silver/tungsten oxide coating on the inward surface of the second substrate exposed by the notch cut in the first substrate. The point contact was sufficient to apply a potential across the electrodes because of the low sheet resistance of the coating on the inward surface of the second substrate.

Upon introduction of an applied potential of about 1.5 volts to the mirror, we observed the reflectance change from a high reflectance of about 77.5% to a low reflectance of about 10.6%.

We also cycled the mirror for about 50,000 cycles at a temperature of about 50° C., and observed that the mirror cycled well and continued to function suitably for use in a motor vehicle.

Example 7

In this example, we used the same electrolyte formulation and an electrochromic mirror cell of the same shape as described in Example 1, supra. After filling the electrochromic mirror cell using the vacuum backfilling method [as described in Varaprasad IV], we removed the tungsten oxide coating from the peripheral edge of the first substrate using a dilute basic solution of potassium hydroxide followed by water. We then connected the bus bars to this newly-exposed ITO surface. Thereafter we applied a secondary weather barrier material. The secondary weather barrier material was formed from "ENVIBAR" UV 1244T ultraviolet curable epoxy, with about 2% of the silane coupling agent A-186 (OSi Specialties Inc., Danbury, Conn.) combined with about 1% of the photoinitiator "CYRACURE" UVI-6990. Thereafter, we cured this material by exposing it to a suitable source of ultraviolet light to form a secondary weather barrier.

Once the secondary weather barrier was formed, we introduced an applied potential of about 1.3 volts to the mirror and observed the reflectance change from a high reflectance of about 77.8% to a low reflectance of about 7.1%.

We made and recorded these observations using the SAE procedure referred to in Example 1, supra.

We also mounted this electrochromic mirror in the cabin of a motor vehicle and found the mirror to operate in a commercially acceptable manner.

Example 8

We used an electrochromic mirror cell having the same shape as described in Example 1, supra, constructed from clear ITO-coated glass as the first substrate (having a sheet resistance of about 80 ohms per square). As the second substrate of the mirror cell, we used ordinary soda-lime glass. The first substrate was dimensioned about 2 to about 3 mm larger in both length and width than the second substrate. A layer of chromium, as an adhesion promoter, was coated directly onto the inward surface of the second glass substrate at a thickness of about 1,000 Å. A thin film of silver, as a reflective element, was thereafter coated onto the layer of chromium at a thickness of about 1,000 Å and tungsten oxide, as an electrochromic solid film, was then coated over the layer of silver at a thickness of about 5,000 Å. These thin films were coated in a vacuum deposition process by electron beam evaporation and were deposited in a unitary deposition process without breaking vacuum during deposition of the chromium/silver/tungsten oxide stack.

Also, when a transparent conductor coated substrate (for example, fluorine doped tin oxide coated glass, such as "TEC-Glass" described supra, that is bendable in an ordinary air atmosphere) is used for the substrate 2, and/or when a bendable reflector-coated substrate (for example, the combination of a silicon based reflector overcoated with a tin oxide transparent conductor described supra), is used for the substrate 3, the process outlined in FIG. 15 can be appropriately modified. For example, a convex or aspherical exterior mirror shape suitable for use as the substrate 2 can be cut from a bent minilite of "TEC-20" glass comprising a fluorine doped tin oxide transparent conductor of about 20 ohms per square sheet resistance and with the tin oxide coating located on the concave surface of the bent minilite. Use of such air-bendable transparent conductors, as are conventionally known, is an alternate to transparent conductor coating the concave surface of a bent, plain glass surface, as illustrated in FIG. 15. Also, use of a bendable, elemental semiconductor reflector layer that is itself rendered conducting, or that is overcoated with a transparent conducting layer such as tin oxide, may be used (in lieu of coating metal layers of aluminum, silver, chromium and the like that are typically non-bendable) on the convex surface of bent substrate 3.

The first substrate and the second substrate were positioned in spaced-apart relationship to form a 88 μm interpane spacing between the ITO-coated surface of the first substrate and the multi-layered surface of the second substrate. The size and shape differential between the first substrate and the second substrate allowed the ITO-coated surface of the first substrate to extend beyond the multi-layered surface of the second substrate. Bus bars were attached substantially all around the peripheral edge of the ITO-coated first substrate onto which were connected the electrical leads. On the multi-layered second substrate, we attached electrical leads at a smaller portion thereof, such as at a mere point contact.

We, formulated an electrolyte containing ferrocene (about 0.015M), phenothiazine (about 0.06M), lithium perchlorate (about 0.05M) and "UVINUL" 400 [about 5% (w/v)] in a solvent combination of tetramethylene sulfone and propylene carbonate [in a ratio of about 50:50 (v/v)]. We dispensed this electrolyte into the mirror cell using the vacuum backfilling method [as described in Varaprasad IV].

Upon introduction of an applied potential of about 1.4 volts, we observed the mirror to dim uniformly and rapidly to a neutral gray colored state. Specifically, we observed the mirror to have a high reflectance in the unpowered, bleached state of about 75.8% and a low reflectance in the dimmed state of about 9.5%. We made and recorded these observations using the SAE procedure referred to in Example 1, supra.

Example 9

In this example, we used the electrolyte formulation and an electrochromic mirror having the same shape as described in Example 8, supra. However, the mirror of this example was constructed from ITO-coated glass as the first substrate having a sheet resistance of about 55 ohms per squares. In addition, the first substrate and the second substrate were positioned in spaced-apart relationship to form a 63 μm interpane spacing between the ITO-coated surface of the first substrate and multi-layered surface of the second substrate.

After dispensing the electrolyte into the mirror cell using the vacuum backfilling method [as described in Varaprasad IV], we observed the mirror to have a high reflectance of about 75.7% and a low reflectance of about 8.6% when a potential of about 1.4 volts was applied thereto. We made and recorded these observations using the SAE procedure referred to in Example 1, supra.

Example 10

In this example, we fabricated an electrochromic glazing device of a construction suitable for use as a window or a sun roof on a motor vehicle containing a solid electrolyte. The glazing device was dimensioned to about 15 cm×about 15 cm, with an interpane spacing between the tungsten oxide coating on the inward surface of the first substrate and the HW-ITO coating on the inward surface of the second substrate of about 74 μm.

The glazing device was constructed using spacers to assist in defining the interpane spacing. The spacers were sprinkled over the tungsten oxide coated surface of the first substrate and an epoxy was applied inward from the peripheral edge of the HW-ITO coated second substrate using a silk-screening technique. While the epoxy was still uncured, the first substrate and the second substrate were off-set from one another by a lateral displacement and a perpendicular displacement. The weather barrier of the electrochromic glazing device was then formed by thermal curing using a vacuum bagging technique (as is known in the laminating art) at a reduced atmospheric pressure of about 10" of mercury and a temperature of about 140° C. for a period of time of about 1 hour in order to maintain a substantially even pressure when curing the epoxy into a weather barrier.

We prepared a formulation of starting components containing ferrocene [about 0.3% (w/w)], phenothiazine [about 0.8% (w/w)], lithium perchlorate [about 0.4% (w/w)], "SARBOX" acrylate resin (500E50) [about 27.9% (w/w)], propylene carbonate (as a plasticizer) [about 67.3% (w/w)] and "IRGACURE" 184 (as a photoinitiator) [about 3.3% (w/w)]. We dispensed this formulation into the electrochromic glazing device using the vacuum backfilling method [as described in Varaprasad IV].

We then in situ polymerized the formulation by exposing it to ultraviolet radiation to form a solid-phase electrolyte.

We then affixed bus bars along the peripheral edges of the electrochromic glazing device, and connected electrical leads to the bus bars.

We introduced an applied potential of about 1.5 volts to the electrochromic glazing for a period of time of about 2 minutes, with the positive polarity applied at the second substrate (the surface of which having tungsten oxide overcoated onto its HW-ITO-coated surface) and observed it to have a high transmittance of about 73.0%. Thereafter, we reversed the polarity, and observed the transmission to dim to a low transmittance of about 17.8% when a potential of about 1.5 volts was applied thereto.

We made and recorded these observations using the SAE procedure referred to in Example 1, supra, except that the reflectometer was set in transmittance mode.

Example 11

In this example, we constructed an electrochromic mirror device having the same shape described in Example 1, supra, with an interpane spacing of about 74 μm and using a solid-phase electrolyte.

We prepared a formulation of starting components containing ferrocene [about 0.2% (w/w)], phenothiazine [about 0.5% (w/w)], lithium perchlorate [about 0.3% (w/w)], polyethylene glycol dimethacrylate (600) (PEGDMA-600) [about 17.9% (w/w)], propylene carbonate (as a plasticizer) [about 76.5% (w/w)], "IRGACURE" 184 (as a photoinitiator) [about 2.1% (w/w)] and "UVINUL" 400 [about 2.5% (w/w)].

The mirror was constructed using spacers to assist in defining the interpane spacing. The spacers were sprinkled over the HW-ITO coated inward surface of the first substrate (whose opposite, non-inward surface had been coated with a layer of silver using conventional wet chemical silver line deposition) and the formulation, which would be transformed into a solid-phase electrolyte, was dispensed thereover. The second substrate, whose inward surface was coated with tungsten oxide at a thickness of about 5,000 Å, was positioned over the spacer-sprinkled HW-ITO coated surface of the first substrate to allow the formulation to spread evenly across and between the coated surfaces of the first substrate and the second substrate.

We temporarily held the first substrate and the second substrate together using clamps and in situ polymerized the formulation located therebetween through exposure to ultraviolet radiation to form a solid-phase electrolyte. Specifically, we placed the mirror onto the conveyor belt of a Fusion UV Curing System F-450 B, with the belt advancing at a rate of about fifteen feet per minute and being subjected to ultraviolet radiation generated by the D fusion lamp of the F-450 B. We passed the mirror under the fusion lamp fifteen times pausing for two minute intervals between every fifth pass.

We then affixed bus bars along the peripheral edges of the device, and attached electrical leads to the bus bars.

We introduced an applied potential of about 1.5 volts to the electrochromic mirror for a period of time of about 2 minutes, with the positive polarity applied at the second substrate (the surface of which having tungsten oxide overcoated onto its HW-ITO-coated surface) and observed it to have a high reflectance of about 73.2%. Thereafter, we reversed the polarity, and observed the reflection to dim to a low reflectance of about 7.1% when a potential of about 1.5 volts was applied thereto.

We made and recorded these observations using the SAE procedure referred to in Example 1, supra.

Example 12

In this example, we constructed an electrochromic mirror cell having the same shape described in Example 4, supra.

We formulated an electrolyte containing ferrocene (about 0.025M), phenothiazine (about 0.06M), lithium perchlorate (about 0.05M) and "UVINUL" 400 [about 5% (w/v)] in a solvent combination of 1,2-butylene carbonate and propylene carbonate [in a ratio of about 50:50 (v/v)]. We dispensed this electrolyte into the mirror cell using the vacuum backfilling method [as described in Varaprasad IV].

Upon introduction of an applied potential of about 1.4 volts to the mirror, we observed the high reflectance change from about 72.0% to a low reflectance of about 6.8%.

We also cycled the mirror for about 50,000 cycles at a temperature of about 50° C., and observed it to cycle well.

Example 13

In this example, we again constructed an electrochromic mirror cell having the same shape described in Example 1, supra.

For this mirror cell, we formulated an electrolyte containing ferrocene (about 0.025M), phenothiazine (about 0.06M), lithium perchlorate (about 0.05M), lithium tetrafluoroborate (about 0.05M) and "UVINUL" 400 [about 5% (w/v)] in propylene carbonate, and dispensed it into the mirror cell using the vacuum backfilling method [as described in Varaprasad IV].

Upon introduction of an applied potential of about 1.4 volts to the mirror, we observed the high reflectance to change from about 72.0% to a low reflectance of about 6.7%.

The mirror demonstrated excellent cycle stability and stability to ultraviolet light.

Example 14

In this example, we constructed an electrochromic mirror cell having the same shape described in Example 1, supra, with an on demand display. For illustrative purposes, see FIG. 9.

To provide the on demand display to this mirror cell, a display window (with dimensions of about 7/16"×3/4") was laser-etched through an overcoating of silver/copper/paint on the rearmost (opposite, non-inward) surface of the second substrate of the mirror cell.

Over and within the display window, we applied an optical adhesive ["IMPRUV" LV potting compound (commercially available from Loctite Corporation, Newington, Conn.)] so that a glass cover sheet, having a thickness of about 0.075", may be disposed over and affixed thereto.

The glass cover sheets suitable for use in this context were prepared by previously exposing a larger glass sheet to a vacuum evaporation process in which a thin film layer of silver was coated onto one of its surfaces. The thin film layer of silver was substantially reflecting (having a reflectance of about 93%) and partially transmitting (having a transmittance of about 5%). The silver-coated glass cover sheet was then cut to size—e.g., about 1"×¾"—, and the silvered-surface disposed over, and affixed to using the optical adhesive, the display window. Over the opposite, non-silvered surface of the glass cover sheet, we placed a layer of epoxy [UV1574RI (commercially available from Master Bond Incorporated, Hackensack, N.J.)] and affixed thereto a vacuum fluorescent display [Part No. FIP2QMSS (NEC Electronics Incorporated, Mountain View, Calif.)].

Into this mirror cell, we dispensed the electrolyte of Example 1, supra.

Example 15

In this example, we constructed an electrochromic mirror cell having the same shape described in Example 1, supra, with an on demand display. For illustrative purposes, see FIG. 10.

In this mirror cell, like the mirror cell of Example 14, supra, a display window (with dimensions of about 7/16"×¾") was laser-etched through the silver/copper/paint overcoating of the rearmost (opposite, non-inward) surface of the second substrate of the mirror cell.

A thin film layer of silver was then coated over the display window so formed by electron beam evaporation in a vacuum chamber as described supra. The thin film layer of silver was substantially reflecting (having a reflectance of about 90%) and partially transmitting (having a transmittance of about 8%).

Over and within the silvered-display window, we applied a layer of epoxy [UV15-74RI (Master Bond)] and affixed thereto a vacuum fluorescent display [Part No. FIP2QM8S (NEC Electronics)].

Into this mirror cell, we dispensed the electrolyte of Example 1, supra.

Example 16

In this example, we constructed an electrochromic mirror cell using as the first substrate and second substrate clear HW-ITO-coated glass. Over the inward surface of the second substrate, we coated a layer of chromium at a thickness of about 100 Å as an adhesion promoter. We then coated a thin film of silver at a thickness of about 450 Å onto the layer of chromium as a reflective element, and a layer of tungsten oxide at a thickness of about 5,800 Å over the layer of silver as an electrochromic solid film. The first substrate and the second substrate were positioned in spaced-apart relationship to form an 88 μm interpane spacing between the coated inward surfaces of the substrates.

We placed an opaque tape on the rearmost surface of the second substrate with apertures provided therein at appropriate locations to accommodate vacuum fluorescent displays and other information indicia.

A vacuum fluorescent display was affixed to this mirror cell as described in Example 14, supra, but dispensing with the reflector coated cover sheet. The display provided compass directional information and, dependent on the vehicle direction when driving, displayed N, NE, E, SE, S, SW, W or NW when any one of which coordinates was activated by compass circuitry included in the mirror housing and assembly into which the electrochromic mirror element was mounted for driving in a vehicle, and such as described in commonly assigned U.S. Pat. No. 5,255,442 (Schierbeek). Turn signal indicia [JKL NEO-Wedge Lamps T2-1/4 (commercially available from JKL Components Corporation, Paloina, Calif.)] were also located behind the rearmost surface of the second substrate, with appropriately shaped apertures cut into the opaque tape at the location of the turn signal indicia. The turn signal indicia was activated through a triggering mechanism from the particular turn signal. For an illustration of the use of turn signal indicia 21 in an electrochromic mirror, see FIG. 12.

Into this mirror cell, we dispensed the electrolyte of Example 1, supra.

Upon introduction of an applied potential of about 1.4 volts to the mirror, we observed the high reflectance to change from about 74.1% to a low reflectance of about 7.0%. We also observed the transmittance to be about 4.5% in the clear state.

This mirror was installed in a vehicle and tested under a variety of actual day and night driving conditions, and was found to operate for its intended purpose.

Example 17

In this example, we constructed an electrochromic mirror suitable for use as an interior rearview mirror for a motor vehicle.

The mirror was constructed from clear ITO-coated glass as the first substrate (having a sheet resistance of about 80 ohms per square). As the second substrate of the mirror cell we used ordinary soda-lime glass. Both substrates were sized and shaped to identical dimensions. A notch was cut in the middle of the top edge of the first substrate and another notch was cut in the middle of the bottom edge of the second substrate. A thin metal film bus bar was formed along the edges of the first substrate by first affixing a mask over the central region leaving most of the perimeter region unmasked, and then depositing by a vacuum evaporation process a thin film of chromium having a thickness of about 2,000 Å followed by a thin film of silver having a thickness of about 5,000 Å.

A layer of chromium at a thickness of about 1,000 Å was coated directly onto the inward surface of the second glass substrate as an adhesion promoter. A thin film of silver at a thickness of about 1,000 Å was then deposited onto the layer of chromium as a reflective element and tungsten oxide at a thickness of about 5,000 Å was then coated over the layer of silver as an electrochromic solid film.

The first substrate and the second substrate were then positioned in a spaced-apart relationship so that the 15 edges of the substrates were flush and a seal was applied to form a cavity between the substrates. In this flush design, the interpane spacing between the coated inward surfaces of the substrates was 88 μm.

For this flush design interior mirror, we formulated an electrolyte as in Example 1, supra. We dispensed this electrolyte into the mirror cell using the vacuum backfilling method [as described in Varaprasad I].

Electrical leads were then attached to the mirror. The notch in the second substrate permitted an electrical lead to be attached at a point contact on the thin metal film bus bar on the bottom edge of the first substrate. Similarly, the notch in the first substrate caused a portion of the top edge of the inward surface of the second substrate to be exposed, permitting an electrical lead to be attached at a point contact on the chromium/silver/tungsten oxide coating.

Upon introduction of an applied potential of about 1.5 volts to the mirror, we observed a reflectance change from a high reflectance of about 85.3% to a low reflectance of about 7.5%.

Example 18

In this example, we constructed an aspherical electrochromic mirror cell using as the first substrate a 0.063" thick clear, HW-ITO-coated glass shape and as the second substrate a 0.093" thick clear HW-ITO-coated glass substrate. The second substrate was silver coated on its rear surface (i.e., the fourth surface of the assembly) using a conventional wet chemical silverline process, as is well-known in the automotive silvering art. The first and second substrates were individually bent to an aspheric radius using a multi-radius design commonly used for driver-side exterior mirrors on vehicles in Europe. This design includes an inboard spherical curvature region of about 2,000 mm radius of curvature and a continuously reducing radius, aspherical curvature outboard region that decreased in radius from about 560 mm through about 230 mm to about 160 mm. The bent, multi-radius substrates were individually press bent, as an oversized lite, in a bending press mold, as previously described, by first heating the glass to a temperature of at least about 550° C. followed by press bending to conform to a precision mold.

After bending and annealing the oversized multi-radius lite, the multi-radius shapes (of the size and shape used as a driver-side exterior mirror on a Peugeot 605 vehicle manufactured by PSA of France for model year 1994), were cut from the oversized, bent, multi-radius lite. The inward facing, ITO-coated surface of the second substrate was coated with a layer of tungsten oxide of thickness about 5,500 Å, using electron beam evaporation and using a rapid cycle process, as previously described, whereby evaporation of the tungsten oxide commenced when, during initial pumpdown, the chamber pressure reached about 2×10^{-4} torr (mm Hg). The first substrate and the second substrate were positioned in spaced apart relationship to form an interpane spacing of about 88 μm between the coated inward facing surfaces of the substrates. The seal material used was EPON 8281 epoxy that was cured with ANCAMINE® 2014FG as a latent curing agent.

To enhance uniformity and conformity of matching a local radius of the first substrate to its corresponding local radius on the second substrate, glass beads having a diameter of about 88 μm were included in the uncured epoxy as well as being sprinkled over the surface of the inward facing surface of the second substrate. Using a computer numerical control ("CNC") controlled ASYMTEK dispenser and a 20 gauge needle, the uncured epoxy was applied around the perimeter of the inward surface of the first substrate. The first substrate was then carefully aligned over the corresponding local radii of the second substrate and was temporarily affixed thereto using simple clamps. This assembly was placed in a "MYLAR" vacuum bag and a vacuum was established so that atmospheric pressure impressed upon the surfaces of the assembly to force conformity between the local radii of the first and second substrates. Next, and while under vacuum and thus still under atmospheric pressure, the vacuum bagged assembly was based in an oven and exposed to a temperature of about 140° C. for a period of time of

about one hour to cure the epoxy. Once cured, the assembly was removed from the oven, the vacuum bag was vented and removed, and the empty cell, so formed, was filled with the electrolyte of Example 1, supra, using vacuum backfilling.

Once cell fabrication was completed, we introduced a voltage of about 1.4 volts to the mirror, and observed the high reflectance to change from about 74.7% to a low reflectance of about 7.3%. This change in reflectance was achieved rapidly and uniformly with little to no double imaging observed.

This mirror was mounted into a bezel, and installed in a vehicle. The mirror was found to operate for its intended purpose.

Also, such mirrors showed the environmental, cycle and performance resilience described supra.

Example 19

In this example, we constructed a multi-radius mirror, similar to that described in Example 18, supra. However, in this example the second substrate was non-ITO coated clear glass, and not silverline mirrored on its fourth surface. Instead, its inward facing plain glass surface was first coated with a layer of chromium (adhesion promoter layer) having a thickness of about 1,000 Å, followed by a layer of aluminum (reflector) having a thickness of about 2,000 Å, and followed by a layer of tungsten oxide (electrochromic solid film) having a thickness of about 6,000 Å.

Once cell fabrication was completed, we introduced a voltage of about 1.4 volts to the mirror and observed the high reflectance to change from about 69.7% to a low reflectance of about 6.4%. This change in reflectance was achieved rapidly and uniformly with little to no double imaging observed.

Example 20

The mirror of this example was fabricated generally as described in Example 3, supra, except that the front substrate was a flat HW-ITO-coated glass shape having a thickness of about 0.043", with dimensions of about 6.75"×12.7". In addition, the rear substrate was flat, plain glass having a thickness of 0.063" with similar dimensions. The interpane spacing in this mirror construction was about 74 microns. The electrolyte comprised lithium perchlorate (about 0.01M), lithium tetrafluoroborate (about 0.04M), ferrocene (about 0.04M) and "UVINUL" 400 [about 5% (w/v)] dissolved in a solvent combination of tetramethylene sulfone and propylene carbonate [in a ratio of about 60:40 (v/v)]. The electrochromic mirror cell so formed was suitable for use in an exterior mirror assembly on a large, Class 8, Kenworth T600 heavy truck manufactured by Kenworth Truck Company, Seattle, Wash.

Once cell fabrication was completed, we introduced a voltage of about 1.4 volts to the mirror (using around-the-perimeter bus bars), and observed the high reflectance to change from about 81.2% to a low reflectance of about 16.5%. This change in reflectance was achieved rapidly and uniformly with little to no double imaging observed.

Example 21

In this example, we report results of rearview mirror constructions otherwise similar to that described in Example 1, supra, except for the use of tungsten oxide doped with tin instead of undoped tungsten oxide. Electrochromic solid films of the tin doped tungsten oxide type were deposited both by physical vapor deposition (specifically, electron beam evaporation) and by non-vacuum deposition [specifically, by wet chemical deposition with the dip/fire technique, see U.S. Pat. No. 4,855,161 (Moser)].

In the physical vapor deposition approach, the procedure and construction described in Example 1, supra, was used but with evaporation of a mixture of tungsten oxide/tin oxide (in a ratio of about 95:5% w/w) to form a tin-doped tungsten oxide having a thickness of about 6,000 Å (with the Sn/WO_3 weight ratio in the coating at about 0.04). Rearview mirror cells so formed using such evaporated tin doped tungsten oxide were tested and operated to determine their suitability for use as rearview mirrors in automobiles. These mirrors were found to be suitable both in terms of performance and in terms of cycle/environmental resilience.

Compared to similar mirror cells fabricated using undoped tungsten oxide, but without other intended differences, tin doping of the tungsten oxide film produced a noticeably more neutral coloration when the mirrors were electrochromically dimmed under applied potential. Also, we found that mixing of tin oxide with the tungsten oxide during its reactive evaporation under vacuum led to less spitting from the evaporation crucible and facilitated, perhaps due to enhanced electrical conductivity in the inorganic oxide mixture, easier evaporation of the mixture to form the oxide film on the glass. This enhances ease of manufacturing of electrochromic devices using, for example, a vacuum deposited, tungsten oxide-based electrochromic film, and the like. We also observed a higher bleached state % reflectivity and a faster bleach time when tin doped tungsten oxide was used compared to undoped tungsten oxide.

In the non-vacuum deposition approach, a wet chemical, dip/fire method was used, such as is described in U.S. Pat. No. 4,855,161 (Moser), the disclosure of which is hereby incorporated herein by reference. A dipping solution was prepared which comprised about 7.5 wt % tungsten hexachloride, about 2.5 wt % dibutyltin oxide, about 55 wt % ethyl acetate, about 30 wt % isopropanol and about 5 wt % methanol. HW-ITO coated glass substrates were coated with this sol-gel formulation dipping solution by a conventional dip-coating method, and transferred to an oven preheated to a temperature of about 120° C. In the oven, the as-dipped coating, having already been air dried, was fired for a period of time of about 2 hours to produce the desired tin doped tungsten oxide coating, with the Sn/WO_3 weight ratio being about 0.25.

Again, rearview mirrors cells were constructed as described in Example 1, supra, except that this dip/fire tin doped tungsten oxide coating was used.

The performance characteristics of such rearview mirrors are reported in Tables VI(a) and VI(b) below:

TABLE VI(a)

Room Temperature, 1.5 V, 5 secs/5 secs cycle				
Number of Cycles	% HR	% LR	Transition Times (secs) 70–20%	10–60%
Initial	79.7	9.5	5.3	5.9
25,000	76.6	9.3	5.1	5.2
50,000	77.0	8.9	4.8	4.9
80,000	76.2	8.9	4.7	4.7
120,000	76.0	8.7	4.7	4.4

TABLE VI(b)

50° C., 1.5 V, 5 secs/5 secs cycle				
Number of Cycles	% HR	% LR	Transition Times (secs) 70–20%	10–60%
Initial	78.7	8.0	4.7	6.2
25,000	77.2	8.2	4.6	5.6
50,000	77.6	8.1	4.6	5.2
80,000	76.6	7.7	4.7	5.4
120,000	75.5	8.1	4.4	5.2

Sol-gel formulations dipping formulations with different Sn/WO_3 weight ratios were coated on transparent conductor coated glass substrates. We found desirable a coating with a ratio between about 0.1 and about 0.5. Different firing temperatures were also used, and we found desirable a firing temperature within the range of about 120° C. and 300° C.

Example 22

In this example, we constructed a continually variable transmission bandpass filter. The spectral content passed by a bandpass filter may be electrically attenuated and thus provide user control over not just the spectral content of radiation (typically, a spectral sub-region band of visible, ultraviolet, near-infrared or infrared electromagnetic radiation), but also over the intensity of the radiation passed by the filter. Such bandpass filters are typically of the interference type comprising multiple thin film layers of determined thickness and refractive index so as to selectively transmit (and occasionally reflect) radiation such as incident light. Such interference filters have wide applications, such as in the diagnosis of disease (by tracing of fluorescent antibodies), spectral radiometry and colorimetry. Continually variable transmissive and reflective filters are useful in optical filters, display devices including heads-up display devices, the control of automotive lighting sources including headlamps, control enhancement filters, laser optic systems and similar applications. Such variable intensity filters are preferably medium-band, narrow-band or restricted band filters that permit isolation of wavelength intervals with a bandwidth as low as a few nanometers (such as, less than about 100 nanometers, and in some applications less than about 10 nanometers in more spectrally selective applications) without requiring use of dispersion elements (such as prisms and gratings), but with electrically controllable modulation of the intensity of light or other radiation which passes therethrough and/or reflects therefrom.

As an example of such a variable intensity filter, we constructed an electrochromic window element having dimensions of about 2"×2", such as is described in Example 5, supra, and attached to the outermost glass surface thereof a 600 nm medium-band interference filter having a bandwidth of about 40 nm, whose % transmission versus wavelength (nm) spectrum is shown as solid curve X in FIG. 17. This filter was fixed to the glass of the electrochromic window cell using an index matching optical adhesive having an index of about 1.5.

A plot of % transmission versus wavelength for this continuously variable intensity filter is shown in FIG. 17 for voltages applied to the electrochromic medium within the range of from about 0 volts to about 1.4 volts. In FIG. 17, light transmission through the band pass filter and the electrochromic window cell with no potential applied is represented by curve A. At an applied potential of about 0.3 volts, light transmission through the band pass filter and the electrochromic window cell is represented by curve B. At an applied potential of about 0.5 volts, light transmission through the band pass filter and the electrochromic window cell is represented by curve C. At an applied potential of about 0.8 volts, light transmission through the band pass filter and the electrochromic window cell is represented by curve D. At an applied potential of about 1.1 volts, light transmission through the band pass filter and the electrochromic window cell is represented by curve E. And at an applied potential of about 1.4 volts, light transmission through the band pass filter and the electrochromic window cell is represented by curve F. In Table VII below, the % transmission at about 600 nanometers is presented in connection with the voltage applied to the variable intensity filter.

TABLE VII

Applied Voltage (volts)	% transmission at about 600 nm
0	47
0.3	42
0.5	35
0.8	25
1.1	17
1.4	9

As seen in FIG. 17, the spectral selectivity is substantially preserved as the light intensity is modulated continuously under a potential variably applied to the electrochromic medium.

Rather than attaching a separate filter to an electrochromic cell as described above, an alternative approach is to deposit an interference stack of thin film coatings on at least one surface of the substrates in the electrochromic cell. In such an arrangement, the transparent conductor and a metal oxide electrochromic solid film layer may comprise, in combination with other dielectric, semi-conductor and conducting layers, the interference stack that provides spectral selectivity.

Example 23

The electrochromic mirror cell of this example was constructed as described in Example 4, supra, except that the electrolyte included AMPT as a redox promoter in place of the redox promoter, phenothiazine. AMPT was synthesized following the procedures described in U.S. Pat. No. 4,666,907 (Fortin), the disclosure of which is hereby incorporated herein by reference.

The synthesized AMPT was purified by recrystallization from methanol.

The elemental analysis of the AMPT was determined to be:

	C	H	N	S	O
Calculated (%)	66.40	4.83	5.16	11.82	11.70
Found (%)	66.55	4.76	5.19	12.19	11.30

The electrolyte comprised AMPT (about 0.035M), ferrocene (about 0.02M), lithium perchlorate (about 0.055M) and "UVINUL" 400 [about 5% (w/v)] dissolved in propylene carbonate. Performance of the filled electrochromic mirror cell is reported in Table VIII below:

TABLE VIII

50° C., 1.3 V, 15 sec/15 sec cycle						
Number?			Transition Times (seconds)			
of Cycles	% HR	% LR	70–20 %	60–20 %	10–60 %	10–50 %
Original	74.6	6.7	3.5	3.1	13.6	7.6
65,000	71.4	8.4	4.1	3.6	5.1	3.6

Example 24

The electrochromic mirror cell of this example was constructed as described in Example 3, supra, except that the electrolyte included C-PT as a redox promoter in place of the redox promoter, phenothiazine. C-PT was synthesized following the procedures described in N. L. Smith, *J. Org. Chem.*, 15, 1125 (1950).

In this example, the substrates were juxtaposed flush to each other and an around-the-perimeter evaporated bus bar (comprising about 1,000 Å of chromium metal) was evaporatively deposited, using a mask to mask off the central portion, around the edge perimeter of the inward facing surface of the first ITO-coated substrate followed by another 10,000 Ø of silver metal evaporated thereover. A chromium adhesion layer/silver reflector layer/tungsten oxide electrochromic solid film layer was evaporated onto the opposing surface of the second substrate, which was plain glass. The electrolyte comprised C-PT (about 0.05M), lithium perchlorate (about 0.05M) and "UVINUL" 400 [about 5% (w/v)] dissolved in propylene carbonate.

With a potential of about 1.3 volts applied between the evaporated bus bar around the perimeter of the inward facing surface of the first substrate and the metal reflector layer on the opposing second substrate, we observed the initial high reflectivity state [HR (%)] to be about 87.3%, which dimmed to a low reflectivity state [LR (%)] of about 7.2%, with the transition from 70 to 20% reflectance occurring in a period of time of about 2.1 seconds and the transition from 10 to 60% reflectance, upon bleaching by shorting the electrodes, occurring in a period of time of about 7.1 seconds.

Example 25

In this example, we constructed an electrochromic mirror suitable for use as an interior rearview mirror for a motor vehicle. Construction was otherwise similar to that described in Example 6, supra, except that the shape of the mirror constructed for this example was of the size and shape commonly used for interior rearview mirrors. In addition, the first substrate was glass coated with a layer of ITO having a thickness of about 300 Å, with a specific resistivity of about 2.4×10^{-4} ohm.centimeter and a sheet resistance of about 80 ohms per square. Also, a thin film of aluminum having a thickness of about 2,000 Å was used as a reflective element instead of the silver reflective element used in the construction of Example 6, supra.

two filled the electrochromic rearview mirror with an electrolyte comprising ferrocene (about 0.015M), phenothiazine (about 0.06M), lithium perchlorate (about 0.05M) and "UVINUL" 400 [about 5% (w/v)] in a solvent combination of propylene carbonate and tetramethylene sulfone [in a ratio of about 50:50 (v/v)].

With about 1.1 to about 1.4 volts applied between the wrap-around silver conductive frit bus bar on the perimeter of the ITO-coated, inward facing surface on the first substrate and the aluminum reflector/chromium adhesion layer combination on the opposing surface of the second substrate, the electrochromic rearview mirror was observed to dim from a high reflectivity state of about 70%±5% reflectance to a dimmed state of about 6%±2% reflectance.

The electrochromic mirror of this example was tested and demonstrated to meet the requirements for commercial use on vehicles, as both interior rearview mirrors and exterior rearview mirrors. Also, in terms of cycle stability, an electrochromic mirror (which initially demonstrated a high reflectivity state of about 70.5% reflectance, and which dimmed to a reflectivity of about 7.1% reflectance when a potential of about 1.4 volts was applied thereto) was repetitively cycled at a temperature of about 50° C. for a total of 39,463 cycles, with each cycle consisting of the introduction of an applied potential of about 1.4 volts for 15 seconds and an applied potential of zero volts for 15 seconds. After cycling was completed, the mirror retained a high reflectivity state of about 68.2 reflectivity, dimmed to about 6.6% reflectivity under an applied potential of about 1.4 volts, and continued to be suitable for use on vehicles. Also, after about 14 days of oven bake at a temperature of about 85° C., a mirror (which initially had a high % reflectivity state of about 71.6% reflectance, and which dimmed to about 7.4% reflectance when an applied potential of about 1.4 volts was introduced thereto) exhibited a high reflectivity state of about 76.1% reflectance and dimmed to about 8.5% reflectance when about 1.4 volts was applied thereto. This mirror continued to be suitable for its intended use on vehicles even after oven bake at 85° C. This mirror satisfied the performance requirements and reliability requirements, such as of automobile manufacturers, to be suitable for use within the interior cabin of an automobile, or for use as an exterior mirror.

These examples are provided for illustrative purposes only, and it will be clear to those of ordinary skill in the art that changes and modifications may be practiced within the spirit of the claims which define the scope of the present invention. Thus, the art-skilled will recognize or readily ascertain using no more than routine experimentation, that equivalents exist to the embodiments of the invention described herein. And, it is intended that such equivalents be encompassed by the claims which follow hereinafter.

What we claim is:

1. An electrochromic rearview mirror for a motor vehicle comprising:

(a) a first substantially transparent substrate coated with a substantially transparent conductive electrode coating on its inward surface;

(b) a second substantially transparent substrate with a substantially transparent conductive electrode coating on its inward surface, said second substrate positioned in spaced-apart relationship with said substrate of (a);

(c) a layer of reflective material coated onto the non-inward opposite surface of said substrate of (b);

(d) an ultraviolet radiation vulnerable electrochromic solid film coated onto said substantially transparent conductive electrode coating of said substrate of (b);

(e) a sealing means positioned toward a peripheral edge of each of said substrate of (a) and said substrate of (b) and sealingly forming a cavity therebetween;

(f) an electrolyte comprising a redox reaction promoter and wherein said electrolyte is located within said cavity in front of said electrochromic solid film forming an electrochromic element whereby said electrolyte shields said electrochromic solid film from ultraviolet radiation; and

(g) a means for introducing an applied potential to said electrochromic element to controllably cause a variation in the amount of light reflected from said mirror.

2. The electrochromic rearview mirror according to claim 1, wherein said electrochromic solid film comprises a metal oxide selected from the group consisting of a Group IV-B metal oxide, a Group V-B metal oxide, a Group VI-B metal oxide and combinations thereof.

3. The electrochromic mirror according to claim 2, wherein said metal oxide is doped with a dopant selected from the group consisting of molybdenum, rhenium, tin, rhodium, indium, bismuth, barium, titanium, tantalum, niobium, copper, cerium, lanthanum, zirconium, zinc and nickel.

4. The electrochromic mirror according to claim 3, wherein said metal oxide comprises tungsten oxide.

5. The electrochromic mirror according to claim 4, wherein said dopant comprises a tin dopant.

6. The electrochromic mirror according to claim 5, wherein said electrochromic solid film is deposited by a non-vacuum deposition method.

7. The electrochromic mirror according to claim 6, wherein said non-vacuum deposition method comprises a wet chemical method.

8. The electrochromic mirror according to claim 7, wherein said wet chemical method comprises a dip/fire deposition method.

9. The electrochromic mirror according to claim 1, wherein said sealing means is deposited with a computer numerical control controlled dispenser.

10. The electrochromic mirror according to claim 1, wherein said first substrate and said second substrate are bent so as to form a convex mirror.

11. The electrochromic mirror according to claim 1, wherein said first substrate and said second substrate are bent so as to form a multi-radius mirror.

12. The electrochromic mirror according to claim 1, wherein said mirror is prepared using a vacuum bagging technique.

13. The electrochromic mirror according to claim 12, wherein said cavity includes rigid, spacer means.

14. The electrochromic mirror according to claim 13, wherein said spacer means comprises glass spacer beads.

15. The electrochromic mirror according to claim 1, wherein said layer of reflective material comprises a silver thin film coating.

16. The electrochromic mirror according to claim 1, wherein said layer of reflective material comprises an aluminum thin film coating.

17. The electrochromic rearview mirror according to claim 1, wherein said reflective material comprises one of silver or aluminum.

18. The electrochromic rearview mirror according to claim 1, wherein said electrochromic solid film comprises an inorganic transition metal oxide.

19. The electrochromic rearview mirror according to claim 18, wherein said electrochromic solid film comprises tungsten oxide.

20. The electrochromic rearview mirror according to claim 1, wherein said redox reaction promoter comprises a metallocene.

21. The electrochromic rearview mirror according to claim 1, wherein said redox reaction promoter comprises a phenothiazine.

22. The electrochromic rearview mirror according to claim 1, wherein said electrolyte further comprises an ultraviolet stabilizing agent.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 5,724,187

DATED : March 3, 1998

INVENTOR(S) : DESARAJU V. VARAPRASAD, ET AL. Page 1 of 5

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

ON THE TITLE PAGE

AT [56] REFERENCES CITED/OTHER PUBLICATIONS

"Maleval" should read --Materials-- and "Lynom" should read --Lynam--.

COLUMN 2

Line 20, "single-compartment" should read --single compartment--;
Line 23, "has" should read --have--; and
Line 45, "U.S. Pat. No. Re. 30,835 (Giglia)" should read --Re. 30,835 (Giglia)--.

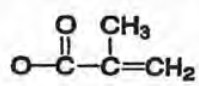
COLUMN 6

Line 24, "eye glass" should read --eyeglasses--.

COLUMN 10

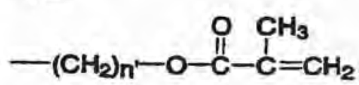
Line 32, "caRbon" should read --carbon--;

Lines 47-49, "



"

should read --



--;

Line 62, "$-(CH_2)_n-N+(CH_3)_3$ X-, wherein,n" should read -- $-(CH_2)_n-N^+(CH_3)_3$ X^-, wherein n--;
Line 63, "Cl-, Br-, I-," should read --Cl, Br, I,--; and

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 5,724;187

DATED : March 3, 1998

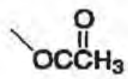
INVENTOR(S) : DESARAJU V. VARAPRASAD, ET AL. Page 2 of 5

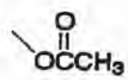
It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

COLUMN 10 (cont.)

Line 64, "ClO_4- or BF_4-" should read --ClO_4 or BF_4-- " and M_e should read --Me--.

COLUMN 11

Lines 62-63, "  "

should read --  --.

COLUMN 12

Line 49, "trillate" should read --triflate--.

COLUMN 13

Line 23, "3-methysulfolfane" should read --3-methylsulfolane--.

COLUMN. 14

Line 58, "include" should read --includes--.

COLUMN 15

Line 28, "substrate" should read --substrate 3).--.

COLUMN 16

Line 23, "resilience" should read --resistance--.

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 5,724,187

DATED : March 3, 1998

INVENTOR(S) : DESARAJU V. VARAPRASAD, ET AL. Page 3 of 5

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

COLUMN 20

Line 46, "outgasing" should read --outgassing--; and
Line 66, "outgasing" should read --outgassing--.

COLUMN 22

Line 36, "assist" should read --assists--.

COLUMN 24

Line 5, "Of" should read --Of--; and
Line 60, "mmcroencapsulated" should read --microencapsulated--.

COLUMN 28

Line 2, "be" should read --be achieved--; and
Line 61, "to" should be deleted.

COLUMN 29

Line 50, "50" should read --50%,--.

COLUMN 35

Line 10, "10" should be deleted;
Line 13, "curved" should read --curved)--;
Line 37, "Bee" should read --see--; and
Line 55, "coatings" should read --coatings 4,4'--.

COLUMN 37

Line 1, "textural" should read --textual--;
Line 2, "textural" should read --textual--;

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 5,724,187

DATED : March 3, 1998

INVENTOR(S) : DESARAJU V. VARAPRASAD, ET AL. Page 4 of 5

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

COLUMN 37 (cont.)

Line 6, "textural" should read --textual--; and
Line 9, "textural" should read --textual--.

COLUMN 38

Line 25, "10" should be deleted and "least" should read --at least--.

COLUMN 44

Line 62, "ITO, tis" should read --such as--.

COLUMN 45

Line 9, "exterior" should read --exteriors of--; and
Line 34, "such," should read --such as--.

COLUMN 46

Line 3, "concave" should read --convex--.

COLUMN 52

Line 43, "75.1 75.9" should read --78.1 78.9--; and
Line 44, "75.S" should read --75.8--.

COLUMN 56

Line 25, "coated/again" should read --coated (again--.

COLUMN 58

Line 12, "We," should read --We--; and
Line 34, "squares" should read --square--.

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 5,724,187

DATED : March 3, 1998

INVENTOR(S) : DESARAJU V. VARAPRASAD, ET AL. Page 5 of 5

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

COLUMN 61

Line 17, "FIP2QMSS" should read --FIP2QM8S--.

COLUMN 62

Line 54, "15" should be deleted.

COLUMN 65

Line 11, "10" should be deleted.

COLUMN 66

Line 15, "formulations" (first occurrence) should be deleted.

COLUMN 68

Line 6, "Number?" should read --Number--;
Line 27, "Ø" should read --Å--; and
Line 59, "two" should read --We--.

Signed and Sealed this

Seventeenth Day of November, 1998

Attest:

Bruce Lehman

BRUCE LEHMAN

Attesting Officer

Commissioner of Patents and Trademarks

US005668663A

United States Patent [19]

Varaprasad et al.

[11] Patent Number: 5,668,663

[45] Date of Patent: Sep. 16, 1997

[54] ELECTROCHROMIC MIRRORS AND DEVICES

[75] Inventors: Desaraju V. Varaprasad; Hamid Habibi; Ian A. McCabe; Niall R. Lynam, all of Holland, Mich.

[73] Assignee: Donnelly Corporation, Holland, Mich.

[21] Appl. No.: 238,521

[22] Filed: May 5, 1994

[51] Int. Cl.[6] G02B 5/08

[52] U.S. Cl. 359/608; 359/265; 359/273; 359/601; 359/603

[58] Field of Search 359/601–608, 359/267–272; 252/583, 586

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Primary Examiner—Thong Nguyen

Attorney, Agent, or Firm—Fitzpatrick, Cella, Harper & Scinto

[57] ABSTRACT

The present invention relates to electrochromic mirrors and devices whose electrochromic element is composed of an electrochromic solid film and an electrolyte comprising redox reaction promoters and alkali ions and/or protons.

38 Claims, 9 Drawing Sheets

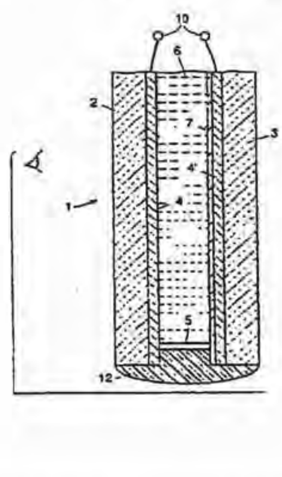

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FIG. 1

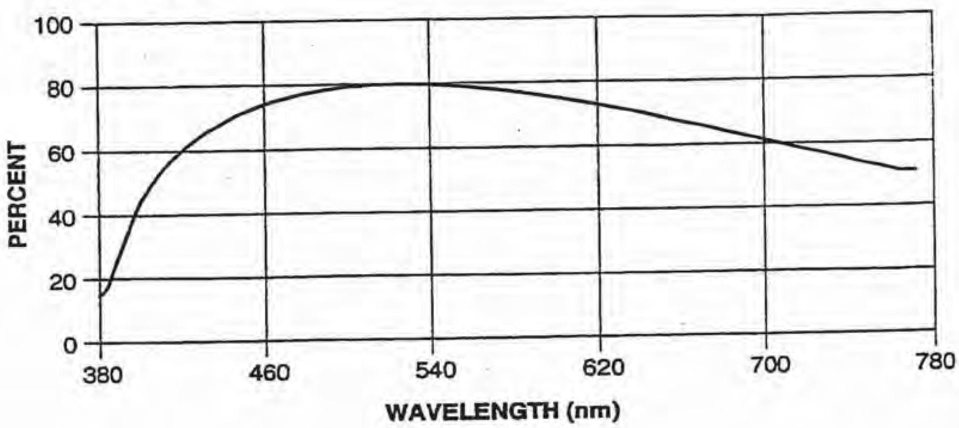
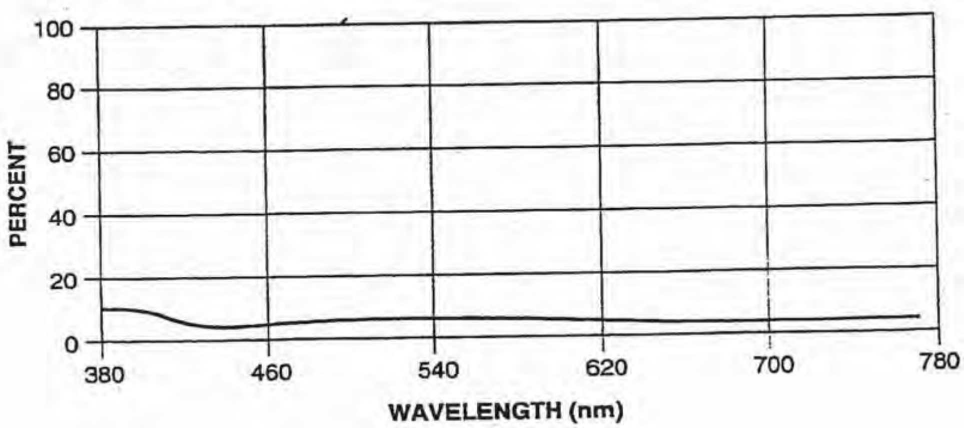

100
80
60
40
20
0
PERCENT
380
460
540
620
700
780
WAVELENGTH (nm)

FIG. 2


100
80
60
40
20
0
PERCENT
380
460
540
620
700
780
WAVELENGTH (nm)

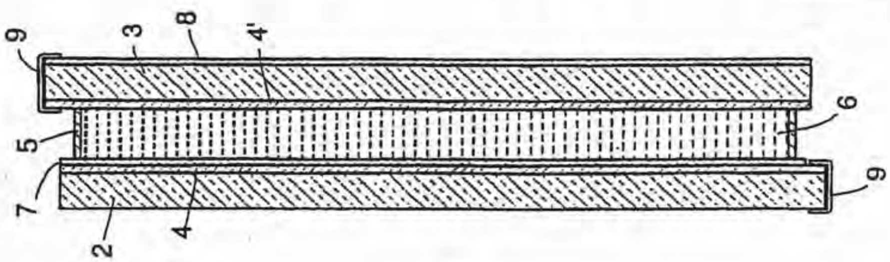


FIG. 3B

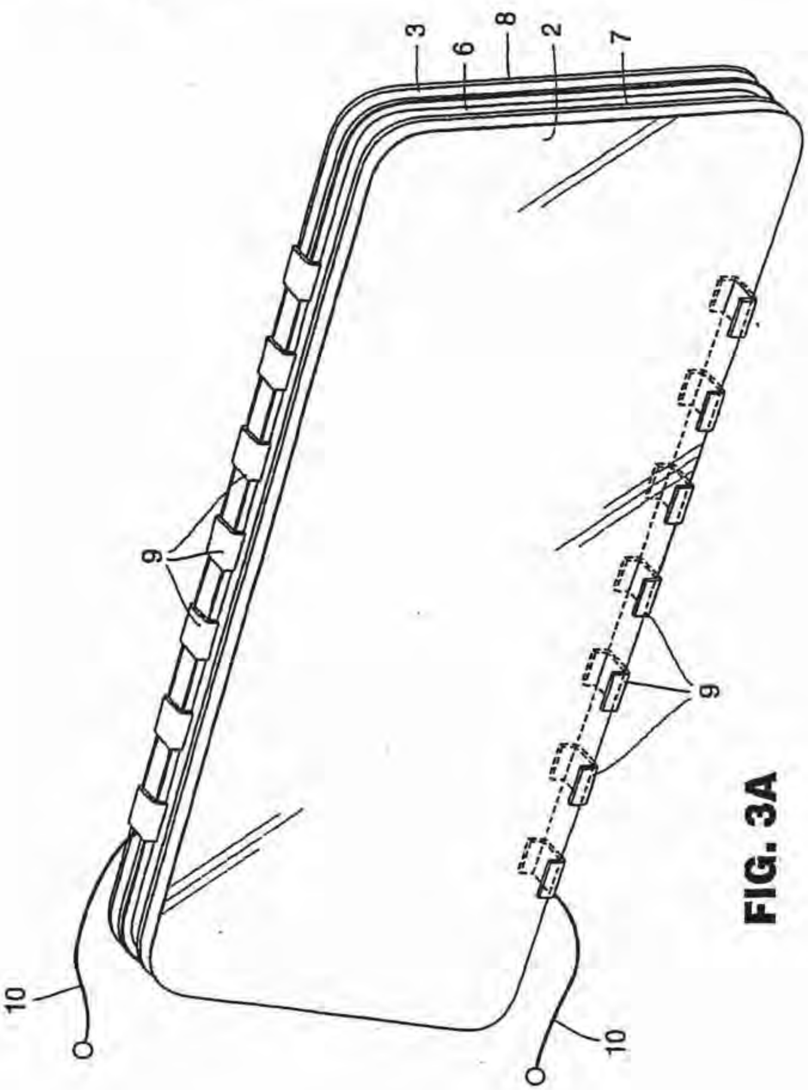


FIG. 3A

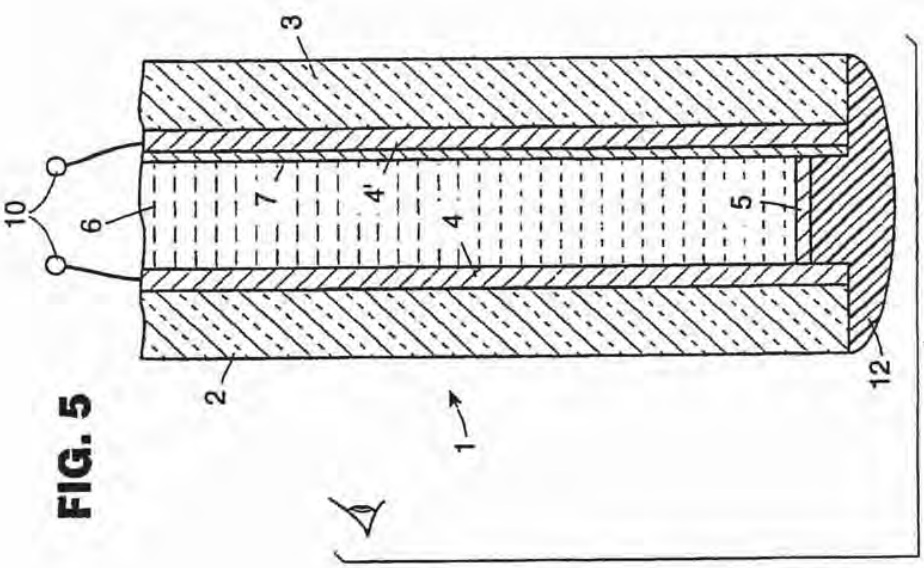


FIG. 5

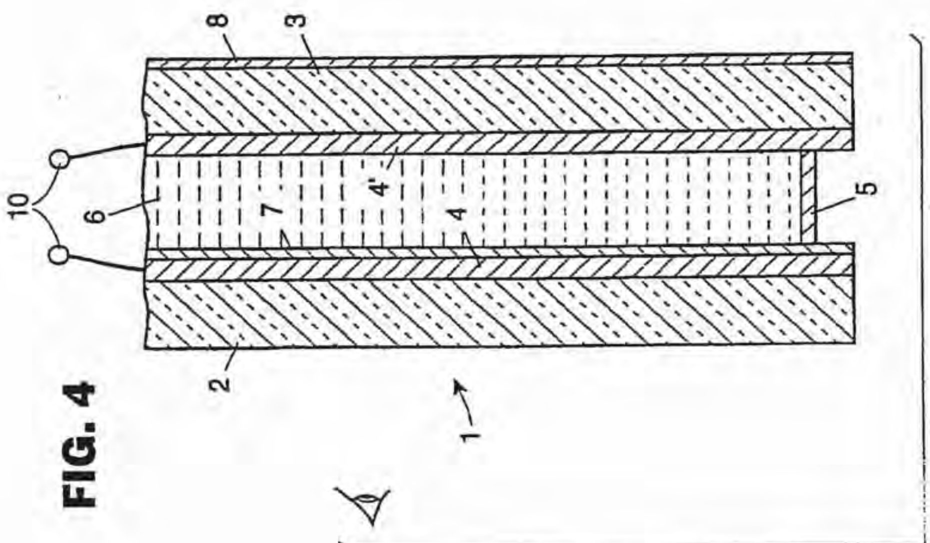


FIG. 4

FIG. 7

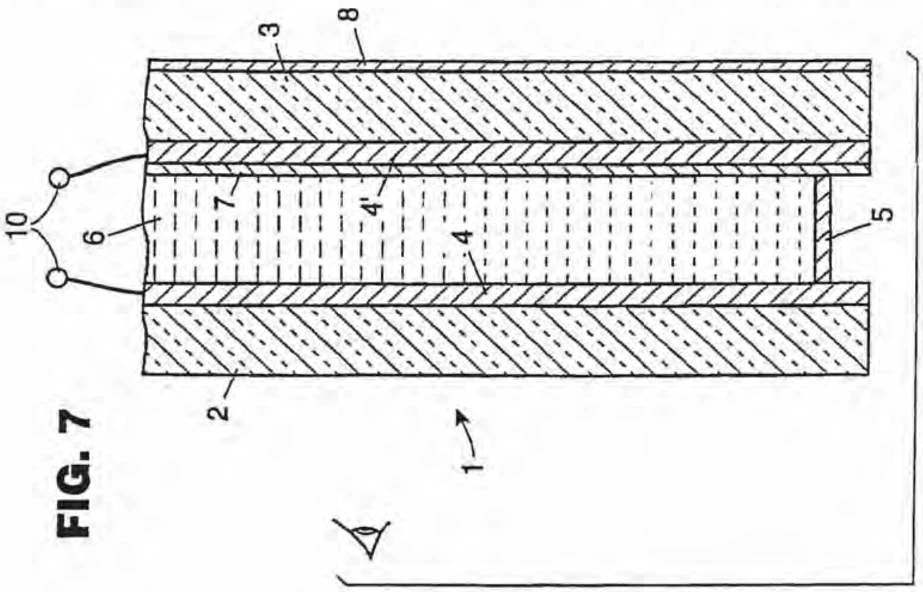


FIG. 6

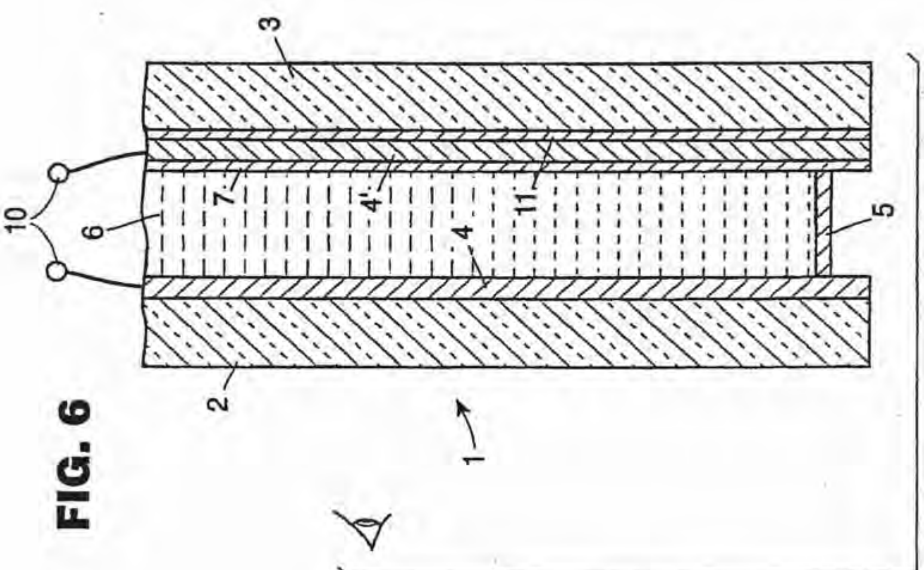
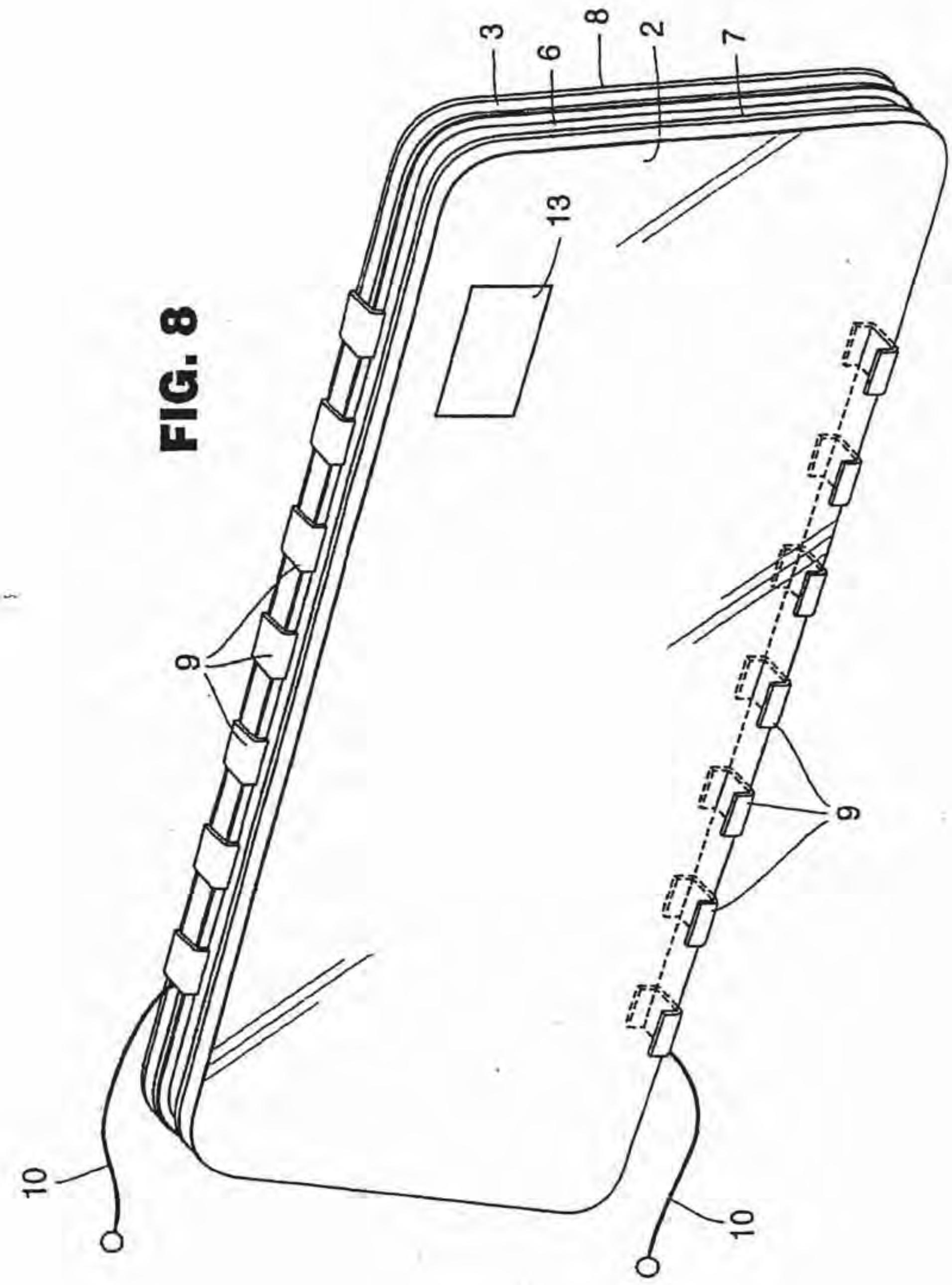


FIG. 8



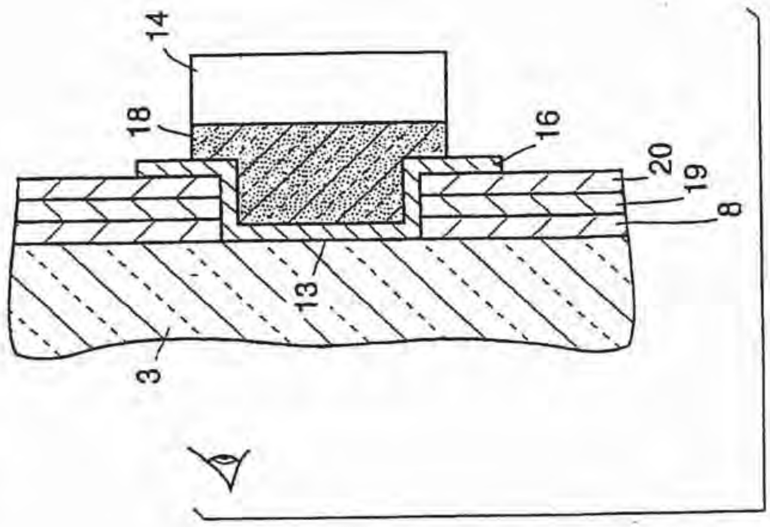


FIG. 10

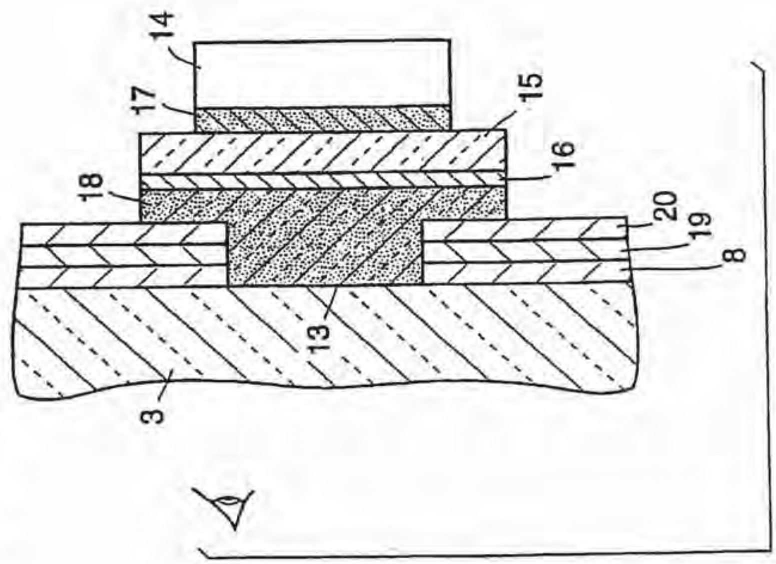


FIG. 9

FIG. 11A

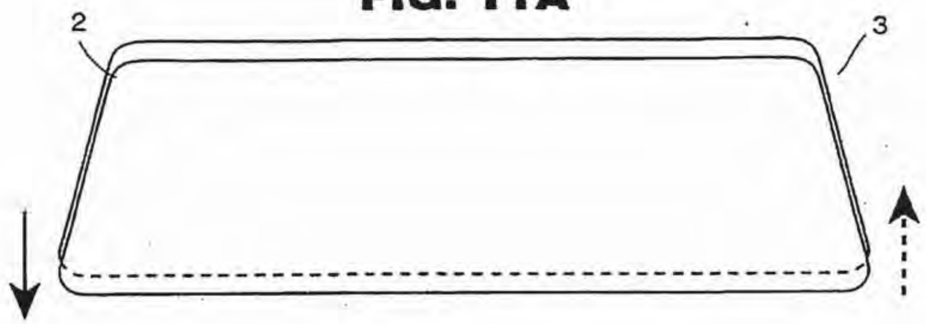


FIG. 11B

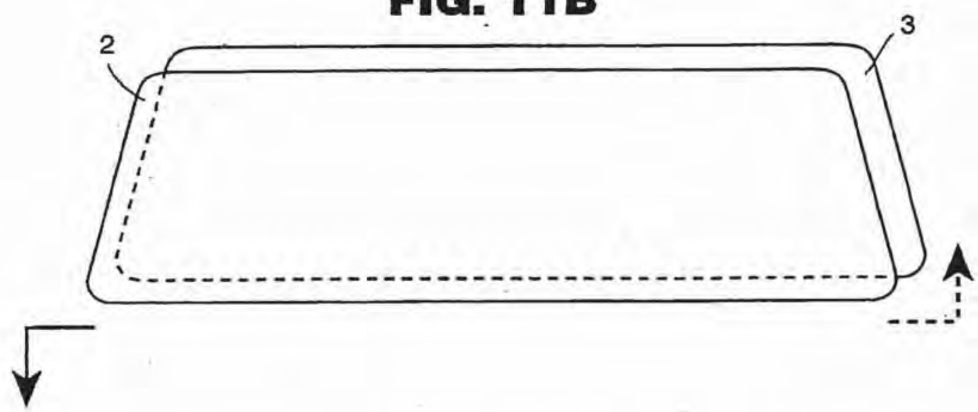
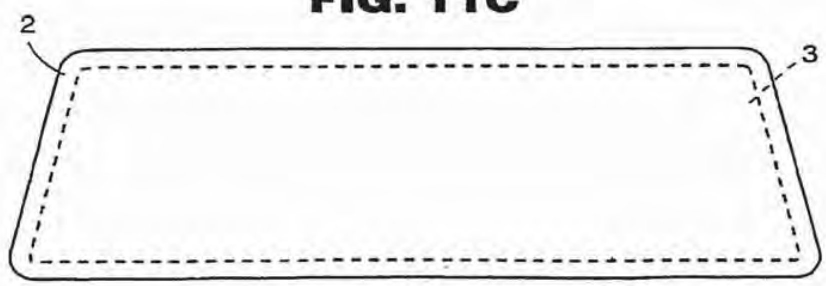


FIG. 11C



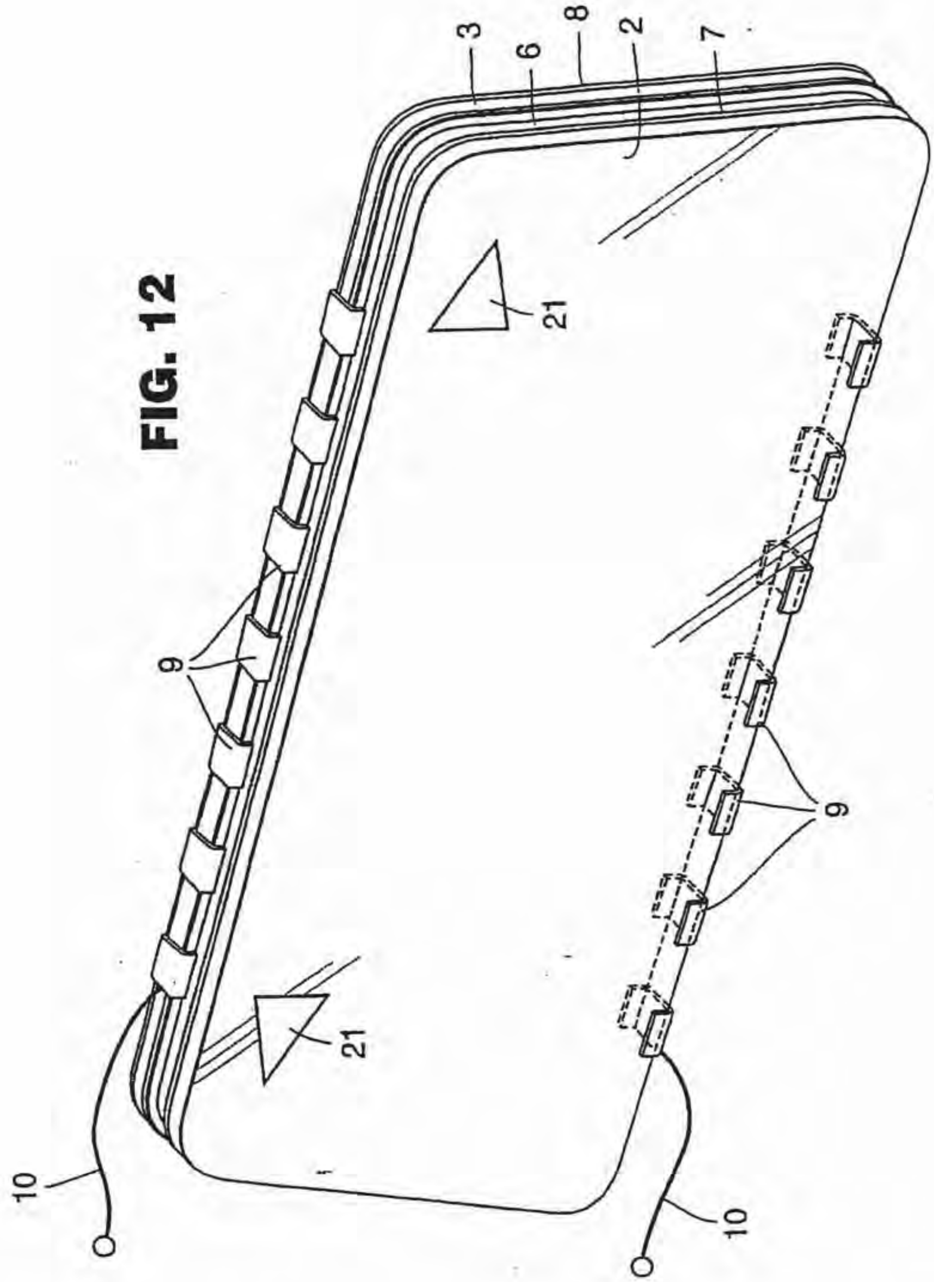
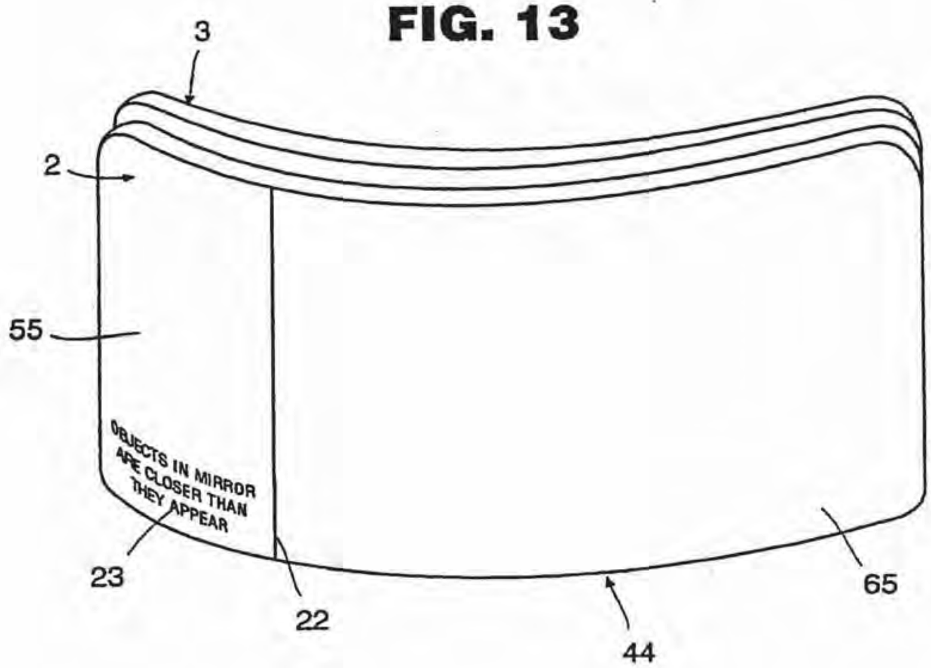


FIG. 12

FIG. 13


3
2
55
OBJECTS IN MIRROR ARE CLOSER THAN THEY APPEAR
23
22
44
65

ELECTROCHROMIC MIRRORS AND DEVICES

BACKGROUND OF THE INVENTION

1. Technical Field of the Invention

The present invention relates to electrochromic devices for continuously varying the transmissivity to light suitable for use in, for example, electrochromic rearview mirrors, windows and sun roofs for motor vehicles, manufactured from electrochromic solid films and electrolytes containing redox reaction promoters and alkali ions and/or protons.

2. Brief Description of the Related Technology

Prior to the introduction of electro-optic mirrors into the automotive marketplace, prismatic rearview mirrors were available to drivers of motor vehicles to determine the whereabouts of neighboring motor vehicles to their rearward surroundings. By using a manual lever located on such mirrors, a driver of a motor vehicle, especially at dusk or later, would be able to employ a prismatic feature on the mirror to vitiate the effect of headlamp glare (the principal source of incoming electromagnetic radiation from the rear of the motor vehicle) from the low beam, and especially high beam, lighting elements of other motor vehicles travelling posterior thereto. Should the lever be flipped to the nighttime position, the driver would be able to view an image in a reflection from a glass-to-air interface on the first surface of the mirror. The light reflected from this first surface would exhibit non-spectral selectivity. That is, the background of any image viewed in the nighttime position of the prismatic mirror would be a neutral color. Such conventional prismatic mirrors are still used on a majority of motor vehicles in the United States today.

With the advent of electro-optic technology, such as electrochromic technology, it has become possible to achieve continuous variability in reflectivity in rearview mirrors for motor vehicles. This continuous variability has been achieved, for example, through the use of reversibly variable electrochromic devices, wherein the intensity of light (e.g., visible, infrared, ultraviolet or other distinct or overlapping electromagnetic radiation) is modulated by passing the light through an electrochromic medium. In such devices, the electrochromic medium is disposed between two conductive electrodes and undergoes electrochromism when potential differences are applied across the two electrodes.

Some examples of these prior art electrochromic devices are described in U.S. Pat. Nos. 3,280,701 (Donnelly); 3,451,741 (Manos); 3,806,229 (Schoot); 4,465,339 (Baucke); 4,712,879 (Lynam) ("Lynam I"); 4,902,108 (Byker) ("Byker I"); Japanese Patent Publication JP 57-30,639 (Negishi) ("Negishi I"); Japanese Patent Publication JP 57-208,530 (Negishi) ("Negishi II"); and I. F. Chang, "Electrochromic and Electrochemichromic Materials and Phenomena", in *Nonemissive Electrooptic Displays*, 155–96, A. R. Kmetz and F. K. von Willisen, eds., Plenum Press, New York (1976).

Numerous devices using an electrochromic medium wherein the electrochromism takes place entirely in a liquid solution are known in the art [see e.g., U.S. Pat. Nos. 5,128,799 (Byker) ("Byker II"); Donnelly, Manos, Schoot and Byker I; and commonly assigned U.S. Pat. Nos. 5,073,012 (Lynam) ("Lynam II"); 5,115,346 (Lynam) ("Lynam III"); 5,140,455 (Varaprasad) ("Varaprasad I"); 5,142,407 (Varaprasad) ("Varaprasad II"); 5,151,816 (Varaprasad) ("Varaprasad III"); 5,239,405 (Varaprasad) ("Varaprasad IV"); and commonly assigned co-pending U.S. patent application Ser. Nos. 07/935,784 (filed Aug. 27, 1992), now U.S. Pat. No. 5,500,760, and 08/061,742 (filed May 17, 1993), now U.S. Pat. No. 5,424,865]. Typically, these electrochromic devices, sometimes referred to as electrochemichromic devices, are single-compartment, self-erasing, solution-phase electrochromic devices. See e.g., Manos, Negishi II, Byker I and Byker II.

In single-compartment, self-erasing, solution-phase electrochromic devices, the intensity of the electromagnetic radiation is modulated by passing through a solution of the color-forming species held in a single-compartment. The color-changing reaction occurs only in this solution-phase. That is, there is no solid material present in the devices that has the color-changing reaction in it. During operation of such devices, the solution of the color-forming species is liquid or fluid, although it may be gelled or made highly viscous with a thickening agent, and the components of the solution do not precipitate. See e.g., Byker I and Byker II.

Numerous devices using an electrochromic medium wherein the electrochromism occurs in a solid layer are also widely described in the art. Among such devices are those that employ electrochromic thin film technology [see e.g., N. R. Lynam, "Electrochromic Automotive Day/Night Mirrors", *SAE Technical Paper Series*, 870636 (1987); N. R. Lynam, "Smart Windows for Automobiles", *SAE Technical Paper Series*, 900419 (1990); N. R. Lynam and A. Agrawal, "Automotive Applications of Chromogenic Materials", *Large Area Chromogenics: Materials & Devices for Transmittance Control*, C. M. Lampert and C. G. Granquist, eds., Optical Eng'g Press, Washington (1990); C. M. Lampert, "Electrochromic Devices and Devices for Energy Efficient Windows", *Solar Energy Materials*, 11, 1–27 (1984); Japanese Patent Document JP 58-30,729 (Kamimori) ("Kamimori I"); U.S. Pat. Nos. 3,521,941 (Deb); 3,807,832 (Castellion); 4,174,152 (Giglia); Re. 30,835 (Giglia); 4,338,000 (Kamimori) ("Kamimori II"); 4,652,090 (Uchikawa); 4,671,619 (Kamimori) ("Kamimori III"); 4,702,566 (Tukude); Lynam I and commonly assigned U.S. Pat. Nos. 5,066,112 (Lynam) ("Lynam IV") and 5,076,674 (Lynam) ("Lynam V")].

In thin film electrochromic devices, an anodic electrochromic layer and/or a cathodic electrochromic layer, each layer usually made from inorganic metal oxides or polymer films, may be separate and distinct from one another. In contrast to the single-compartment, self-erasing, solution-phase devices referred to supra, these thin film electrochromic devices modulate the intensity of electromagnetic radiation by passing through the individual anodic electrochromic layer and/or cathodic electrochromic layer.

In certain thin film electrochromic devices, a thin film layer of a solid electrochromic material, such as a tungsten oxide-type solid film, may be placed in contact with a liquid electrolyte containing redox promoters, such as ferrocene and iodide, and a solvent. See e.g., Kamimori III. In these electrochromic devices, the intensity of electromagnetic radiation is primarily modulated by passing through the solid electrochromic material. When dimmed to a colored state, these tungsten oxide-type solid films typically dim to a blue-colored state.

Having grown accustomed to conventional prismatic rearview mirrors for motor vehicles, some consumers of motor vehicles may show a preference for rearview mirrors possessing substantial non-spectral selectivity. That is, some consumers may prefer mirrors which present a substantially gray color when dimmed to a colored state; in other words, a mirror that exhibits a viewing background comparable in spectral reflectivity to that of conventional prismatic mirrors.

On another note, the reflective element of the mirror is often constructed from silver and is typically situated on the rearmost surface of the mirror. That is, the reflective element is placed on the surface of a glass substrate farthest from that surface which first comes in contact with incident light. However, such placement has certain disadvantages. For instance, double imaging is a recognized problem in such mirror construction. In addition, in its path to reaching the reflective element of the mirror, incident light must first pass through each of the glass substrates of the mirror assembly. Therefore, in these mirror constructions, to achieve good optical performance, higher quality glass should be used for both substrates. Moreover, these mirror constructions typically require the use of a thin film transparent conductive electrode coating on the inward surface of each substrate in order to apply a potential to the electrochromic element. Requiring each substrate of the mirror to be of such higher quality glass and the use of two such transparent conductive electrodes increases material and production costs. Further, placement of the reflective element on the rearmost surface of the mirror requires an additional manufacturing step, which also increases production costs. And, such placement increases material and production costs due to necessary measures taken to protect the reflective element (typically, a highly reflective material, such as silver or aluminum) against environmental degradation, such as through the use of a paint or the like. Frequently, lead-based paints have been used for this purpose, thereby presenting environmental concerns.

It has been suggested and attempts have been made to place the reflective element of the mirror, such as silver, on the inward facing surface of the rear substrate so as to act as a conductive electrode coating as well as a reflective element. See e.g., Donnelly, Negishi I, Byker I and Byker II. This configuration is plainly attractive since it eliminates the need for a separate transparent conductive coating on the rear substrate, thereby reducing the cost of manufacture.

In order to function in the dual role of reflective element and conductive electrode, a coating must (1) be electrochemically stable so as not to degrade during operation of the device, (2) remain securely adhered to the rear substrate to maintain the integrity of the device, and (3) be highly reflective so that the mirror as a whole will have an acceptable level of reflectance. However, no known mirror construction meets all of these requirements—for example silver, commonly used as the reflective element in conventional mirror constructions, is highly reflective but is not electrochemically stable and is difficult to adhere to the surface of a glass substrate. Other materials, such as rhodium or Inconel, which have been used as a combined reflective element and conducting electrode in prior art mirrors are not sufficiently reflective to provide a highly reflective electrochromic mirror. Perhaps for these reasons, the prior art suggestions and attempts have not resulted in any commercially successful electrochromic mirror in which a single coating is used as both reflective element and conducting electrode.

Electrochromic devices, such as those using a solid film electrochromic material, like tungsten oxide, may also exhibit deleterious performance when exposed to ultraviolet radiation over prolonged periods of time (e.g., conditions typically encountered during outdoor weathering). This deleterious performance may be linked to any of a variety of sources, including a potential propensity for photochromism to occur.

On yet another note, displays, indicia and sensors, such as photosensors, motion sensors, cameras and the like, have heretofore been incorporated into certain electrochromic mirror constructions [see e.g., U.S. Pat. Nos. 5,189,537 (O'Farrell) and 5,285,060 (Larson)]. In these constructions, the reflective element of the mirror has been locally removed to create a highly transmissive local window. However, such use of displays and the like positioned behind the reflective element of electrochromic mirrors has been limited. One reason for this limited use is due to diminished rear vision capability in that portion of the reflective element of the mirror which has been removed. Moreover, the displays and the like known to date may be distracting as well as aesthetically non-appealing to the driver and/or passengers of motor vehicles insofar as they may be visible and observable within the mirror mounted in the motor vehicles when in the inactivated state. In addition, the known methods of incorporating such displays and the like into mirrors have been only partially successful, labor intensive and economically unattractive from a manufacturing standpoint.

Further, although it has been suggested to use semi-transparent reflectors in rearview mirrors [see e.g., U.S. Pat. Nos. 5,014,167 (Roberts) ("Roberts I") and 5,207,492 (Roberts) ("Roberts II")], previous attempts have included the use of dichroic reflectors which are complex to design and expensive to fabricate. Also, where use of metallic reflectors has been suggested [see e.g., U.S. Pat. No. 4,588,267 (Pastore)], it has been in the context of conventional mirrors such as prismatic mirrors. These suggestions fail to recognize the problems that must be overcome to provide a highly reflecting and partially transmitting electrochromic rearview mirror.

Therefore, the need exists for an electrochromic mirror that provides substantial non-spectral selectivity when dimmed to a colored state, akin to that exhibited by conventional prismatic mirrors when in the nighttime position, along with continuous variability in reflectivity, ease and economy of manufacture and enhanced outdoor weathering resilience. It would also be desirable, particularly in this connection, to have an electrochromic mirror construction that reduces material and manufacturing costs by employing as only one of its substrates a high quality glass as a substrate and also as only one of its electrodes a thin film, substantially transparent conductive electrode coating. In addition, it would be desirable for a mirror to have display-on-demand capability where a display could become activated to be viewed on demand, and where the display is (1) aesthetically appealing and not distracting in its inactivated state, and (2) is manufactured with ease and economy.

SUMMARY OF THE INVENTION

The present invention meets the needs expressed above concerning the desirability of a substantially non-spectral selective electrochromic mirror by providing such an electrochromic mirror that exhibits substantially non-spectral selectivity in the form of a substantially neutral or neutral gray appearance when dimmed to a colored state by the introduction of an applied potential. The electrochromic element of this mirror comprises an electrochromic solid film and an electrolyte, which itself comprises redox reaction promoters and alkali ions and/or protons.

Another aspect of the present invention provides a commercially practicable electrochromic mirror having a novel construction. More specifically, this novel mirror construction provides a layer of reflective material coated on the inward surface of the second substrate which also serves as a conductive electrode coating. The layer of reflective material is overcoated with an electrochromic solid film and may also be undercoated to promote its adhesion to the substrate.

This construction employs a higher quality glass for only one of its substrates and employs for only that substrate made from a higher quality glass a conductive electrode coating that is substantially transparent. That is, the construction permits the use of (1) a lower quality glass as the second or rearmost substrate while maintaining good optical performance in the mirror; (2) a higher resistance, and hence more economical, conductive electrode coating for the first or frontmost substrate which is made from a higher quality glass; and (3) only one substantially transparent conductive electrode coating (to be used on the inward surface of the first substrate made from a higher quality glass), which further reduces material costs incurred in the manufacture of such mirrors.

In addition, the layer of reflective material in this novel construction reduces further still the material and production costs associated with such mirrors since it serves the additional role of a conductive electrode coating thereby obviating manufacturing costs associated with a separate substantially transparent conductive electrode coating. Moreover, in this construction, the reflective element of the mirror is located within, and protected by, the sealed cavity which forms the electrochromic element of the mirror. The reflective element of the mirror is thus protected from degradation through environmental exposure without having to resort to the use of protective materials, such as lead-based overcoating paints or the like. The novel construction of this electrochromic mirror also enhances the resistance of the reflective material to physical, chemical and/or electrochemical degradation. Further, the construction so provided also reduces image separation which can lead to the recognized problem of double imaging.

In addition, another aspect of the invention provides an "on demand display" for mirrors, as described hereinafter. The mirror construction referred to supra and described in detail hereinafter, facilitates placement of displays, indicia and sensors and the like behind the mirror element so that they may be viewed as an "on demand display".

As stated supra, the electrochromic mirrors of the present invention exhibit a substantially gray appearance when dimmed to a colored state upon the introduction of an applied potential. The coloring capability of these mirrors determines the extent to which glare may be reflected from the mirrors. As with other electrochromic mirrors, this coloring capability may be continuously varied by controlling the magnitude, duration and polarity of the applied potential introduced thereto. The appearance of the substantially gray color may be appealing to consumer preferences (especially to certain drivers of motor vehicles which employ these mirrors) and to commercial design and manufacture concerns by virtue of its substantial color neutrality relative to the color of the housing, casing, structure, machine, instrument or vehicle with which it is to be used. That is, even when dimmed to a colored state, the electrochromic mirrors of the present invention are often aesthetically complementary to the color of the other component(s) with which they are to be used.

The electrochromic mirrors of the present invention are suitable for use as electrochromic rearview mirrors (e.g., truck mirrors, interior and exterior mirrors for motor vehicles), architectural mirrors or specialty mirrors, like those useful in aeronautical, periscopic or dental and medical applications.

In addition to electrochromic mirrors, electrochromic devices, such as electrochromic glazings (e.g., architectural glazings, like those useful in the home, office or other edifice; aeronautical glazings, such as those which may be useful in aircraft; or vehicular glazings, for instance, windows, like windshields, side windows and backlights, sun roofs, sun visors or shade bands); electrochromic optically attenuating contrast filters, such as contrast enhancement filters, suitable for use in connection with cathode ray tube monitors and the like; electrochromic privacy or security partitions; electrochromic solar panels, such as sky lights; electrochromic information displays; and electrochromic lenses and eye glass, may also benefit from that which is described herein, especially where substantially non-spectral selective coloring is desired.

Thus, the present invention exemplifies an advance in the art that will become readily apparent and more greatly appreciated by a study of the detailed description taken in conjunction with the figures which follow hereinafter.

BRIEF DESCRIPTION OF THE FIGURES

FIG. 1 depicts a spectral scan of percent reflectance versus wavelength in nanometers of an electrochromic mirror according to the present invention when in its bleached state;

FIG. 2 depicts a spectral scan of percent reflectance versus wavelength in nanometers of an electrochromic mirror according to the present invention when dimmed to a neutral colored state;

FIG. 3A depicts a perspective view of an electrochromic mirror—i.e., an interior rearview automobile mirror—according to the present invention;

FIG. 3B depicts a cross-sectional view of the electrochromic mirror of FIG. 3A;

FIG. 4 depicts another cross-sectional view of the electrochromic mirror of FIGS. 3A and 3B;

FIG. 5 depicts a cross-sectional view of another electrochromic mirror construction according to the present invention. In this construction, a secondary weather barrier 12 has been applied to the joint at which sealing means 5 joins substrates 2,3;

FIG. 6 depicts a cross-sectional view of still another electrochromic mirror construction according to the present invention. This mirror construction is similar to the mirror construction of FIG. 5, except that an adhesion promoter 11 is coated between substrate 3 and conductive electrode coating 4';

FIG. 7 depicts a cross-sectional view of yet another electrochromic mirror construction according to the present invention;

FIG. 8 depicts a perspective view of an electrochromic mirror constructed with an on demand display;

FIG. 9 depicts a cross-sectional view of an electrochromic mirror constructed with an on demand display using a glass cover sheet over the display window in the mirror construction;

FIG. 10 depicts a cross-sectional view of another electrochromic mirror constructed with an on demand display;

FIGS. 11A, 11B and 11C depict the orientation of the substrates in different constructions of the electrochromic mirrors and electrochromic devices of the present invention. FIG. 11A depicts a perpendicular displacement of the first substrate and the second substrate. FIG. 11B depicts a lateral displacement and a perpendicular displacement of the first substrate and the second substrate. FIG. 11C depicts an arrangement of the first substrate and the second substrate, wherein the dimensions of the length and width of the first substrate are slightly greater than those of the second substrate. In this arrangement, the peripheral edge of the first substrate extends beyond the peripheral edge of the second substrate;

FIG. 12 depicts a perspective view of an electrochromic mirror constructed with turn signal indicia; and

FIG. 13 depicts a perspective view of a multi-radius electrochromic mirror according to the present invention.

The depictions in these figures are for illustrative purposes only and are not drawn to scale. Unless otherwise indicated, in the following detailed description of the invention the element numbers discussed are descriptive of like elements of all figures.

DETAILED DESCRIPTION OF THE INVENTION

In accordance with the teaching of the present invention, there are provided electrochromic mirrors, such as electrochromic rearview mirrors for a motor vehicle. These mirrors are constructed from a first substantially transparent substrate with a substantially transparent conductive electrode coating on its inward surface and a second substrate, which may or may not be substantially transparent, with a conductive electrode coating, which also may or may not be substantially transparent, on its inward surface. Whether the second substrate and the conductive electrode coating thereon are or are not substantially transparent will depend on the particular construction of the mirror.

The first substrate and second substrate may be positioned in spaced-apart relationship with one another, being substantially parallel or substantially tangentially parallel depending upon whether the substrates are flat or bent. These substrates may also be laterally displaced from, or in a substantially flush relationship with, one another. The substrates may also have respective dimensions such that one of the substrates is sized and shaped to have a slightly greater length and width than the other substrate. Thus, when the substrates are positioned in central alignment with one another, the peripheral edges of the slightly larger substrate extend beyond the peripheral edges of the slightly smaller substrate.

The mirrors have a layer of reflective material coated either onto (a) the rearmost (non-inward) surface of the second substrate, where it serves a single role as a reflective element of the mirror or (b) the inward surface of the second substrate, where it serves a dual role as a conductive electrode coating and a reflective element of the mirror.

In these mirrors, an electrochromic solid film is coated either onto (a) the transparent conductive electrode coating of the first substrate, (b) the layer of reflective material when acting as a conductive electrode coating on the inward surface of the second substrate or (c) the substantially transparent conductive electrode coating on the inward surface of the second substrate, when the layer of reflective material is placed on the rearmost (non-inward) surface of the second substrate.

A sealing means is positioned toward the peripheral edge of each of the first substrate and the second substrate to form a cavity, in which is located, either in a liquid-phase or a solid-phase, an electrolyte comprising redox reaction promoters and alkali ions and/or protons. In the cavity, the electrolyte is in contact with the electrochromic solid film (which itself is in contact with a conductive electrode coating on the inward surface of one of either the first substrate or second substrate) and a conductive electrode coating (on the inward surface of the other of the first substrate or second substrate) to form an electrochromic element.

Finally, a means for introducing an applied potential to the electrochromic element is also provided to controllably vary the amount of light reflected from the mirror.

Decreased light transmissivity in the electrochromic devices of the present invention (and reflectivity in the electrochromic mirrors) is primarily provided by the color-forming reaction that occurs in the electrochromic solid film. This electrochromic solid film may be a thin film layer of an inorganic transition metal oxide. Stoichiometric and substoichiometric forms of transition metal oxides, such as Group IV-B, V-B or VI-B oxides like tungsten oxide, molybdenum oxide, niobium oxide, vanadium oxide, titanium dioxide and combinations thereof, may be used. Other conventional inorganic transition metal oxides, such as those recited in Kamimori III, may also be employed. Preferably, however, tungsten oxide or doped tungsten oxide, with suitable dopants including molybdenum, rhenium, tin, rhodium and the like, may be used as the electrochromic solid film. A beneficial effect of the addition of the dopant may be to move the spectral absorption edge of the doped tungsten oxide coating farther into the visible range of the electromagnetic spectrum.

Where doped tungsten oxide is used, the dopant should be present in a concentration within the range of from about 0.1% (by mole) to about 20% (by mole) or even greater. Preferred doped tungsten oxides include those where a molybdenum dopant is used within the range of about 0.5% (by mole) to about 10% (by mole).

The electrochromic solid film may be a stack of thin films, such as a layer of tungsten oxide overcoated and/or undercoated with a thin film like silicon dioxide, titanium dioxide, tantalum pentoxide or cerium oxide. Such overcoats and/or undercoats may help promote enhanced adhesion of the tungsten oxide electrochromic solid film to its substrate and/or passivate it from the electrolyte which it contacts in the electrochromic element.

The thickness of the electrochromic solid film may be within the range of from about 0.05 μm to about 1.0 μm or greater, with about 0.25 μm to about 0.75 μm being preferred, and about 0.3 μm to about 0.6 μm being more preferred.

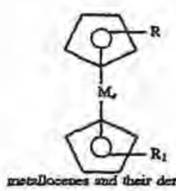
The electrochromic solid film may have a microstructure that is amorphous, crystalline, polycrystalline or combinations thereof. In electrochromic devices where the occurrence of photochromism is a concern, it may be desirable for the electrochromic solid film to possess a microstructure that is at least partially crystalline. Such a crystalline microstructure is believed to minimize the photochromic effect, which may be deleterious to the operation of the electrochromic devices. It may also be desirable for the electrochromic solid film to possess a microstructure that is porous. In this connection, it may be desirable for the electrochromic solid film, such as tungsten oxide or doped tungsten oxide, to have a density of less than about 90%, preferably less than about 80%, of the density of the bulk oxide.

The electrolyte useful in the electrochromic element of the electrochromic mirrors of the present invention should comprise redox reaction promoters, and alkali ions and/or protons. The electrolyte may be in a liquid-phase or in a solid-phase.

The redox reaction promoters of the electrolyte comprise two individual species, a metallocene and a phenothiazine, used in combination.

The metallocenes suitable for use as a redox reaction promoter in the present invention are represented by the following structure:

I



metallocenes and their derivatives

wherein R and R_1 may be the same or different, and each may be selected from the group consisting of H; any straight- or branched-chain alkyl constituent having from about 1 carbon atom to about 8 carbon atoms, such as CH_3, CH_2CH_3, $CH_2CH_2CH_3$, $CH(CH_3)_2$, $C(CH_3)_3$ and the like; acetyl; vinyl; allyl; hydroxyl; carboxyl; $-(CH_2)_n-OH$, wherein n may be an integer in the range of 1 to about 8; $-(CH_2)_n-COOR_2$, wherein n may be an integer in the range of 1 to about 8 and R_2 may be any straight- or branched-chain alkyl constituent having from about 1 carbon atom to about 8 carbon atoms, hydrogen, lithium, sodium,

$$-(CH_2)_{n'}-O-\overset{O}{\overset{\|}{C}}-CH=CH_2,$$

wherein n' may be an integer in the range of 2 to about 8, or

$$-(CH_2)_{n'}-O-\overset{O}{\overset{\|}{C}}-\overset{CH_3}{\overset{|}{C}}=CH_2,$$

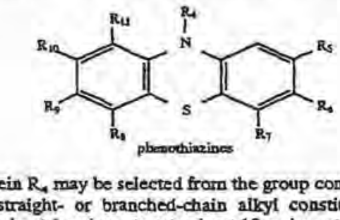
wherein n' may be an integer in the range of 2 to about 8; $-(CH_2)_n-OR_3$, wherein n may be an integer in the range of 1 to about 8 and R_3 may be any straight- or branched-chain alkyl constituent having from about 1 carbon atom to about 8 carbon atoms,

$$-\overset{O}{\overset{\|}{C}}-CH=CH_2 \text{ and } -\overset{O}{\overset{\|}{C}}-\overset{CH_3}{\overset{|}{C}}=CH_2;$$

or $-(CH_2)_n-N^+(CH_3)_3X^-$, wherein n may be an integer in the range of 1 to about 8 and X may be Cl^-, Br^-, I^-, ClO_4^- or BF_4^-; and M_e is Fe, Ni, Ru, Co, Ti, Cr and the like.

The phenothiazines suitable for use as a redox reaction promoter in the present invention include, but are not limited to, those represented by the following structure:

II



phenothiazines

wherein R_4 may be selected from the group consisting of H; any straight- or branched-chain alkyl constituent having from about 1 carbon atom to about 10 carbon atoms; phenyl; benzyl; $-(CH_2)_2-CN$; $-(CH_2)_2-COOH$;

$$-\overset{O}{\overset{\|}{C}}-CH_3\text{; allyl;}$$

-continued

$$-(CH_2)_2-\overset{O}{\overset{\|}{C}}-O-(CH_2)_{n'}-O-\overset{O}{\overset{\|}{C}}-CH-CH=CH_2,$$

$$-(CH_2)_2-\overset{O}{\overset{\|}{C}}-O-(CH_2)_{n'}-O-\overset{O}{\overset{\|}{C}}-\overset{CH_3}{\overset{|}{C}}H=CH_2,$$

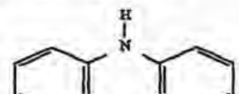
wherein n' may be an integer in the range of 2 to about 8;

$$-(CH_2)_2-\overset{O}{\overset{\|}{C}}-O-R_2,$$

wherein R_2 may be any straight- or branched-chain alkyl constituent having from about 1 carbon atom to about 8 carbon atoms; and R_5, R_6, R_7, R_8, R_9, R_{10} and R_{11} may be selected from H, Cl, Br, CF_3, CH_3, NO_2, COOH, SCH_3 or OCH_3.

Preferred among phenothiazines II is phenothiazine III as depicted in the following structure:

III



phenothiazine

Combinations of redox reaction promoters may be selectively chosen to achieve a desired substantially non-spectral selectivity when the electrochromic element (and the mirror in which the electrochromic element is to function) is dimmed to a colored state.

The redox reaction promoters may be present in the electrolyte in a total concentration of about 0.005M to about 0.5M, with a total concentration of about 0.02M to about 0.1M being preferred. The ratio of this combination (i.e., total metallocene to total phenothiazine) should be within the range of about 1:1 to about 1:10, with a preferred combination of redox reaction promoters being ferrocene and phenothiazine (III) in about a 1:2 (by mole) to about a 1:4 (by mole) ratio and, more preferably, having a total concentration of about 0.07M to about 0.09M.

A source of alkali ions may also be included in the electrolyte. Suitable sources of alkali ions are lithium salts, such as lithium perchlorate ("$LiClO_4$"), lithium tetrafluoroborate ("$LiBF_4$"), lithium iodide ("LiI"), lithium hexafluorophosphate ("$LiPF_6$"), lithium hexafluoroarsenate ("$LiAsF_6$"), lithium styrylsulfonate ("LiSS"), lithium triflate ("$LiCF_3SO_3$"), lithium methacrylate, lithium halides other than LiI such as lithium chloride ("LiCl"), lithium bromide ("LiBr") and the like, lithium trifluoroacetate ("CF_3COOLi") and combinations thereof. Of these, $LiClO_4$ or combinations of $LiClO_4$ and $LiBF_4$ are preferred. These sources of alkali ions may be present in the electrolyte in a concentration of about 0.01M to about 1.0M, with a concentration of about 0.05M to about 0.1M being preferred.

A source of protons may also be included in the electrolyte, by, for example, incorporating into the electrolyte water [for example, in a concentration of less than about 5% (v/v), preferably in a concentration within the range of about 0.5% (v/v) to about 2% (v/v)], or by incorporating into the electrolyte organic acids, inorganic acids or other protonic sources suitable for use in conjunction with organic solvents as are known in the art.

The electrolyte itself may be in a liquid-phase or a solid-phase, however, where the electrolyte is in a liquid-phase, a suitable solvent for use in the electrolyte may solubilize the redox reaction promoters and alkali ions (and other optional components such as ultraviolet stabilizing agents which absorb and/or screen ultraviolet radiation) while remaining substantially inert thereto (as well as to any other optional components in the electrolyte). Any material that remains in its liquid form over the range of temperatures to which the devices manufactured with the electrolytes of the present invention will likely be subjected is suitable for use as a solvent in a liquid-phase electrolyte [for a non-exhaustive recitation of such solvents, see e.g., Varaprasad I and Varaprasad III]. Practically speaking, the solvent may be an organic solvent, preferably a substantially non-aqueous organic solvent, which is stable to electrolysis and other phenomena likely to be encountered during the practice of this invention.

Suitable solvents may be selected from acetonitrile, 3-hydroxypropionitrile, methoxypropionitrile, 3-ethoxypropionitrile, 2-acetylbutyrolactone, propylene carbonate, ethylene carbonate, glycerine carbonate, tetramethylene sulfone, cyanoethyl sucrose, γ-butyrolactone, 2-methylglutaronitrile, N,N'-dimethylformamide, 3-methylsulfolane, glutaronitrile, 3,3'-oxydipropionitrile, methylethyl ketone, cyclopentanone, cyclohexanone, benzoyl acetone, 4-hydroxy-4-methyl-2-pentanone, acetophenone, 2-methoxyethyl ether, triethylene glycol dimethyl ether, 4-ethenyl-1,3-dioxalane-2-one, 1,2-butylene carbonate, glycidyl ether carbonates (such as those commercially available from Texaco Chemical Company, Austin, Tex.) and combinations thereof, preferred of which include propylene carbonate, 1,2-butylene carbonate, the combination of tetramethylene sulfone and propylene carbonate and the combination of 1,2-butylene carbonate and propylene carbonate.

Where the electrolyte of the present invention is desirably a solid-phase electrolyte, a formulation of starting components may be in situ transformed such as by polymerization reaction through, for instance, exposure to ultraviolet radiation or application of thermal energy, to produce a solid electrolyte. In the context of ultraviolet radiation activated polymerization, ultraviolet polymerizable components [such as those taught by and described in commonly assigned co-pending U.S. patent application Ser. Nos. 08/023,675, filed Feb. 26, 1993 ("the '675 application") and 08/193,557, filed Feb. 8, 1994 ("the '557 application")] may be used to transform into a solid-phase electrolyte when exposed to ultraviolet radiation.

Other components may also be added to the electrolyte, with such components preferably being in solution in liquid-phase electrolytes. These components may include, but are not limited to, ultraviolet stabilizing agents, infrared radiation reducing agents, color tinting agents (e.g., dyes or colorants) and combinations thereof. Suitable ultraviolet stabilizing agents and color tinting agents are recited in Lynam III, the disclosure of which is hereby incorporated herein by reference. For example, a blue-colored dye of the phthalocyanine-type, such as "NEOPEN" 808 (commercially available from BASF Corp., Parsippany, N.J.), may be added to the electrolyte as a color tinting agent.

Because many redox reaction promoters show a substantial absorbance in the ultraviolet region of the electromagnetic spectrum from about 250 nm to about 350 nm and the electrochromic solid film itself may be deleteriously affected by exposure to ultraviolet radiation, it is often desirable to shield the redox reaction promoters and electrochromic solid film from ultraviolet radiation. Thus, by introducing an ultraviolet stabilizing agent to the electrolyte, or using a solvent which itself acts to absorb ultraviolet radiation, the lifetime of the electrochromic device may be extended. It may be particularly advantageous to include ultraviolet stabilizing agents in the electrolyte for electrochromic mirrors and electrochromic devices whose intended use may result in exposure to outdoor weathering conditions, such as that encountered by the exterior of a motor vehicle.

Although many materials known to absorb ultraviolet radiation may be employed herein, preferred ultraviolet stabilizing agents include "UVINUL" 400 [2,4-dihydroxybenzophenone (manufactured by BASF Corp., Wyandotte, Mich.)], "UVINUL" D 49 [2,2'-dihydroxy-4,4'-dimethoxybenzophenone (BASF Corp.)], "UVINUL" N 35 [ethyl-2-cyano-3,3-diphenylacrylate (BASF Corp.)], "UVINUL" N 539 [2-ethyl hexyl-2-cyano-3,3'-diphenylacrylate (BASF Corp.)], "UVINUL" M 40 [2-hydroxy-4-methoxybenzophenone (BASF Corp.)], "UVINUL" M 408 [2-hydroxy-4-octoxy-benzophenone (BASF Corp.)], "TINUVIN" P [2-(2H-benzotriazole-2-yl)-4-methylphenyl (manufactured by Ciba Geigy Corp., Hawthorne, N.Y.)], "TINUVIN" 327 [2-(3',5'-di-t-butyl-2'-hydroxyphenyl)-5-chloro-benzotriazole (Ciba Geigy Corp.)], "TINUVIN" 328 [2-(3',5'-di-n-pentyl-2'-hydroxyphenyl)-benzotriazole (Ciba Geigy Corp.)], "CYASORB" UV 24 [2,2'-dihydroxy-4-methoxy -benzophenone (manufactured by American Cyanamid Co., Wayne, N.J.)] and combinations thereof, where a suitable range of the ultraviolet stabilizing agents is from about 0.2% (w/v) to about 40% (w/v), with about 5% (w/v) to about 15% (w/v) being preferred. The ultraviolet stabilizing agent should be chosen with an eye toward avoiding an adverse affect on performance and electrolyte function.

In addition, ultraviolet absorbing interlayers may be coated onto, or adhered to, the first substrate and/or second substrate, particularly the first substrate, to assist in shielding the electrochromic element from the degradative effect of ultraviolet radiation. Suitable ultraviolet absorbing interlayers include those recited in Lynam III.

Moreover, to assist in extending the lifetime of the electrochromic device, the electrochromic solid film may be placed onto the inward surface of the second substrate—i.e., coated onto either the reflective element or the substantially transparent conductive electrode coating depending on the particular construction. Location of the electrochromic solid film on the inward surface of the second substrate may be desirable where an electrochromic rearview mirror suitable for use on the exterior of a motor vehicle is intended to be exposed to outdoor weathering, including exposure to ultraviolet radiation.

It may also be desirable to employ ultraviolet absorbing glass or laminates thereof for the first substrate or for the second substrate in an electrochromic mirror, particularly for the first substrate, or for the first substrate and/or the second substrate in an electrochromic device. Suitable ultraviolet absorbing glass include that which is recited in Lynam IV. In addition, it may be desirable to employ tin oxide, doped tin oxide, zinc oxide or doped zinc oxide as a substantially transparent conductive electrode coating on the inward surface of the first substrate, ultraviolet stabilizing agents in the electrolyte, ultraviolet absorbing interlayers, ultraviolet absorbing glass and combinations thereof in conjunction with positioning the electrochromic solid film on the inward surface of the second substrate. Such constructions, particularly with additional ultraviolet stabilizing agents included in the electrolyte as described supra, facilitate screening and/or absorption of ultraviolet radiation by the components used in the electrochromic mirror or electrochromic device, including the first substrate, the conductive electrode coating thereon, and the electrolyte and its components that are positioned effectively in front of the potentially ultraviolet sensitive electrochromic solid film.

Addition of ultraviolet stabilizing agents may be particularly advantageous when the electrochromic solid film 7 is coated onto conductive electrode 4' on the inward surface of substrate 3. (See FIG. 5.) In this construction, the ultraviolet stabilizing agents may act to screen and/or absorb incident ultraviolet radiation before it reaches the electrochromic solid film 7. By so doing, the chance of irradiating the potentially photochromic or otherwise ultraviolet radiation vulnerable electrochromic solid film 7 may be reduced or even substantially eliminated. In contrast, when coated onto substantially transparent conductive electrode 4 on the inward surface of substrate 2 (see FIG. 4), the electrochromic solid film 7 may be directly irradiated by any incident ultraviolet light that passes through substrate 2. The ultraviolet screening and/or absorbing affect of the electrolyte, which in this construction is now positioned behind the electrochromic solid film 7, has less of an opportunity to shield the electrochromic solid film 7 from incident ultraviolet light (although the electrolyte may effectively absorb any ultraviolet light which is reflected from the reflective element on substrate 3).

Those of ordinary skill in the art may make appropriate choices among the various materials available as described herein for the substrates, coatings, electrochromic solid films and electrolyte components —e.g., redox reaction promoters, sources of alkali ions and/or protons, solvents, and other components to prepare electrochromic mirrors and electrochromic devices capable of generating a substantially non-spectral selective gray color suitable for the desired application. In addition, while glass is a suitable choice of material from which the substrates may be constructed, other materials may be used, such as optical plastics like acrylic, polycarbonate, polystyrene and allyl diglycol carbonate (commercially available from Pittsburgh Plastic Glass Industries, Pittsburgh, Pa. under the tradename "CR-39").

Reference to the figures will now be made in order to more faithfully describe the electrochromic devices, particularly the electrochromic mirrors, of the present invention.

With reference to FIGS. 3A, 3B and 4, it may be seen that the electrochromic element 1 includes a front substrate 2 and a rear substrate 3, each of which is typically glass. However, as described in detail hereinafter, in certain mirror constructions only the front or first substrate 2 needs to be at least substantially transparent, and in those constructions the rear or second substrate 3 need not be transparent at all. (See FIG. 5.) In fact, substrate 3 may be a polished metal plate, a metal-coated glass substrate or a conductive ceramic material.

By convention, the first substrate 2 (the frontmost or outermost substrate) is the substrate of the electrochromic device positioned closest to any principal source of incoming or incident electromagnetic radiation and, in an electrochromic mirror, the second substrate 3 is the substrate onto which a layer of reflective material 8 is coated. Put another way, the first substrate 2 is the substrate into which a driver of or passenger in a motor vehicle may first look through to view an image. In an electrochromic device, such as a glazing, a window or a sun roof for a motor vehicle, the first substrate 2 is the substrate exposed directly to, and often in contact with, the outdoor environment and is exposed directly to solar ultraviolet radiation.

Substrates 2,3 should be positioned substantially parallel to one another if planar (or positioned substantially tangentially parallel to one another if bent), or as close to parallel (or tangentially parallel) to one another as possible so as to minimize image separation which may lead to double imaging. Double imaging is particularly noticeable when mirrors are colored to a dimmed state. Double imaging may be further minimized in mirror constructions as described hereinafter.

Onto each of the inward surfaces of substrates 2,3 is coated a conductive electrode coating 4 or 4'. The conductive electrode coatings 4,4' may be constructed from the same material or different materials, including transparent electronic conductors, such as tin oxide; indium tin oxide ("ITO"); half-wave indium tin oxide ("HW-ITO"); full-wave indium tin oxide ("FW-ITO"); doped tin oxides, such as antimony-doped tin oxide and fluorine-doped tin oxide; doped zinc oxides, such as antimony-doped zinc oxide and aluminum-doped zinc oxide, with tin oxide, doped tin oxide, zinc oxide or doped zinc oxide being preferred where long-term ultraviolet resilience is desired in the device.

In certain mirror constructions, the conductive electrode coating 4' need not be substantially transparent. Rather, the layer of reflective material that serves as the reflective element of the mirror (with any other coatings used to form a thin film stack) may also serve as conductive electrode coating 4', thereby allowing a potential to be applied to the electrochromic element 1. Suitable materials for this layer of reflective material include metals, such as aluminum, palladium, platinum, titanium, chromium, silver, nickel-based alloys and stainless steel, with a high reflector (having a reflectance greater than about 70%), like silver or aluminum, being preferred. However, where resistance to scratching and environmental degradation is a concern, a medium reflector (having a reflectance within the range of about 40% to about 70%), like chromium, stainless steel, titanium and nickel-based alloys, is preferred. As an alternative to the use of these metals as a reflective element, multi-coated thin film stacks of inorganic oxides, halides, nitrides or the like, or a thin film layer of high index material may also be used.

The conductive electrode coatings 4,4' may be thin films of metal, such as silver, aluminum and the like, with a thickness of less than about 200 Å, which may be as low as less than about 100 Å, so that the conductive electrode coatings 4,4' are sufficiently conductive yet sufficiently transmissive. It may be desirable to index match a thin film of metal through the use of a thin film layer of a transparent metal oxide, metal nitride, metal halide or the like, such as indium oxide, zinc oxide, tin oxide, magnesium fluoride, titanium nitride, silicon dioxide, tungsten oxide or titanium dioxide, either as an overcoat or an undercoat to the thin film of metal to assist in reducing its reflectance, and increasing its transmittance, of incident visible light [see e.g., commonly assigned U.S. Pat. No. 5,239,406 (Lynam) ("Lynam VI")].

The sheet resistance of the conductive electrode coated glass substrates 2,3 should be less than about 100 ohms per square, with less than about 20 ohms per square being preferred. (However, as described in greater detail hereinafter, for reasons of economy it may sometimes be preferable to use substantially transparent conductive electrodes having a sheet resistance of greater than about 20 ohms per square.) Conductive electrode coated glass substrates are available commercially. For instance, ITO-coated glass substrates made from a glass substrate having deposited thereon a conductive coating of indium oxide that has been doped with tin oxide may be obtained from Donnelly Corporation, Holland, Mich. In addition, tin oxide-coated glass substrates, known as "TEC-Glass" products, may be obtained from Libbey-Owens-Ford Co., LOF Glass Division, Toledo, Ohio.

The "TEC-Glass" products are manufactured by an on-line chemical vapor deposition process. This process pyrolytically deposits onto clear float glass a multi-layer thin film structure, which includes a microscopically thin coating of fluorine-doped tin oxide (having a fine grain uniform structure) with additional undercoating thin film layers disposed between the fluorine-doped tin oxide layer and the underlying glass substrate. This structure inhibits reflected color and increases light transmittance. The resulting "TEC-Glass" product is a non-iridescent glass structure having a haze within the range of from about 0.1% to about 5%; a sheet resistance within the range of from about 10 to about 1000 ohms per square or greater; a daylight transmission within the range of from about 77% to about 87%; a solar transmission within the range of from about 64% to about 80%; and an infrared reflectance at a wavelength of about 10 μm within the range of from about 30% to about 87%.

Examples of the "TEC-Glass" products include "TEC 10" (10 ohms per square sheet resistance), "TEC 12" (12 ohms per square sheet resistance) and "TEC 20" (20 ohms per square sheet resistance) tin oxide-coated glass.

More specifically, "TEC 10", for instance, is made from an on-line pyrolytically-coated float glass, onto which has been coated a fluorine-doped tin oxide layer containing as an undercoat an anti-iridescence means. This anti-iridescence means includes a double layer composed of a layer of silica-silicone deposited onto a layer of tin oxide.

The specific resistivity of the conductive electrode coatings 4,4' useful in the present invention may be between about 5×10^{-3} to about 1×10^{-6} ohm.centimeter, depending on the material from which the conductive electrode coatings 4,4' are constructed, and on the method of deposition and formation of the conductive electrode coatings 4,4'. For instance, where the conductive electrode coatings 4,4' are ITO, the specific resistivity is typically within the range of about 1×10^{-4} to about 3×10^{-4} ohm.centimeter. And where the conductive electrode coatings 4,4' are doped tin oxide, the specific resistivity is typically within the range of about 3×10^{-4} to about 5×10^{-3} ohm.centimeter. Where the conductive electrode coating 4' is a metal, the specific resistivity is typically less than about 5×10^{-5} ohm.centimeter. And where the conductive electrode coating 4' is silver, the specific resistivity is typically less than about 3×10^{-5} ohm.centimeter. The thickness of the metal should be such that the sheet resistance of conductive electrode coating 4' is less than about 0.75 ohms per square, preferably less than about 0.5 ohms per square and more preferably less than about 0.25 ohms per square. Preferably, the thickness of the metal used for conductive electrode coating 4' should be within the range of about 200 Å to about 5,000 Å, with a thickness within the range of 500 Å to about 2,500 Å being preferred and a thickness within the range of about 750 Å to about 1,500 Å being most preferred.

The substantially transparent conductive electrode coating 4 on the inward surface of substrate 2 is preferably highly transmissive in the visible spectrum; that is, with a light transmittance within the range of at least about 60% to greater than about 80%. Likewise, when the conductive electrode coating 4' on the inward surface of substrate 3 is to be highly transmissive, similar high light transmittance is desirable.

The conductive electrode coatings 4,4' should also be highly and uniformly conductive in each direction to provide a substantially uniform response when a potential is applied to the electrochromic element 1. And, the conductive electrode coatings 4,4' should be inert (physically, chemically and electrochemically inert) to the constituents of the electrochromic solid film 7 and the electrolyte 6.

Where the electrochromic solid film 7 is deposited as a coating onto the inward surface of either of conductive electrode coated glass substrates 2,3, it is a barrier coating between whichever of the conductive electrode coatings 4,4' it is deposited on and the electrolyte 6, as well as a barrier coating between the conductive electrode coatings 4,4' themselves.

The electrochromic solid film 7 may be deposited using a variety of film deposition means including, but not limited to, vacuum deposition techniques, such as thermal evaporation, electron beam evaporation, sputter deposition, ion plating, laser-assisted deposition, microwave-assisted deposition and ion-assisted deposition; thermal spraying; pyrolytic deposition; chemical vapor deposition ("CVD"), including atmospheric CVD, plasma enhanced CVD, low pressure CVD and the like; wet chemical deposition, including dip coating, spin coating and spray coating; and thick film methods such as those used in the application of pastes and inks. Suitable deposition results may be obtained with wet chemical deposition as taught by and described in U.S. Pat. Nos. 4,855,161 (Moser); 4,959,247 (Moser); 4,996,083 (Moser); 5,252,354 (Cronin) and 5,277,986 (Cronin), the disclosures of each of which are hereby incorporated herein by reference.

It may be beneficial to deposit the electrochromic solid film using vacuum deposition, preferably with an electron beam evaporation technique where the electrochromic solid film 7 is tungsten oxide and is to be placed in direct contact with, or deposited (for example, with an alternate evaporation filament, crucible, boat or an alternate electron beam gun assembly, or the like) as a layer on, the inward surface of substrate 3, which is already coated with a layer of reflective material that serves the dual role as a reflective element and a conductive electrode coating 4'.

The layer of reflective material, which also serves as a conductive electrode coating 4', with or without any adhesion enhancing undercoat layers (discussed hereinafter), may be deposited on the inward surface of substrate 3, with tungsten oxide deposited as an overcoat, without the need to refixture, break vacuum or the like. Thus, it is seen that such a dual purpose reflective element may be deposited with manufacturing ease and economy. This is particularly so when compared with conventional mirror constructions where the reflective element is coated over the rearmost (non-inward) surface of a substrate (which itself is coated with a substantially transparent conductive electrode coating on the opposite, inward surface) in one operation, and thereafter loaded into a vacuum chamber to deposit tungsten oxide onto the other surface of the substrate, which is coated with a substantially transparent conductive electrode.

When vacuum depositing the electrochromic solid film 7 by evaporation or the like, a backfill pressure in a vacuum chamber within the range of about 1×10^{-4} torr to greater than about 5×10^{-4} torr may be used. This backfill pressure may typically be achieved by evacuating the vacuum chamber to some lower base pressure (e.g., less than about 5×10^{-5} torr) and then backfilling the vacuum chamber with a gas such as nitrogen, argon, krypton, oxygen, water vapor and the like, or combinations thereof, to elevate the pressure in the vacuum chamber to a desired backfill pressure. Alternatively, the vacuum chamber may be pumped from atmospheric pressure down to about a pressure within the range of about 1×10^{-4} torr to greater than about 5×10^{-4} torr, and tungsten oxide, for instance, may then be evaporated onto the desired surface of substrates 2,3. It may be desirable during such vacuum deposition to monitor and to control the pressure within the vacuum chamber using pumps, valves and closed loop controls as is known in the vacuum deposition art.

With reference to FIG. 4, the conductive electrode coatings 4,4' in the mirror construction so depicted are substantially transparent. Likewise, in the mirror construction depicted in FIG. 7, conductive electrode coatings 4,4' and substrate 3 are substantially transparent.

With reference to FIG. 5, however, only the conductive electrode coating 4 of the first substrate 2 in the mirror construction so depicted need be substantially transparent; that is, the conductive electrode coating 4' need not be substantially transparent. In addition, the second substrate 3 need not be substantially transparent. In this aspect of the present invention, the layer of reflective material may be coated directly onto the inward surface of the second substrate 3 to serve as the conductive electrode coating 4' as well.

Onto one of conductive electrode coatings 4,4' is deposited a coating of an electrochromic solid film 7, such as an inorganic transition metal oxide, like tungsten oxide. As noted herein, where photochromism may be a concern, the electrochromic solid film 7 should be positioned at the inward surface of substrate 3 (which surface is coated with conductive electrode coating 4'). By so doing, the electrochromic solid film 7 should benefit from the ultraviolet screening and/or absorbing capabilities of the components of the mirror positioned in front of it and closer to incident light.

Silver or aluminum are suitable choices for conductive electrode coating 4' of substrate 3 because either metal may serve as a reflective element for the mirror and metal coatings in general are significantly more conductive than semiconducting oxides, such as ITO or doped tin oxide. As a consequence of using a thin film of metal as conductive electrode coating 4', the substantially transparent conductive electrode coating 4 of substrate 2 may be chosen with an eye toward higher sheet resistance, such as, for example, about 40 to about 100 ohms per square. This is desirable because conductive electrode coatings of higher sheet resistance are typically thinner and less expensive than conductive electrode coatings of lower sheet resistance. ITO or doped tin oxide are suitable choices for substantially transparent conductive electrode coating 4 used in conjunction with a thin film of metal as a reflective element, such as silver or aluminum, that is to serve as conductive electrode coating 4'. In addition, the use of such a thin film of metal as conductive electrode coating 4' permits the conductive strip or clip connectors (known as "bus bars") to be reduced in length, even to a point contact, on conductive electrode coating 4', rather than being used about a substantial portion of the periphery. That is, bus bars 9 may be attached at only a portion of the thin film of metal and still apply an adequate potential across the conductive electrode coatings 4,4'.

Moreover, use of the reflective element of the mirror as the conductive electrode coating 4' is also appealing from a production standpoint. Such use reduces material and manufacturing costs since an additional electrode layer or reflective element need not be provided. In addition, this dual purpose reflective element/conductive electrode coating is environmentally appealing because it is no longer necessary to enhance resistance to degradation, such as environmental degradation, by applying a paint overcoat, which may be lead-based. In addition, such conventional reflective elements located on the rearmost surface of the mirror construction are typically opaque, and, as described hereinafter, such opacity may result in additional manufacturing effort should an "on demand display" be desirable in a particular mirror construction.

Between the layer of reflective material, typically silver, and the surface of substrate 3 to which it is applied, may desirably be coated a thin film adhesion enhancing means to act as an adhesion promoter ("adhesion promoter"). (See FIG. 6.) The adhesion promoter 11 enhances long-term adhesion of the layer of reflective material to the surface of substrate 3. It is known in the art that there are certain difficulties in adhering a reflective material such as silver to a substrate such as glass, especially where the reflective material is to be deposited by a vacuum deposition process such as evaporation. The adhesion promoter 11 of the present invention overcomes these difficulties and provides a practical way of applying a coating which will function as a dual purpose reflective element/conductive electrode in an electrochromic mirror.

Suitable adhesion promoters 11 include thin films of metal and metal oxides that provide enhanced adhesion over a silver to glass interface, such as chromium, stainless steel, nickel-based alloys (e.g., Hastelloy), titanium, monel, nichrome, molybdenum, metal oxides (e.g., silver oxide, aluminum oxide, indium oxide, indium tin oxide, tin oxide, doped tin oxide, zinc oxide, doped zinc oxide and chromium oxide) and the like. The use of thin films of metal or conducting metal oxides (such as indium tin oxide and doped tin oxides) as adhesion promoters as described herein is advantageous in view of their low cost (due to the relative simplicity of evaporating metal onto a surface of a substrate to form metal or metal oxide coatings), their electrical conductivity that augments that of conductive electrode coating 4', and their mechanical hardness. In addition, use of such thin films of metal or conducting metal oxides as adhesion promoters which undercoat the layer of reflective material assist in maintaining the conductivity of the bus bars 9. This is particularly advantageous in the event a bus bar (e.g., a clip connector) should pierce through the layer of reflective material, because the adhesion promoter is a conductive material that sustains electrical continuity.

An adhesion promoter 11 may be an undercoat of a thin film of a single metal, a metal oxide, or a combination of a metal and a metal oxide. A method for promoting adhesion of the layer of reflective material to a surface of substrate 3 involves deposition, such as by vacuum evaporation or sputtering of a metal, typically silver, initially in an oxygen-rich atmosphere. In this atmosphere, a thin film of silver oxide is applied onto a surface of substrate 3. Then, by progressively decreasing the oxygen atmosphere to zero, a progressively decreased amount of oxide is formed with respect to the metal content in the thin film deposited on the substrate 3. Finally, with little to no oxygen remaining in the atmosphere, a thin film of silver may be built-up upon the previously formed undercoat of its own oxide/gradient oxide to form an adhesion-promoting layer between the surface of substrate 3 and the layer of reflective material. Likewise, chromium may be deposited initially as a thin film of chromium oxide in an atmosphere of enhanced partial pressure of oxygen, followed by deposition of a thin film of metallic chromium by depleting the supply of oxygen. Oxygen may be introduced again to permit the deposition of silver oxide, and finally with deposition of a thin film of metallic silver following in an inert atmosphere. The substrate may also be heated, such as to a temperature within the range of from about 100° C. to about 500° C. (and preferably within the range of from about 150° C. to about 400° C.), during reactive deposition of metal to form a metal oxide. Heating the substrate in this manner may assist reactive formation of the oxide from the metal and may further enhance adhesion. Moreover, a metal oxide, such as chromium oxide, silver oxide, aluminum oxide, indium oxide, tin oxide, titanium oxide or tantalum oxide, may be deposited, such as reactively deposited in an oxygen-rich atmosphere, by vacuum deposition (e.g., evaporation to sputtering) to form adhesion promoter 11.

The adhesion promoter 11 should have a thickness within the range of from about 10 Å to about 2,500 Å or greater, with about 50 Å to 1,000 Å being preferred.

Adhesion promoter 11 can be a single thin film coating or a stack of thin film coatings. For example, the inward facing surface of substrate 3 can first be coated with a conducting metal oxide adhesion promoter coating of indium tin oxide, which in turn is overcoated with a metal adhesion promoter coating of chromium, with this stack in turn being overcoated with a reflective coating of silver.

In addition to mirrors employing an electrochromic solid film, adhesion promoter 11 of the present invention may also be used in mirrors employing other types of electrochromic technology, such as electrochromic solution technology of the electrochemichromic type (e.g., Byker I, Byker II, Varaprasad I and Varaprasad III). Thus, adhesion promoter 11 may be used to construct electrochromic mirrors containing an electrochromic solution in which a single coating or stack of coatings functions as a dual purpose reflective element/conductive electrode.

For some applications, it may be desirable to prevent build-up of deposited materials (such as, tungsten oxide and/or silver) at a portion or portions of the inward surface of substrates 2 or 3 inboard from an edge thereof. In this regard, a magnetizable metal mask may be placed over the portion(s) where it is desired to prevent build-up of such deposited materials. The magnetizable metal mask may then be held at that portion of the substrate under a magnetic influence while the material is deposited. For example, a magnetizable metal mask may be placed at the desired location on the inward surface of substrate 3 prior to coating the inward surface thereof with an adhesion promoter (e.g. chromium), a layer of reflective material (e.g., silver) and a layer of an electrochromic solid film (e.g., tungsten oxide). A magnet may be placed on the rearmost surface of substrate 3 behind that location on the inward surface of substrate 3 to ensure that the mask is held in place. Upon removal of the mask after completion of deposition of the chromium/silver/tungsten oxide stack onto the inward surface of substrate 3, a deposition-free portion of that surface is formed.

As stated supra, the spaced-apart glass substrates 2,3 have a sealing means 5 positioned therebetween to assist in defining the interpane spacing in which the electrochromic solid film 7 and the electrolyte 6 are located. The sealing means 5 may be constructed of any material inert (physically, chemically and electrochemically inert) to the electrochromic solid film 7 and the components of the electrolyte 6, as well as to any other material used in the device. To that end, the sealing means 5 may be chosen from the following materials including, but not limited to, various thermosetting materials, such as epoxy resins and silicones, various thermoplastic materials, such as plasticized polyvinyl butyral, polyvinyl chloride, paraffin waxes, ionomer resins, various inorganic materials and the like. For a further recitation of suitable sealing materials, see commonly assigned U.S. Pat. No. 5,233,461 (Dornan).

The thickness of the sealing means 5 may vary from about 10 μm to about 1,000 μm. Preferably, however, this thickness is about 50 μm to about 100 μm.

In addition, the sealing means 5 may prevent escape of the electrolyte 6, when in a liquid-phase, from the electrochromic element 1 or penetration of environmental contaminants into the electrolyte, whether in a liquid-phase or in a solid-phase. Of course, when the electrolyte is in a solid-phase, leakage or seepage of the electrolyte from the mirror is not a concern, but contamination may be.

To enhance the integrity of a long-lasting seal in terms of seal resiliency, any electrochromic solid film 7 deposited toward the peripheral edges of one of the substrates 2,3 may be removed so that a seal may be formed directly between a conductive electrode coating 4 of substrate 2 and a conductive electrode coating 4' of substrate 3—i.e., directly between at least a portion of the conductive electrode coated glass substrates 2,3. This may be accomplished, for example, by depositing tungsten oxide onto larger sheets of glass and then cutting substrates therefrom. By so doing, the tungsten oxide coating extends to the cut edge of the substrate. A variety of removal means may then be employed to remove that portion of the coating from the substrate—up to less than about 2 mm to about 6 mm or thereabouts—inward from the peripheral edges of the substrates. These removal means may include chemical removal, such as with water or with a slightly acidic or basic aqueous solution; physical removal, such as with a blade; laser etching; sandblasting and the like. The conductive electrode coatings 4,4' at the peripheral edge may also be removed in like fashion along with the tungsten oxide overcoat.

Alternatively, substrates 2,3 may be pre-cut to a desired size and shape prior to depositing an electrochromic solid film 7 thereon. These pre-cut substrates may be loaded into a masking fixture to prevent deposition of the electrochromic solid film 7 a pre-determined distance from the edges of the substrates—such as, inward from the edge up to less than about 2 mm to about 6 mm. The masking system may also allow for small tab-out portions to facilitate electrical connection with the conductive electrode coatings 4,4' and the electrochromic solid film 7 deposited in one and the same deposition operation. Of course, it may be possible to employ movable fixturing or to break vacuum and rearrange fixtures should tab-outs not be desired.

Moisture is known to permeate through electrochromic solid films, such as tungsten oxide. Thus, where sealing means 5 is positioned entirely or partially over the electrochromic solid film 7, a secondary weather barrier 12 may be advantageously employed about the periphery of the joint of the assembled laminate (see FIG. 5) to optimize seal integrity which may be compromised by such moisture permeation or permeation of other environmental degradants. Suitable materials for use as a secondary weather barrier 12 include adhesives, such as silicones, epoxies, epoxides and urethanes, which may be ultraviolet curable, room temperature curable or heat curable.

Commercially available adhesives include the cycloalkyl epoxides sold under the "CYRACURE" tradename by Union Carbide Chemicals and Plastics Co., Inc., Danbury, Conn., such as the "CYRACURE" resins UVR-6100 (mixed cycloalkyl epoxides), UVR-6105 epoxycyclohexylmethyl-3,4-epoxycyclohexane carboxylate), UVR-6110 (3,4-epoxycyclohexylmethyl-3,4-epoxycyclohexane carboxylate) and UVR-6128 [bis-(3,4-epoxycyclohexyl) adipate], and the "CYRACURE" diluents UVR-6200 (mixed cycloalkyl epoxides) and UVR-6216 (1,2-epoxyhexadecane); those epoxides commercially available from Dow Chemical Co., Midland, Mich., such as D.E.R. 736 epoxy resin (epichlorohydrin-polyglycol reaction product), D.E.R. 755 epoxy resin (diglycidyl ether of bisphenol A-diglycidyl ether of polyglycol) and D.E.R. 732 epoxy resin (epichlorohydrin-polyglycol reaction product), and the NOVOLAC epoxy resins such as D.E.N. 431, D.E.N. 438 and D.E.N. 439 (phenolic epoxides), and those epoxides commercially available from Shell Chemical Co., Oak Brook, Ill., like the "EPON" resins 825 and 1001F (epichlorohydrin-bisphenol A type epoxy resins).

Other commercially available adhesives that are particularly well-suited for use herein as a secondary weather barrier 12 include those epoxides commercially available under the "ENVIBAR" tradename from Union Carbide Chemicals and Plastics Co., Inc., Danbury, Conn., such as "ENVIBAR" UV 1244T (cycloalkyl epoxides).

A secondary weather barrier 12 may be formed around the sealed joint between substrates 2,3 at any point of contact between the sealing means 5 and the electrochromic solid film 7, using in the case of ultraviolet curable adhesives, commercially available curing systems, such as the Fusion UV Curing Systems F-300 B and F-450 [Fusion UV Curing Systems, Buffalo Grove, Ill.], Hanovia UV Curing System [Hanovia Corp., Newark, N.J.], RC-500 A Pulsed UV Curing System [Xenon Corp., Woburn, Mass.] and a Sunlighter UV chamber fitted with low intensity mercury vapor lamps and a turntable.

A source of an applied potential may be introduced to the electrochromic element 1 of the electrochromic mirror by the electrical leads 10, which may be wire, solder and the like. The electrical leads 10 may typically be connected or affixed to bus bars 9, which themselves may typically be connected or affixed to the conductive electrode coatings 4,4'. The bus bars 9 may be constructed from a variety of conducting materials including metals, alloys, solder such as ultrasonically-applied solder (e.g., Cerasolzer™ manufactured by the Asahi Glass Co., Tokyo, Japan), metal ribbon connecters, conducting polymers (e.g., conducting rubbers and conducting epoxies), conducting frits, such as silver frits [e.g., silver conductive frit #7713 (commercially available from E.I. du Pont de Nemours and Company, Wilmington, Del.)] and the like. A non-exhaustive recitation of such conducting materials may be found in Lynam IV. Bus bar materials such as conducting silver frits or solders may even overlap onto the cut edge of the substrate to facilitate connection of elecrical leads in the flush assemblies of the invention.

An exposed portion of the conductive electrode coatings 4,4' may be provided through displacement in opposite directions relative to one another—i.e., laterally from, but parallel to, the cavity which is created by the substrates 2,3 and the sealing means 5—of the substrates 2,3 onto which the bus bars 9 may be affixed or adhered. (See FIG. 11A.) In addition, substrates 2,3 may be off-set to provide an exposed portion of the conductive electrode coatings 4,4' through displacement in opposite directions relative to one another followed by perpendicular displacement relative to one another. (See FIG. 11B.) The dimensions of substrates 2,3 may also be such that, for example, substrate 2 may have a greater width and/or length than substrate 3. Thus, simply by positioning substrates 2,3 in spaced-apart relationship and so that their central portions are aligned will allow for peripheral edges of the substrate with greater dimensions to extend beyond the peripheral edges of the substrate with smaller dimensions. Thus, a portion of conductive electrode coating 4 or 4' will be exposed, depending on whichever of substrates 2,3 is dimensioned with a larger width and/or length. (See FIG. 11C.)

An exposed portion of the conductive electrode coatings 4,4' may also be provided in a flush design, where the substrates 2,3 are sized and shaped to like dimensions. In such a flush design, the first substrate 2 and the second substrate 3 may each be notched at appropriate positions along their respective edges. The notches so provided present convenient areas for bus bars and/or point contacts to which are connected or affixed electrical leads 10 for the introduction of an applied potential thereto.

It may also be desirable to apply a layer of reflective material onto the inward surface of substrate 3, and with substrate 3 notched in at least one appropriate position along its edges. In this way, direct access is available to the conductive electrode coated inward surface of substrate 2. Likewise, substrate 2 may be notched at a position appropriately spaced from the notch or notches on substrate 3 to provide access to the conductive electrode coated inward surface of substrate 3. These notches provide convenient areas for electrical leads 10 to be connected or affixed, and allow for such connection or affixation to be made within the overall dimensions of the mirror assembly. For example, one or both of the substrates 2,3 may be notched along one or more edges, and bus bars 9 may then be affixed over the exposed portion of conductive electrode coatings 4,4' of substrates 2,3. Electrical leads 10 may then be joined to the bus bars 9. The electrical connection may be made to the inward surfaces of substrates 2,3 without requiring further electrical connection on the peripheral edge of the mirror assembly. As such, the electrical connection to conductive electrode coatings 4,4' will be hidden from view by the reflective element and/or the mirror case or housing.

Alternatively, one or more localized lobe(s) may be provided at appropriate positions along the respective edges of substrates 2,3 to facilitate direct access to the conductive coated inward surfaces of substrates 2,3.

The bus bars 9 may also comprise thin metal films, preferably with a thickness within the range of about 500 Å to about 50,000 Å or greater. These thin metal film bus bars may be deposited onto conductive electrode 4 and/or 4' by vacuum deposition, such as by evaporation or sputtering, and typically have a width within the range of about 0.05 mm to about 6 mm (and preferably with a thickness in the range of 0.05 μm to about 5 μm or greater) and are inboard from the perimeter edge of the substrate.

To form the thin metal film bus bars, a mask may be affixed over the central region of the substantially transparent conductive electrode coated substrate leaving at least a portion, and preferably most, of the perimeter region unmasked. Then a thin film of metal, such as chromium and/or silver, or other metals such as copper, titanium, steel, nickel-based alloys, and the like, may be deposited using a vacuum deposition process across the entire surface, coating both the masked central region and the unmasked perimetal region. Thereafter, the mask may be removed leaving the central region of the substrate transparent and with a conducting thin metal film bus bar deposited on at least a portion of the perimetal region. For manufacturing economy, it may be desirable to establish thin metal film bus bars on the inward surface of substrate 2, conductive electrode coating 4' and electrochromic solid film 7 in a unitary vacuum deposition process step. Thus, it may be convenient to overlay in central alignment, for example, substrate 3 (being uncoated glass) onto the substantially transparent conductive electrode coated surface of substrate 2, where substrate 3 is sized and shaped about 2 mm to about 4 mm smaller in both length and width than substrate 2 (see e.g., FIG. 11C). A peripheral edge of substrate 2 of about 2 mm to about 4 mm will then extend beyond the peripheral edge of substrate 3. In this instance, substrate 2 is made, for example, from ITO-coated glass, and substrate 3 is made from clear soda-lime glass. With this configuration, a vacuum deposition process may be used to deposit a thin metal film and, optionally, a metal oxide thereover, across the entire surface.

Upon completion of the deposition process, the substrates 2,3 may be separated from one another. The formation of a thin metal film bus bar consisting of a chromium/silver coating about the peripheral edge of substrate 2 may then be seen where, because of its smaller dimensions, substrate 3 has served the role of a mask to the major, central region of substrate 2 during deposition. That is, when substrate 3 is removed, the major, central region of substrate 2 has not been coated during the deposition and the transparency of the major, central region of substrate 2 is maintained. Because this thin metal film bus bar is highly conductive and extends about the entire periphery of substrate 2, electric potential may be supplied by means of a point electrical contact (optionally with local removal of any metal oxide) without the need for a large metal clip or ribbon connector wire as has been conventionally used heretofore. Moreover, because the thin metal film bus bar consists of a chromium/silver coating it forms a highly reflective perimeter coating which may be used to conceal any seal and/or electrical connection for the electrochromic cell. [See U.S. Pat. No. 5,060,112 (Lynam), the disclosure of which is hereby incorporated herein by reference.]

In addition, the surface of substrate 3 which was exposed during deposition is now coated with a chromium/silver/tungsten oxide stack, which may be used as the inward surface in forming an electrochromic cell. The cut edge of substrate 3 is also coated with a chromium/silver coating during the unitary vacuum deposition process due to the inevitable overspray which occurs in such a process. This chromium/silver coating around the cut edge of substrate 3 may itself conveniently be used to establish an electrical connection to apply potential to electrochromic solid film 7.

The applied potential may be supplied from a variety of sources including, but not limited to, any source of alternating current (AC) or direct current (DC) known in the art, provided that, if an AC source is chosen, control elements, such as diodes, should be placed between the source and the conductive electrode coatings 4,4' to ensure that the potential difference between the conductive electrode coatings 4,4' does not change with variations in polarity of the applied potential from the source. Suitable DC sources include storage batteries, solar thermal cells, photovoltaic cells or photoelectrochemical cells.

The applied potential generated from any of these sources may be introduced to the electrochromic element 1 within the range of about 0.001 volts to about 5.0 volts. Typically, however, an applied potential of about 0.2 volts to about 2.0 volts is preferred to cause the electrochromic element to dim to a colored state—i.e., to change the amount of light transmitted therethrough. For electrochromic solid films like tungsten oxide, the negative polarity of the potential should be applied onto whichever of substrates 2,3 the electrochromic solid film 7 is deposited.

The teaching of the present invention is well-suited for use in electrochromic mirrors whose functional surface is substantially planar or flat. For example, flat electrochromic mirrors for motor vehicles may be manufactured with the electrochromic element of the present invention.

In addition, the present teaching is well-suited for use in electrochromic mirrors having a curved functional surface, with a convex curvature, a compound curvature, a multi-radius curvature, aspherical curvature, an aspheric curvature, or combinations of such curvature. (See FIG. 13.) Convex electrochromic mirrors for motor vehicles may be manufactured with the electrochromic element of the present invention, with radii of curvature typically within the range of about 25" to about 250", preferably within the range of about 35" to about 120", as are conventionally known.

Multi-radius mirrors for motor vehicles, such as those described in U.S. Pat. No. 4,449,786 (McCord), may also be manufactured in accordance with the present invention. Multi-radius mirrors for motor vehicles may typically be used on the driver-side exterior of a motor vehicle to extend the driver's field of view and to enable the driver to see safely and to avoid blind-spots in the rearward field of view. Generally, such mirrors have a region of a higher radius (i.e., substantially planar or flat) closer or inboard to the driver that serves principally as the primary driver's rear vision function and a region of a lower radius (i.e., more curved) farther or outboard from the driver that serves principally as the blind-spot detection zone in the mirror.

In forming spherical mirrors, such as convex exterior mirrors, or aspherical mirrors such as the multi-radius mirror 44 in FIG. 13, the radius of curvature for the substrates to be used for the laminate assembly formed by the electrochromic element 1 between substrates 2,3 should be matched. Moreover, in aspherical mirrors, the two substrates 2,3 in the laminate assembly should be matched so that the local radius in one substrate, for example in the first substrate 2, is located over, and oriented to align with, its corresponding local radius in the other substrate, for example, in the second substrate 3. (See FIG. 13.)

To achieve such radius of curvature matching, a desired shape for the substrates of the aspherical mirrors may be cut from a flat substrate of dimensions greater than that of the desired multi-radius shape. This initial flat substrate ("a flat minilite") may have a rectangular, square or circular shape, or may be of the general shape of the desired multi-radius shape, or any other convenient alternative shape. Glass lites from which the flat minilites may be cut are desirably substantially colorless or tinted soda-lime sheets of glass. In addition, depending on the particular mirror construction and whether the desired bent shape derived from the flat minilite is to be employed as the front substrate 2 or the rear substrate 3, glass lites/flat minilites, from which the desired bent shape may be derived, may be coated with a substantially transparent conductive electrode coating, such as ITO or fluorine-doped tin oxide. As noted supra, fluorine-doped tin oxide coated glass is commercially available from Libbey-Owens-Ford Co. under the "TEC-Glass" tradename.

Once cut, the oversized flat minilites may be bent to the desired multi-radius using either conventional slump bending or press bending. Also, individual minilites may be bent to compound curvature or two flat minilites may be bent together as a matched pair. To manufacture a matched pair of bent minilites, two flat minilites may be stacked on top of one another, loaded in a tandem orientation into a bending press and bent together to the desired curvature (which may be spherical or aspherical) in one bending process step.

Where individual bent minilites are to be manufactured, any one bent minilite manufactured in any one bending process step is intended to match any other bent minilite. In electrochromic mirrors, it may be advantageous to use the twin bent minilites manufactured in tandem one on top of the other in the one bending operation step as a given matched pair to assemble a laminate construction.

The desired substrates may be cut from bent minilites to the dimension and shape suitable for use in the intended laminate construction of the particular electrochromic mirror. To the extent that the cullet trimmed away from the bent minilite manufactured as described supra conforms least to the intended radius design, bending oversized minilites is recommended. However, and particularly where the bending operation is to be attentively supervised, the desired dimensioned shape may first be cut from flat glass lites, with the desired dimensioned shape then bent to the desired multi-radius curvature.

It may be advantageous to cut multi-radius front and rear substrates from their respective bent minilites to facilitate proper alignment of a local radius on the first substrate relative to its corresponding local radius on the second substrate. In this regard, a matched pair of bent minilites may be assembled into a laminate construction with the first substrate laterally displaced from the second substrate, yet sustaining local to local radius alignment there between. In addition, should there be an asymmetry in radius, one perimeter length, LC, of the bent minilite may be identified as the lower radius (more curved) part of the minilite compared with its opposite perimeter length, LF, identified as the higher radius (more flat) part of that same bent minilite. Likewise, for its twin match in a matched pair of bent minilites, there may exist corresponding LC' and LF' perimeter lengths.

Suitable jigs or the like may be used to assemble a laminate construction of an electrochromic mirror with their corresponding perimeter lengths aligned. For example, LC may be aligned a few millimeters (e.g., 3 mm) inboard relative to LC' so that their local radii are mutually aligned and the desired electrical connection is established along LC' and LF. This may be accomplished by cutting a measured portion (e.g., 3 mm) of bent glass away from along LC and LF' and using jigs to align the now-cut edge of LC to the same measured distance (e.g., 3 mm) inboard from LC', with the respective substrates juxtaposed. Because of this alignment, local radius conformity between the substrates in a laminate construction may be established.

Alternatively, the bent minilites may be cut from oversized minilites so that one cut substrate may be laid on top of another cut substrate aligned in substantially flush relationship so that local to local radius conformity may be maintained and electrical connection may be established [see Lynam IV, the disclosure of which is hereby incorporated herein by reference].

While not required, the minilites may be sufficiently oversized to allow more than one substrate to be cut out from a given minilite, if the bending tool is appropriately designed. By so doing, the substrate cutting process benefits from economies of scale. For example, two substrates may be cut from the one sufficiently oversized bent minilite. These side-by-side matched twin substrates may be used as substrates 2,3 to construct the same electrochromic laminate assembly, or they may be used to serve as a substrate in any electrochromic laminate assembly.

Also, certain substantially transparent conductive electrode coatings, such as doped tin oxides, are aerobically inert, and as such may be bent in an ordinary air atmosphere without taking precautions to exclude oxygen. However, suitable precautions should be taken to avoid any crazing, hazing or optical deterioration of the conductive electrode coatings 4,4' during the bending process. Other substantially transparent conductive electrode coatings, such as ITO, may be bent from flat sheet stock using techniques such as those described in U.S. Pat. No. 4,490,227 (Bitter), the disclosure of which is hereby incorporated herein by reference. After or during heat treatment of ITO, such as in a bending/annealing

process which produces spherical and aspherical shaped substrates suitable for assembling laminate constructions for electrochromic mirrors or when firing ceramic frit bus bar material such as silver conductive frit #7713 (Du Pont), it may be desirable to establish a reducing atmosphere, as described in Bitter, such as a hydrogen-rich atmosphere, like that established with forming gas.

Glass lites and minilites may also be manufactured into spherical and/or aspherical shaped substrates without first being coated with a conductive electrode. In such instances, after the spherical and/or aspherical bent minilites or shaped substrates are manufactured, a conductive electrode coating, such as ITO, may thereafter be deposited onto the concave surface of the substrate 2 and the convex surface of the substrate 3.

A demarcation means 22 may be used in the multi-radius mirrors as described herein to separate the more curved, outboard region 55 (i.e., that portion of an exterior driver-side multi-radius mirror outboard and farthest from the driver) used by the driver principally as the blind-spot detection zone from the less curved, more flat inboard region 65 (i.e., closer to the driver) used by the driver principally for the primary rear vision function. (See FIG. 13.)

The demarcation means 22 may be a black or darkly colored continuous line or closely interspaced dots, dashes or spots (silk-screened or otherwise applied), which divides the outboard region from the inboard region of the multi-radius mirror. This black or darkly colored dividing line (or its aforestated equivalent) may assist the driver of a motor vehicle to discern the difference between images in the outermost, more curved region from those in the innermost, more flat region of the mirror. The thickness of this dividing line should be within the range of about 0.1 mm to about 3 mm, with about 0.5 mm to about 2 mm being preferred.

The demarcation means 22 may be constructed from an organic material, such as a polymer like an epoxy; an inorganic material, such as a ceramic frit; or a mixed organic/inorganic material. Such demarcation means 22 may be constructed to include, for example, an epoxy coupled with glass spacer beads, or plastic tape or a die cut from plastic tape. The demarcation means may be placed onto the conductive electrode coatings 4,4' of either or both of substrates 2,3 by silk-screening or other suitable technique prior to assembling the device. Also, the demarcation means 22 may be applied to any or all of the surfaces of substrates 2,3—i.e., the inward surfaces of substrates 2,3 or the opposite, non-inward surfaces of substrates 2,3. Additives may be included in the material used as a demarcation means to provide or enhance color, such as a dark color, like black, or dark blue or dark brown; to enhance stability (e.g., ultraviolet stabilizing agents such as described herein); or to increase adhesion (e.g., coupling agents, such as silane-, titanium-, or zirconium-based coupling agents). Alternatively, a dividing line may be established by etching a surface of substrate 2 and/or 3 (such as by sand blasting, laser etching or chemical etching) with optional staining of the etched-surface to develop a dark colored dividing line.

Where ceramic frits are used as a demarcation means and/or where bus bars are formed by applying a silver conductive frit [e.g., #7713 (Du Pont)] around the periphery and inboard from the edge of the inward surface(s) of substrate 2 and/or substrate 3, it may be convenient to silk-screen or otherwise apply the material to either or both of the substrates 2,3 prior to bending. In this way, the bending operation serves the dual purpose of bending and firing/curing the ceramic frit onto the substrates. In addition, where epoxies or other organic-based materials are used as the demarcation means and/or materials which act as bus bars, it may be convenient to silk-screen or otherwise apply the material to either or both of the substrates prior to final cure of the material used as the sealing means so that the sealing means, the demarcation means and/or material which acts as bus bars may be fired/cured in one and the same operation step. A dividing line may also be established within the cavity formed between substrates 2,3.

A driver textural warning 23, such as the conventional textural warning "objects in mirror are closer than they appear", may be included in the outermost more curved portion 55 of an electrochromic multi-radius exterior mirror according to this invention. (See FIG. 13.) Alternatively, a driver textural warning may be included in the innermost less curved region 65. Heretofore, such warnings have been established through sandblasting or as described in O'Farrell. Alternatively, textural warnings may be applied by silkscreening onto a surface of one of the substrates 2,3 of the mirror assembly or by other suitable techniques, such as laser etching, onto the reflective element of the mirror which is coated onto a surface of substrate 3.

On demand displays 14 may be positioned behind the reflective element of the mirror (see FIGS. 9 and 10) and become activated by user input or by input from a sensor, such as a supplementary vision device (e.g., camera, sensor, proximity detector, blind-spot detector, infrared and microwave detector), temperature sensor, fuel sensor, fault detector, compass sensor, global positioning satellite detector, hazard detector or the like. In addition, a vehicle function (such as a turn signal, hand brake, foot brake, high beam selection, gear change, memory feature selection and the like) may activate the on demand display. The on demand display may also be activated by a function such as a compass, clock, a message center, a speedometer, an engine revolution per unit meter and the like. In the context of their use in conjunction with rearview mirrors for motor vehicles, an on demand display, when not active or activated, should desirably remain at least substantially unobservable or undetectable by the driver and/or passengers. Similarly, in other applications with which these on demand displays may be desirably used, they should remain at least substantially unobservable or undetectable when not activated.

On demand displays 14 should be an emitting electronic display, such as a vacuum fluorescent display, a light emitting diode, a gas discharge display, a plasma display, a cathode ray tube, an electroluminescent display and the like.

Conventionally, the reflective element in electrochromic mirrors is constructed by coating the rearmost (non-inward) surface of the second substrate 3, with a reflective element using a wet chemical silver line mirror coating. This rearmost surface is typically coated with a layer of silver 8, and then protected with a thin film layer of copper 19 which itself is overcoated with a protective material 20, typically a paint such as a lead-based paint. In this construction, the light transmissivity through the mirror is substantially opaque—i.e., substantially less than about 0.01%. To place a display, camera, sensor or the like behind such a conventional mirror, a "window" 13 through which light may pass must be created as described hereinafter.

With reference to FIGS. 8, 9 and 10, it may be seen that on demand display capability may be introduced to a mirror through the window 13 that has been previously created therein [typically, by sand blasting, mechanical erosion (e.g., with a spinning rubber), laser etching, chemical etching and the like] by coating a layer of reflective material, such as a thin film of a metal 16 (e.g., a medium reflector, such as chromium, titanium, stainless steel and the like, having a thickness preferably less than about 750 Å), onto the rearmost (non-inward) surface of substrate 3 at the portion of the substrate where the window 13 exists. (See FIG. 10.) It may be preferable to use a medium reflector, such as chromium, titanium, stainless steel and the like, because such medium reflectors are durable, scratch resistant and resistant to environmental degradation without the need for additional overcoat layers like paints, lacquers, or other oxide coatings. Nevertheless, such overcoat layers may, of course, be used. Also, a high reflector such as silver or aluminum may be used, if desired. The window 13, now being only partially opaque in light transmissivity, is substantially light reflecting.

This partially transmitting/substantially reflecting window may be established through evaporating or sputtering (using vacuum deposition techniques) chromium metal over the window to a thickness of up to about 750 Å. By so doing, light transmittance within the range of about 1% to about 10% may be achieved, while also achieving light reflectance within the range of about 40% to about 65%. This method, however, introduces increased manufacturing costs (e.g., by first creating the window in the silver line-coated rearmost surface of substrate 3 and then vacuum depositing thereover the thin film of chromium). Also, the differences in reflectivity between the higher reflectance off the silver reflective element and the lower reflectance off the partially transmitting, lesser reflecting window may be detectable by or noticeable to an observer.

An alternative method involves the use of a partially transmitting (i.e., light transmission within the range of at least about 1% to about 20%), substantially reflecting (i.e., light reflectance within the range of least about 40% to greater than about 70%) metal foil or reflector-coated polymer sheet or film 15, such as metalized polymer sheet or film, like aluminum or chromium coated acrylic sheet or polyester "MYLAR" film (commercially available from Du Pont). Such a foil, or sheet or film 15, reflector coated with a thin film of metal 16 may be contacted with, or adhered to using an optical adhesive 18, preferably an index matching adhesive such as described hereinafter, the window 13 in the layer of reflective material on substrate 3.

Likewise, an appropriately sized glass cover sheet 15 (or a polymer cover sheet) which is coated with a thin film of metal 16 that is partially light transmitting (preferably, about 1% to about 20%), and yet substantially light reflecting (preferably, at least about 40% to greater than about 70%) may be contacted with, or adhered to using an optical adhesive 18 as described herein, the window 13 in the layer of reflective material on substrate 3. (See FIG. 9.) The glass cover sheet 15 may be any desired shape and should be sufficiently large to at least cover the entire window 13 created in the silver-coated, rearmost surface of substrate 3 (which may be suitable to accommodate, for example, compass displays, like the compass displays described in O'Farrell and Larson).

It may be convenient to coat glass lites with a high reflector, such as a thin film coating of aluminum or silver, to a thickness that achieves the desired partial light transmittance and substantial light reflectance. Alternatively, a medium reflector, such as a thin film coating of chromium, stainless steel, titanium or the like, may be used to coat the glass lites.

An inorganic oxide coating, such as silicon dioxide, titanium dioxide, zinc oxide or the like, may also be overcoated onto the thin film metal reflector coating to impart resilience, resistance against environmental degradation, enhance scratch resistance and enhance optical performance. Likewise, a thin film of magnesium fluoride, or a combination of thin films of dielectric materials such as described supra, may be used to overcoat the thin film metal reflector coating. A clear coat of a lacquer, such as an acrylic- or a urethane-based lacquer or the like, is still another choice which may be used to overcoat the thin film metal reflector coating.

Once formed, the partially transmitting/substantially reflecting glass lites may be subdivided into a multitude of smaller sized cover sheets to cover the window in the reflector on the rearmost (non-inward) surface of substrate 3. More specifically, a square, circle or rectangle may be cut to dimensions of about 1 to about 6 mm or larger than the dimensions of the window for the display. The square- or rectangular-shaped glass cover sheets may then be contacted with, or adhered to, the rearmost (non-inward) surface of substrate 3 to cover the previously established window for the display.

An optical adhesive 18 that is index matched to the refractive index of glass (i.e., about 1.52) may be used to adhere the glass cover sheet 15 to the rearmost (non-inward) surface of substrate 3. Such optical adhesives maximize optical quality and optical index matching, and minimize interfacial reflection, and include plasticized polyvinyl butyral, various silicones, polyurethanes such as "NORLAND NOA 65" and "NORLAND NOA 68", and acrylics such as "DYMAX LIGHT-WELD 478". The glass cover sheet 15 may be positioned with its semitransparent metal reflector coating 16 closest to the rearmost (non-inward) surface of substrate 3 so that the mirror construction comprises an assembled stack of the glass cover sheet 15/semitransparent reflector metal coating 16/optical adhesive 18/rearmost (non-inward) surface of substrate 3. In this construction, the optical adhesive is used as both an adhesive and as a protectant for the semitransparent metal reflector-coating 16 of the glass cover sheet 15. Such a use of semitransparent reflector-coated glass cover sheets 15/16 lends itself to economical and automated assembly. Also, the cover sheet may be made from glass that is coated with a dichroic mirror or made from polymer reflector material ("PRM"), as described hereinafter.

As an alternative to localized reflector coating with a thin metal film as shown in FIG. 10, or localized use of cover sheets, foils, films, and the like as shown in FIG. 9, at the non-inward surface of substrate 3 at window 13, similar localized reflector means can be employed at the inward facing surface of substrate 3 at the location of window 13.

An emitting display 14 may also be positioned behind the rearmost (non-inward) surface of the glass cover sheet 15 (which itself is positioned behind substrate 3 of the electrochromic mirror assembly). In this regard, it may be desirable to use a thin glass for the cover sheet 15 to minimize multiple imaging and/or double imaging. The thickness of the cover sheet need not be thicker than about 0.063", with suitable thicknesses being about 0.063"; about 0.043"; about 0.028"; about 0.016" and about 0.008". However, if desired the thickness of the cover sheet 15 may be greater than about 0.063".

Again with reference to FIG. 5, where the layer of reflective material is coated onto the inward surface of substrate 3, improved optical performance may be observed without reducing the thickness of substrate 3. In such constructions, a relatively thick glass (having a thickness of greater than about 0.063") may be used for substrate 3 with a thin glass (having a thickness of about 0.063" or less) used for substrate 2 while maintaining good mechanical properties due to the relatively greater stiffness of substrate 3. Improved optical performance may also be observed due to the relative closeness of the layer of reflective material (coated onto the inward surface of substrate 3) and the frontmost (non-inward) surface of substrate 2.

An illustration of this aspect of the present invention may be seen where substrate 3 is fabricated from "TEC 10" glass (having a sheet resistance of about 10 ohms per square), with a thickness of about 3 mm, and substrate 2 is fabricated from soda-lime glass (coated with HW-ITO having a sheet resistance of about 12 ohms per square as a substantially transparent conductive electrode coating 4), with a thickness of about 0.043". In this construction, the fluorine-doped tin oxide surface of the substrate 3 fabricated from "TEC 10" glass is positioned inward (and overcoated with a metal reflector/conductive electrode coating 4') and the HW-ITO coated surface of substrate 2 is also positioned inward so that the coated substrates 2,3 face one another.

A silicon or similar elemental semiconductor material may also be used as a reflective element 8 coated onto either the rearmost (non-inward) surface or the inward surface of substrate 3. Methods for making elemental semiconductor mirrors for motor vehicles are taught by and described in commonly assigned co-pending U.S. patent application Ser. No. 07/700,760, filed May 15, 1991 ("the '760 application"), the disclosure of which is hereby incorporated herein by reference. Where it is desired that the high reflectance off the elemental semiconductor reflector be within the range of at least about 60% to greater than about 70%, an undercoat of a thin film layer of silicon dioxide between a thin film layer of silicon and the surface of the substrate onto which it is coated may be used to enhance reflectivity performance [see e.g., the '760 application; and U.S. Pat. Nos. 4,377,613 (Gordon) and 4,419,386 (Gordon), the disclosures of each of which are hereby incorporated herein by reference].

In addition, the layer of silicon and/or an undercoat of silicon dioxide may be deposited using techniques such as vacuum deposition, spray deposition, CVD, pyrolysis and the like. For example, in-line deposition on a float glass line, and preferably in-bath, in-line deposition on a float glass line (as known in the glass manufacturing art) using CVD may be employed to deposit silicon layers and silicon/silicon dioxide thin film stacks onto float glass to provide a reflector for substrate 3 that is both highly reflecting and partially transmitting. A further advantage of these elemental semiconductor coatings is that they are bendable.

For example, a glass coated with a reflective element may be constructed by depositing onto a glass substrate a first layer of elemental silicon at an optical thickness of about 6,950 Å, followed by deposition of a second layer of silicon dioxide at an optical thickness of about 1,050 Å, which in turn is followed by deposition of a third layer of elemental silicon at an optical thickness of about 1,600 Å. Such a construction has a luminous reflectance of about 69% before heating and bending; and a luminous reflectance of about 74% after heating and bending. A substantially transparent conductive electrode coating, such as doped tin oxide (e.g., fluorine-doped tin oxide) and the like, may be coated over the third layer of elemental silicon to construct a highly reflecting, electrically conducting glass substrate suitable for use in electrochromic mirrors and electrochromic devices where the coated substrate may be bent without unacceptable deterioration in its optical and electrical properties. Preferably, reflector-coated substrates constructed using multi-layer stacks, such as a glass/silicon/silicon dioxide/silicon stack (with or without additional undercoating or overcoating stack layers), may be deposited in-bath, on-line onto glass being manufactured on a float glass line.

It may also be advantageous to employ bendable reflector-coated substrates and techniques for manufacturing the same as taught by and described in the '760 application, and multi-layer stacks, such as the glass/silicon/silicon dioxide/silicon stack as described supra, with or without an additional overcoating of a substantially transparent conductive electrode coating such as fluorine-doped tin oxide and the like. Bendable coatings may be advantageous in minimizing manufacturing requirements since depositing a thin film of metal generally requires the steps of first bending the non-reflector coated substrate and then coating the bent substrate with the layer of reflective material.

As described supra, it may be advantageous to construct electrochromic mirrors whose reflective element 8 is located within the laminate assembly. This may be achieved by coating the inward surface of substrate 3 with a layer of reflective material 8, such as silver, so that the silver coating (along with any adhesion promoter layers 11) is protected from the outside environment. For example, a layer of reflective material 8 may be vacuum deposited onto the inward surface of substrate 3 in one and the same process step as the subsequent deposition of the electrochromic solid film 7 onto substrate 3. This construction and process for producing the same not only becomes more economical from a manufacturing standpoint, but also achieves high optical performance since uniformity of reflectance across the entire surface area of the mirror is enhanced. The thin film stack [which comprises the electrochromic solid film 7 (e.g., tungsten oxide), the layer of reflective material 8 (e.g., silver or aluminum) and any undercoat layers between the layer of reflective material 8 and substrate 3] should have a light reflectance within the range of at least about 70% to greater than about 80%, with a light transmission within the range of about 1% to about 20%. Preferably, the light transmission is within the range of about 3% to about 20%, and more preferably within the range of about 4% to about 8%, with a light reflectance greater than about 80%.

A light reflectance of at least 70% (preferably, at least 80%) for the reflective element to be used in an electrochromic mirror incorporating on demand displays is desirable so that the bleached (unpowered) reflectivity of the electrochromic mirror can be at least 55% (preferably, at least 65%) as measured using SAE J964a, which is the recommended procedure for measuring reflectivity of rearview mirrors for automobiles. Likewise, a transmission through the reflective element of, preferably, between about 1% to 20% transmission, but not much more than about 30% transmission, (measured using Illuminant A, a photopic detector, and at near normal incidence) is desirable so that emitting displays disposed behind the reflective element of the electrochromic mirror are adequately visible when powered, even by day but, when unpowered and not emitting, the displays (along with any other components, circuitry, backing members, case structures, wiring and the like) are not substantially distinguishable or visible to the driver and vehicle occupants.

With reference to FIGS. 9 and 10, emitting displays 14, such as vacuum fluorescent displays, light emitting diodes, gas discharge displays, plasma displays, cathode ray tubes, electroluminescent displays and the like may also be placed in contact with, or adhered to using an adhesive 17, 18 such as an epoxy, the rear of substrate 3. Generally, such emitting displays may only be observable when powered so as to emit light.

A variety of emitting displays 14 may be used in this connection including, but not limited to, double heterojunction AlGaAs very high intensity red LED lamps, such as those solid state light emitting display LED lamps which use double heterojunction Al/GaAs/GaAs material technology [commercially available from Hewlett Packard Corporation, Palo Alto, Calif. under the designation "T-1¾ (5 mm) HLMP-4100-4101"].

Alternatively, vacuum fluorescent displays, such as 12 V battery driven high luminance color vacuum fluorescent displays may be advantageously used [commercially available from Futaba Corporation of America, Schaumburg, Ill. under the designations S-2425G, S-24-24G, S-2396G and S2397G]. It may also be advantageous to use displays 14 that operate efficiently at about 12 V or lower since these voltages are particularly amenable to motor vehicles. Also, ultrahigh luminance vacuum fluorescent displays, suitable for heads-up-display applications in motor vehicles may be used with appropriate circuitry, such as Type 3-LT-10GX [commercially available from Futaba Corporation]. Suitable vacuum fluorescent displays are also commercially available from NEC Electronics Incorporated, Mountain View, Calif., such as under the designation Part No. FIP2QM8S.

It may also be desirable, particularly where the reflective element is at least partially light transmitting, to use a light absorbing means, such as a black-, brown- or blue-colored or other suitably colored absorbing coating, tape, paint, lacquer and the like, on portions of the rearmost (non-inward) surface of substrate 3 where displays are not mounted. It may be desirable to use substantially opaque, and preferably dark colored tape or plastic film and the like, across the surface of substrate 3, such as by adhering to protective material 20, preferably across substantially the entire rear surface, except where any displays are to be positioned. By so doing, any secondary images or aesthetically non-appealing mirror case illumination due to stray light emittance from the display may be reduced.

Placement of apertures or cutouts in a tape or film backing may expedite the assembly of such mirrors by guiding the assembler to the point where the desired display or displays is to be mounted. The tape or film backing may also serve as an anti-scatter means to enhance safety and prevent injury by retaining any glass shards which may result due to mirror breakage, for example caused by impact from an accident.

Suitably colored paints, inks, plastic films or the like may be applied to the surface of substrate 3 where the display 14 is to be placed to change or effect the color of the display. Also, the display 14 may be adhered to a surface of the substrate using an adhesive 18, such as an index matching adhesive 17, 18, that may be dyed to effect color and/or contrast enhancement in the display [see e.g., Larson, the disclosure of which is hereby incorporated herein by reference].

Generally, and particularly when the electrochromic element is in its bleached, uncolored state, it may be desirable for the image of the display—e.g., an information display, such as a compass display, a clock display, a hazard warning display or the like—to have a luminance within the range of at least about 30 foot lamberts to about 80 foot lamberts (preferably, within the range of at least about 40 foot lamberts to about 60 foot lamberts), as measured with the display placed behind, and emitting through, the electrochromic mirror and with the electrochromic element in its fully transmitting, bleached state. With this level of luminance, such a display may be read easily even with bright ambient levels of light. Also, the electronic circuitry taught by and described in Larson may be used to appropriately dim the display to suit nighttime driving conditions and/or to compensate for any dimming of the electrochromic element. Generally, at night the luminance of the display is about 15–40%, preferably about 20–35%, that of the daytime value.

During daytime lighting conditions, drivers of motor vehicles mounted with an electrochromic mirror (interior, exterior or both) benefit from relatively high reflectance (at least about 55%, with at least about 65% typically being preferred) when in the bleached "day" state. Any display positioned behind the electrochromic mirror should have a sufficiently high luminance to permit the display (which may be digital, alpha-numeric, analog or combinations thereof) to emit therethrough and be readable. The display 14 should be readable even when ambient conditions within the cabin of a motor vehicle (or outside, where electrochromic exterior rearview mirrors are used or where the electrochromic interior rearview mirror is mounted in a convertible with its top down) are bright, such as midday on a sunny, cloudless day. The mirrors of the present invention may achieve a light reflectance of at least about 55% for the high reflectance state where a high reflector in the form of a thin film metal coating is used with a sufficient thickness to allow for light to transmit through the electrochromic element 1, preferably within the range of about 1% to about 15% transmission, but not exceeding about 30% (as measured using Illuminant A and a photopic detector, with near normal incidence). More specifically, where silver is used as a high reflector, the mirrors of the present invention may achieve a light reflectance of at least about 65% for the high reflectance state with a light transmission therethrough within the range of about 1% to about 20% transmission (measured as described supra). The thin film metal coating may have a thickness within the range of about 200 Å to about 1,500 Å, preferably within the range of about 200 Å to about 750 Å.

It may also be desirable, particularly when used in conjunction with highly spectrally selective light emitting diodes and the like, to use PRM as a reflector placed between the display 14 and the rearmost (non-inward) surface of substrate 3. PRM is a spectrally selective, substantially reflecting (greater than about 50%) and significantly transparent polymer reflector material [see T. Alfrey, Jr. et al., "Physical Optics of Iridescent Multilayered Plastic Films", *Polym. Eng'g. & Sci.*, 9(6), 400–04 (1969); W. Schrenk et al., "Coextruded Elastomeric Optical Interference Film", *ANTEC* '88, 1703–07 (1988); and see generally U.S. Pat. Nos. 3,711,176 (Alfrey, Jr.); 3,557,265 (Chisolm) and 3,565,985 (Schrenk). PRM is commercially available from Dow Chemical Co., Midland, Mich., such as under the designation PRM HU75218.03L, which is a 0.125" thick sheeting made of multiple polymer layers (e.g., 1305 layers), having differing refractive indices and transparent/transparent CAP layers. This PRM exhibits a light reflectance of about 58% and a generally neutral light transmittance. Another PRM, designated as PRM HU75218.08L, also is a 0.125" thick sheeting, made from multiple polymer layers (e.g., 1305 layers), with a light reflectance of about 58%. However, this PRM has transparent/red CAP layers which results in a transmission which has a distinctly red tint. As such, it may be particularly well-suited for use in conjunction with the mirrors of the present invention that employ in their construction red light emitting diodes, such as those typically employed in hazard warning devices.

An array of light emitting diodes may be positioned behind a window 13 in a mirror with an appropriately sized piece of PRM positioned between the emitting displays 14 and the rearmost (non-inward) surface of the substrate 3. By choosing a PRM with a selective transmission which permits the passage of the bandwidth of light emitted by the emitter but that substantially attenuates other wavelengths not within that bandpass of light, optical efficiency may be enhanced. Indeed, PRM itself may be an appropriate reflective element behind which display emitters may be disposed. While PRM may be vulnerable to scratching and susceptible to degradation from environmental exposure, substrates 2,3 offer desirable protection from such damage. Use of PRM where the piece of PRM is larger than and covers the window created in the reflective element on substrate 3 (but is smaller than the entire surface area of substrate 3) is particularly attractive compared to the use of conventional dichroic mirrors [such as thin film dielectric stack dichroic mirrors (commercially available from Optical Coatings Labs, Santa Rosa, Calif.)] as the reflective element because of economic benefits.

Should it be desirable to use a PRM/emitting display, a substrate with or without a thin film of metal reflector coating that is substantially transmitting may be positioned in front of the PRM. Suitable optical adhesives, preferably index matching adhesives as described supra, may be used to construct a mirror that comprises a light emitting element which emits light through a sheet of PRM, which is positioned behind a glass substrate through which the emitted light also passes. Such a mirror would appear reflective when the light emitting element (e.g., a red LED such as described supra) is unpowered, yet would efficiently display a warning indicia when the light emitting element is powered, strobed or flashed. Also, PRM being a polymer material is relatively easily formed by molding, slumping, bending and similar polymer forming methods, so conformance to a compound curvature or convex curvature is facilitated.

In that aspect of the present invention directed to exterior rearview mirrors for motor vehicles, it may be advantageous to use in conjunction therewith signal lights, security lights, flood lights, remote actuation and combinations thereof as taught by and described in commonly assigned co-pending U.S. patent application Ser. No. 08/011,947, filed Feb. 1, 1993 ("the '947 application"), now U.S. Pat. No. 5,371,659, the disclosure of which is hereby incorporated herein by reference.

The electrochromic mirrors of the present invention may also include an anti-reflective means, such as an anti-reflective coating, on the front (non-inward) surface of the outermost or frontmost substrate as viewed by an observer (see e.g., Lynam V); an anti-static means, such as a conductive coating, particularly a substantially transparent conductive coating, such as ITO, tin oxide and the like; index matching means to reduce internal and interfacial reflections, such as thin films of an appropriately selected optical path length; and/or light absorbing glass, such as glass tinted to a neutral density, such as "GRAYLITE" gray tinted glass (commercially available from Pittsburgh Plate Glass Industries) and "SUNGLAS" gray tinted glass (commercially available from Ford Glass Co., Detroit, Mich.), which assists in augmenting contrast enhancement. Moreover, polymer interlayers, which may be tinted gray, such as those used in electrochromic devices as taught by and described in Lynam I, may be incorporated into the electrochromic mirrors described herein.

The mirrors of this present invention, particularly rearview mirrors intended for use on the exterior motor vehicles, may also benefit from an auxiliary heating means used in connection therewith such as those taught by and described in U.S. Pat. No. 5,151,824 (O'Farrell) and U.S. patent application Ser. No. 07/971,676, filed Nov. 4, 1992 ("the '676 application"), now U.S. Pat. No. 5,446,576, the disclosures of each of which are hereby incorporated herein by reference. Preferred among such heating means are positive temperature coefficient ("PTC") heater pads such as those commercially available from ITW Chromomatic, Chicago, Ill. These heater pads employ conductive polymers, such as a crystalline organic polymer or blend within which is dispersed a conductive filler like carbon black, graphite, a metal and a metal oxide, [see e.g., U.S. Pat. No. 4,882,466 (Friel)]. The heater pads exhibit a positive temperature coefficient; that is, their resistance increases when the surrounding temperature increases. Thus, the heater pads may be used as a self-regulating heating element.

If a display is to be mounted behind the reflective element, an appropriately sized and shaped aperture through the auxiliary heating means should be used to accommodate the display but not leave portions of the mirror unheated for de-icing or de-misting purposes. Likewise, should a heat distribution pad be used, such as an aluminum or copper foil as described in the '676 application, an appropriately sized and shaped aperture should also be provided therein to accommodate such displays. Where apertures are to be included in a PTC heater pad, a pattern of resistive electrodes which contact the conductive polymer, which may typically be applied by a silk-screening process as described in Friel, should be designed to accommodate the apertures in the pad. In addition, such a pattern may also be useful to thermally compensate for the apertures in the pad. Alternatively, the resistive electrode/conductive polymer combination may be applied, for example, directly onto the rearmost (non-inward) surface of substrate 3, or onto a heat distribution pad that is contacted and/or adhered thereto.

It may also be advantageous to provide mirrors in the form of a module, which module comprises the mirror itself and its electrical connection means (e.g., electrical leads); any heater pad (optionally, including a heat distribution pad) and associated electrical connection means; bezel frames; retaining members (e.g., a one-piece plate) and electrical connection means (see e.g., O'Farrell); actuators [e.g., Model No. H16-49-8001 (right-hand mirror) and Model No. H16-49-8051 (left-hand mirror), commercially available from Matsuyama, Kawoge City, Japan] or planetary-gear actuators [see e.g., U.S. Pat. No. 4,281,899 (Oskamo) and the '947 application, the disclosures of each of which are hereby incorporated herein by reference] or memory actuators that include memory control circuitry such as Small Electrical Actuator #966/001 which includes a 4 ear adjusting ring, 25 degree travel and an add-on memory control and is available from Industrie Koot B.V. (IKU) of Montfort, Netherlands; and brackets for mounting the module within the casing or housing of a mirror assembly such as taught by and described in the '947 application. Electrochromic mirrors may be assembled using these items to provide modules suitable for use with a mirror casing or housing that includes the electrochromic element, which incorporates the reflective element and any associated components such as heater means, bezel means, electrically or manually operable actuation means, mounting means and electrical connection means. These components may be preassembled into a module that is substantially sealed from the outside environment through the use of sealants like silicones, epoxies, epoxides, urethanes and the like. These components may also be formed and/or assembled in an integral molding process, such as with those processes described in U.S. Pat. Nos. 4,139,234 (Morgan) and 4,561,625 (Weaver), each of which describe suitable molding processes in the context of modular window encapsulation. An added-value electrochromic mirror module, including the actuators which allow adjustment and selection of reflector field of view when mounted within the outside mirror housings attached to the driver-side and passenger-side of a vehicle, may be preassembled and supplied to outside vehicular mirror housing manufacturers to facilitate ease and economy of manufacturing.

Many aspects of the present invention, particularly those relating to the use of PRM and emitting displays; glass cover sheets, foils and the like; and thin film metal coatings that are applied locally and that are substantially reflecting and partially transmitting, may of course be employed with non-electrochromic rearview mirrors for motor vehicles, such as conventional prismatic mirrors. For instance, with exterior rearview mirrors for motor vehicles, a driver-side rearview mirror and a passenger-side rearview mirror may be mounted in combination on a motor vehicle to be used to complement one another and enhance the driver's rearward field of view. One of such mirrors may be an electrochromic mirror and the other mirror may be a non-electrochromic mirror, such as a chromed-glass mirror, with both exterior mirrors benefitting from these aspects of the present invention. In addition, these aspects of the present invention may be employed in connection with a display window that has been established in a prismatic mirror.

Substrate 2 may be of a laminate assembly comprising at least two transparent panels affixed to one another by a substantially transparent adhesive material, such as an optical adhesive as described herein. This laminate assembly assists in reducing the scattering of glass shards from substrate 2 should the mirror assembly break due to impact. Likewise, substrates 2,3 may each be of such a laminate assembly in a glazing, window, sun roof, display device, contrast filter and the like.

It is clear from the teaching herein that should a glazing, window, sun roof, display device, contrast filter and the like be desirably constructed, the reflective element 8 need only be omitted from the assembled construction so that the light which is transmitted through the transparent substrate is not further assisted in reflecting back therethrough.

In the aspects of the present invention concerning electrochromic devices, particularly electrochromic optical attenuating contrast filters, such contrast filters may be an integral part of an electrochromic device or may be affixed to an already constructed device, such as cathode ray tube monitors. For instance, an optical attenuating contrast filter may be manufactured using an electrochromic element as described herein and then affixing it to a device, using a suitable optical adhesive. In such contrast filters, the constituents of the electrochromic element should be chosen so that the contrast filter may color to a suitable level upon the introduction of an applied potential thereto, and no undesirable spectral bias is exhibited.

Many aspects of the present invention, especially those concerning mirror construction, use of elemental semiconductor layers or stacks (with or without an additional undercoat of silicon dioxide and/or an overcoat of doped tin oxide), PRM, localized thin film coatings, cover sheets and on demand displays, may of course be incorporated into electrochromic mirrors and electrochromic devices that employ electrochromic technology for the electrochromic element different from that which is taught and described herein, such as electrochromic solution technology of the electrochemichromic type (e.g., Byker I, Byker II, Varaprasad I and Varaprasad III) and electrochromic solid film technology (e.g., the '675 application, the '557 application and Lynam I), including electrochromic organic thin film technology, in which a thin film of organic electrochromic material such as a polymerized viologen is employed in the electrochromic element [see e.g., U.S. Pat. No. 4,473,693 (Wrighton)].

Once constructed, the electrochromic device, such as an electrochromic mirror, may have a molded casing or housing placed therearound. This molded casing or housing may be pre-formed and then placed about the periphery of the assembly or, for that matter, injection molded therearound using conventional techniques, including injection molding of thermoplastic materials, such as polyvinyl chloride or polypropylene, or reaction injection molding of thermosetting materials, such as polyurethane or other thermosets. These techniques are well-known in the art [see e.g., Morgan and Weaver, respectively].

Each of the documents cited herein is hereby incorporated by reference to the same extent as if each document had individually been incorporated by reference.

In view of the above description of the instant invention, it is evident that a wide range of practical opportunities is provided by the teaching herein. The following examples of electrochromic mirrors and electrochromic devices are provided to illustrate the utility of the present invention only and are not to be construed so as to limit in any way the teaching herein.

EXAMPLES

Example 1

An electrochromic interior rearview automotive mirror cell having a shape commonly used for interior rearview mirrors was constructed from clear HW-ITO-coated glass as the first substrate (having a sheet resistance of about 12 ohms per square), with a tungsten oxide electrochromic solid film coated over its HW-ITO coating (which is coated onto the inward surface of the substrate). As the second substrate of the mirror cell, a HW-ITO-coated glass substrate (also having a sheet resistance of about 12 ohms per square) with the ITO coated onto its inward surface was used. A reflective element was formed by coating a layer of silver onto the rearmost (opposite, non-inward) surface of the second substrate of the mirror cell. The HW-ITO was coated onto the glass substrates at a thickness of about 1,500 Å; the tungsten oxide electrochromic solid film was coated over the HW-ITO coating of the first substrate at a thickness of about 5,000 Å; and the silver was coated onto the rearmost surface of the second substrate using conventional wet chemical silver line deposition as known in the mirror art. The first substrate was positioned in spaced-apart relationship with the second substrate to form a 88 μm interpane spacing between the coated inward surfaces of the substrates. The first substrate was also laterally displaced from the second substrate to provide a convenient area for bus bar attachment.

We formulated an electrolyte for this mirror cell containing ferrocene (about 0.015M), phenothiazine (about 0.06M), lithium perchlorate (about 0.05M) and "UVINUL" 400 [about 5% (w/v)] in a solvent combination of tetramethylene sulfone and propylene carbonate [in a ratio of about 50:50 (v/v)].

We dispensed the electrolyte described above into the mirror cell by the vacuum backfilling method [as described in Varaprasad IV].

Upon application of about 1.4 volts, we observed that the mirror dimmed uniformly and rapidly to a neutral gray colored state. Specifically, we observed that the mirror dimmed from about 70% reflectance to about 20% reflectance in a response time of about 3.2 seconds. In addition, we observed that the mirror exhibited a high reflectance in the unpowered, bleached state of about 74.7% and a low reflectance in the dimmed state of about 5.9%

We made and recorded these observations following the standard procedure J964A of the Society of Automotive Engineers, using a reflectometer—set in reflectance mode—equipped with a light source (known in the art as Standard Illuminant A) and a photopic detector assembly.

Spectral scans were recorded using a conventional spectrophotometer operating in reflection mode in both the bleached state [see FIG. 1 and Tables I(a) and I(b)] and the colored state at an applied potential of about 1.5 volts [see FIG. 2 and Tables II(a) and II(b)].

TABLE I(a)

Reflectance Data In The Unpowered, Bleached State

WL (nm)	0	5	10	15	20	25	30	35	40	45
380	14.5	20.4	29.1	38.2	45.9	51.7	56.1	59.5	61.9	64.2
430	65.9	67.6	68.9	70.4	71.6	72.7	73.6	74.8	75.4	76.2
480	77.0	77.7	78.1	78.9	79.5	80.2	80.6	80.7	80.7	80.9
530	80.7	80.6	80.0	80.1	79.4	79.3	78.8	78.5	78.1	77.8
580	77.2	76.9	76.5	75.8	75.1	74.5	74.1	73.5	72.5	71.9
630	71.4	70.6	70.1	69.4	68.7	67.9	67.2	66.5	65.6	64.9
680	64.5	63.6	62.9	62.0	61.3	60.6	60.2	59.6	58.6	57.4
730	57.1	56.6	55.7	55.0	54.6	53.9	52.5	51.6	51.2	50.7
780	50.5									

TABLE I(b)

Color Statistics - C.I.E. Convention Using 2 Degree Eye

Illuminant	x	y	DomWave	Purity	Y
A	0.4422	0.4172	547.0	3.2	77.0
C	0.3097	0.3304	549.7	3.8	77.8

TABLE II(a)

Reflectance In The Colored State at 1.5 Volts										
WL (nm)	0	5	10	15	20	25	30	35	40	45
380	11.4	11.6	11.8	11.5	10.6	9.5	8.6	7.7	6.8	6.1
430	5.5	5.0	5.0	5.1	5.6	5.6	5.8	6.0	6.2	6.3
480	6.5	6.7	6.8	6.9	7.0	7.1	7.2	7.2	7.2	7.3
530	7.4	7.6	7.8	8.0	8.1	8.1	8.0	7.8	7.6	7.4
580	7.3	7.0	6.8	6.6	6.3	6.1	6.0	5.7	5.6	5.4
630	5.4	5.2	5.2	5.1	6.0	4.9	4.9	4.8	4.8	4.8
680	4.8	4.8	4.8	4.7	4.8	4.8	4.8	4.8	4.8	4.8
730	4.9	4.9	4.9	5.0	5.1	5.0	5.1	5.2	5.1	5.2
780	5.4									

TABLE II(b)

Color Statistics - C.I.E. Convention Using 2 Degree Eye at 1.5 Volts					
Illuminant	x	y	DomWave	Purity	Y
A	0.4323	0.4342	545.3	8.5	7.0
C	0.3098	0.3499	549.3	8.9	7.1

We also cycled the mirror as described in Table III below.

TABLE III

Number of	Cycled	Color/bleach	
Cycles	Temperature (°C.)	Cycle (secs)	Voltage
30,000	50	5/5	1.4/0.0
40,000	room temperature	5/5	1.4/0.0
30,000	−30	5/5	1.4/0.0
90,000	50	5/5	1.6/0.0
11,000	80	30/30	1.4/0.0

After subjecting this mirror to such cycling conditions, we observed the reflectance of the mirror to decrease from about 70% to about 20% in a response time of about 3.2 seconds. In addition, we observed the mirror to have a high reflectance in the unpowered, bleached state of about 78.6% and a low reflectance in the dimmed state of about 6.4% when a potential of 1.4 volts was applied thereto. We made and recorded these observations using the SAE procedure referred to supra.

We observed that these mirrors exhibited excellent stability to temperature extremes. For example, after storage at temperatures in the 80° C.–110° C. range, for periods ranging from about 2 hours to in excess of 336 hours, performance remained excellent, and, indeed, in aspects such as transition times from low to high reflectance states performance was even better after heat exposure.

Example 2

In this example, we used the same electrolyte formulation and an electrochromic mirror constructed in the same manner as in Example 1, supra.

We introduced an applied potential of about 1.4 volts to the mirror and observed its center portion to change from a high reflectance of about 75.9% to a low reflectance of about 6.3%, which decreased from about 70% reflectance to about 20% reflectance in a response time of about 3.5 seconds.

We then subjected this mirror to an accelerated simulation of outdoor weathering conditions to investigate its resilience and stability to ultraviolet light. Specifically, we subjected the mirror to about 1300 KJ/m^2 of ultraviolet exposure in an Atlas CI35A Xenon Weather-o-meter (Atlas Electric Devices Company, Chicago, Ill.), equipped with a Xenon lamp emitting about 0.55 w/m^2 intensity at about 340 nm. After accelerated outdoor weathering, we observed that the mirror continued to function suitably for use in a motor vehicle. We also observed that the mirror cycled well. In addition, we observed the high reflectance to be about 75.2% and the low reflectance to be about 6.9% when a potential of about 1.4 volts was applied thereto.

We made and recorded these observations using the SAE procedure referred to in Example 1, supra.

Example 3

The electrochromic mirror cell of this example was constructed from clear HW ITO-coated glass as the first substrate as in Example 1, supra. However, the second substrate was constructed of ordinary soda-lime glass. Using electron beam evaporation in a vacuum chamber, a layer of chromium was coated directly onto the inward surface of the second glass substrate as an adhesion promoter. Next, and without breaking vacuum, a thin film of silver was coated onto the layer of chromium as a reflective element, and thereafter (again without breaking vacuum) tungsten oxide was coated over the layer of silver as an electrochromic solid film. The layer of chromium was coated onto the second substrate at a thickness of about 1,000 Å; the thin film of silver was coated over the chromium at a thickness of about 1,000 Å; and the tungsten oxide was coated over the silver at a thickness of about 5,000 Å. The sheet resistance of the silver so undercoated with chromium was about 0.4 to 0.5 ohms per square. As with the mirror cell of Example 1, supra, the first substrate was positioned in spaced-apart relationship with the second substrate to form an 88 μm interpane spacing between the coated inward surfaces of the substrates. The first substrate was laterally displaced from the second substrate to provide a convenient area for bus bar attachment.

We used the electrolyte of Example 1, supra, and dispensed it into the mirror cell using the vacuum backfilling method [as described in Varaprasad IV].

We introduced an applied potential of about 1.4 volts to the mirror and observed the change from a high reflectance of about 81.6% to a low reflectance of about 5.9%, which decreased from about 70% reflectance to about 201% reflectance in a response time of about 1.9 seconds.

We made and recorded these observations using the SAE procedure referred to in Example 1, supra.

We also cycled the mirror as described in Table IV below.

TABLE IV

Number of	Cycled	Color/bleach	
Cycles	Temperature (°C.)	Cycle (secs)	Voltage
30,000	50	5/5	1.4/0.0
40,000	room temperature	5/5	1.4/0.0

After subjecting the mirror to such cycling conditions, we observed the reflectance of the mirror in the unpowered, bleached state to be about 77.3%, and the mirror dimmed to 6.2% reflectance with 1.4 volts applied thereto.

Example 4

We used an electrochromic mirror cell constructed in the same format and with the same shape and dimensions as in Example 1, supra, except that a tungsten oxide electrochromic solid film (having a thickness of about 5,000 Å) was coated over the HW-ITO coating on the inward surface of the second substrate.

We formulated an electrolyte containing ferrocene (about 0.025M), phenothiazine (about 0.05M), lithium perchlorate (about 0.05M) and "UVINUL" 400 [about 10% (w/v)] in a solvent combination of tetramethylene sulfone and propylene carbonate [in a ratio of about 25:75 (v/v)]. We dispensed the electrolyte into the mirror cell using the vacuum backfilling method [as described in Varaprasad IV].

Upon introduction of an applied potential of about 1.4 volts, we observed the mirror to dim uniformly and rapidly to a neutral gray colored state. Specifically, we observed the mirror to have a high reflectance in the unpowered, bleached state of about 70.7% and a low reflectance in the dimmed state of about 7.3%. We made and recorded these observations using the SAE procedure referred to in Example 1, supra.

We also cycled the mirror and subjected the mirror to an accelerated simulation of outdoor weathering conditions to investigate its resilience and stability to ultraviolet light as described in Example 2, supra, but at an exposure of about over 2,500 KJ/m^2. We observed that the mirror cycled well, and after accelerated outdoor weathering, we also observed that the mirror continued to function in a manner suitable for use in a motor vehicle.

Example 5

In this example, we fabricated an electrochromic glazing cell of a construction suitable for use as a window or a sun roof for a motor vehicle. The glazing cell was dimensioned to about 15 cm×about 15 cm, with an interpane spacing between the tungsten oxide coating on the inward surface of the second substrate and the HW-ITO coating on the inward surface of the first substrate of about 105 μm.

The glazing cell was constructed using spacers to assist in defining the interpane spacing. The spacers were sprinkled over the tungsten oxide-coated surface of the first substrate and, inward from the peripheral edge of the HW-ITO-coated second substrate, an epoxy was applied using a silk-screening technique. While the epoxy was still uncured, the first substrate and the second substrate were off-set from one another by a lateral displacement and a perpendicular displacement. The epoxy was then cured into a seal for the electrochromic glazing cell using a vacuum bagging technique (as is known in the laminating art) at a reduced atmospheric pressure of about 10" of mercury and a temperature of about 110° C. for a period of time of about 2 hours in order to achieve substantially even pressure while curing the epoxy into a seal.

We formulated an electrolyte containing ferrocene (about 0.015M), phenothiazine (about 0.06M), lithium perchlorate (about 0.05M) and "UVINUL" 400 [about 5% (w/v)] in a solvent combination of tetramethylene sulfone and propylene carbonate [in a ratio of about 50:50 (v/v)]. We dispensed this electrolyte into the electrochromic glazing cell using the vacuum backfilling method [as described in Varaprasad IV].

Upon introduction of an applied potential of about 1.4 volts to the electrochromic glazing, we observed the transmissivity change from a high transmittance of about 78.6% to a low transmittance of about 12.9%.

We made and recorded these observations using the SAE procedure referred to in Example 1, supra, except that the reflectometer was set in transmittance mode.

Example 6

In this example, we constructed an electrochromic mirror suitable for use as an exterior rearview mirror for a motor vehicle.

The mirror was constructed from clear HW-ITO-coated glass as the first substrate as in Example 1, supra.

However, as the second substrate we used ordinary soda-lime glass. Both substrates were sized and shaped to dimensions of 9.5 cm×15 cm. A notch was cut in one edge of the first substrate, and another notch was cut in a different location on one edge of the second substrate. A bus bar was formed along the edges of the first substrate by silk-screening a silver conductive frit material [#7713 (Du Pont)] all around the perimetal region of the HW-ITO-coated surface of the substrate to a width of about 2.5 mm, and then firing the frit at an elevated temperature in a reducing atmosphere to avoid oxidizing the HW-ITO.

A layer of chromium at a thickness of about 1,000 Å was coated directly by vacuum deposition onto the inward surface of the second glass substrate as an adhesion promoter. Thereafter, without breaking vacuum, a thin film of silver at a thickness of about 1,000 Å was coated onto the layer of chromium as a reflective element, and tungsten oxide at a thickness of about 5,000 Å was then coated (again, without breaking vacuum) over the layer of silver as an electrochromic solid film. The first substrate and the second substrate were then positioned in spaced-apart relationship so that the edges of the substrates were flush, and a seal was applied so as to form a cavity between the two substrates. In this flush design, the interpane spacing between the coated inward surfaces of the substrates was 88 μm.

For this exterior mirror, we formulated an electrolyte containing ferrocene (about 0.025M), phenothiazine (about 0.06M), lithium tetrafluoroborate (about 0.05M) and "UVINUL" 400 [about 5% (w/v)] in propylene carbonate. We dispensed this electrolyte into the mirror cell using the vacuum backfilling method described in Varaprasad IV].

Electrical leads were then attached to the mirror. The notch on the second substrate permitted an electrical lead to be attached at a point contact on the silver frit bus bar formed around and substantially circumscribing the perimeter of the HW-ITO-coated inward surface of the first substrate. Another electrical lead was attached to the portion of the chromium/silver/tungsten oxide coating on the inward surface of the second substrate exposed by the notch cut in the first substrate. The point contact was sufficient to apply a potential across the electrodes because of the low sheet resistance of the coating on the inward surface of the second substrate.

Upon introduction of an applied potential of about 1.5 volts to the mirror, we observed the reflectance change from a high reflectance of about 77.5% to a low reflectance of about 10.6%.

We also cycled the mirror for about 50,000 cycles at a temperature of about 50° C., and observed that the mirror cycled well and continued to function suitably for use in a motor vehicle.

Example 7

In this example, we used the same electrolyte formulation and an electrochromic mirror cell of the same shape as described in Example 1, supra. After filling the electrochromic mirror cell using the vacuum backfilling method [as described in Varaprasad IV], we removed the tungsten oxide coating from the peripheral edge of the first substrate using a dilute basic solution of potassium hydroxide followed by water. We then connected the bus bars to this newly-exposed ITO surface. Thereafter we applied a secondary weather barrier material. The secondary weather barrier material was formed from "ENVIBAR" UV 1244T ultraviolet curable epoxy, with about 2% of the silane coupling agent A-186 (OSi Specialties Inc., Danbury, Conn.) combined with about 1% of the photoinitiator "CYRACURE" UVI-6990. Thereafter, we cured this material by exposing it to a suitable source of ultraviolet light to form a secondary weather barrier.

Once the secondary weather barrier was formed, we introduced an applied potential of about 1.3 volts to the mirror and observed the reflectance change from a high reflectance of about 77.8% to a low reflectance of about 7.1%.

We made and recorded these observations using the SAE procedure referred to in Example 1, supra.

We also mounted this electrochromic mirror in the cabin of a motor vehicle and found the mirror to operate in a commercially acceptable manner.

Example 8

We used an electrochromic mirror cell having the same shape as described in Example 1, supra, constructed from clear ITO-coated glass as the first substrate (having a sheet resistance of about 80 ohms per square). As the second substrate of the mirror cell, we used ordinary soda-lime glass. The first substrate was dimensioned about 2 to about 3 mm larger in both length and width than the second substrate. A layer of chromium, as an adhesion promoter, was coated directly onto the inward surface of the second glass substrate at a thickness of about 1,000 Å. A thin film of silver, as a reflective element, was thereafter coated onto the layer of chromium at a thickness of about 1,000 Å and tungsten oxide, as an electrochromic solid film, was then coated over the layer of silver at a thickness of about 5,000 Å. These thin films were coated in a vacuum deposition process by electron beam evaporation and were deposited in a unitary deposition process without breaking vacuum during deposition of the chromium/silver/tungsten oxide stack.

The first substrate and the second substrate were positioned in spaced-apart relationship to form a 88 μm interpane spacing between the ITO-coated surface of the first substrate and the multi-layered surface of the second substrate. The size and shape differential between the first substrate and the second substrate allowed the ITO-coated surface of the first substrate to extend beyond the multi-layered surface of the second substrate. Bus bars were attached substantially all around the peripheral edge of the ITO-coated first substrate onto which were connected the electrical leads. On the multi-layered second substrate, we attached electrical leads at a smaller portion thereof, such as at a mere point contact.

We formulated an electrolyte containing ferrocene (about 0.015M), phenothiazine (about 0.06M), lithium perchlorate (about 0.05M) and "UVINUL" 400 [about 5% (w/v)] in a solvent combination of tetramethylene sulfone and propylene carbonate [in a ratio of about 50:50 (v/v)]. We dispensed this electrolyte into the mirror cell using the vacuum backfilling method [as described in Varaprasad IV].

Upon introduction of an applied potential of about 1.4 volts, we observed the mirror to dim uniformly and rapidly to a neutral gray colored state. Specifically, we observed the mirror to have a high reflectance in the unpowered, bleached state of about 75.8% and a low reflectance in the dimmed state of about 9.5%. We made and recorded these observations using the SAE procedure referred to in Example 1, supra.

Example 9

In this example, we used the electrolyte formulation and an electrochromic mirror having the same shape as described in Example 8, supra. However, the mirror of this example was constructed from ITO-coated glass as the first substrate having a sheet resistance of about 55 ohms per squares. In addition, the first substrate and the second substrate were positioned in spaced-apart relationship to form a 63 μm interpane spacing between the ITO-coated surface of the first substrate and multi-layered surface of the second substrate.

After dispensing the electrolyte into the mirror cell using the vacuum backfilling method [as described in Varaprasad IV], we observed the mirror to have a high reflectance of about 75.7% and a low reflectance of about 8.6% when a potential of about 1.4 volts was applied thereto. We made and recorded these observations using the SAE procedure referred to in Example 1, supra.

Example 10

In this example, we fabricated an electrochromic glazing device of a construction suitable for use as a window or a sun roof on a motor vehicle containing a solid electrolyte. The glazing device was dimensioned to about 15 cm×about 15 cm, with an interpane spacing between the tungsten oxide coating on the inward surface of the first substrate and the HW-ITO coating on the inward surface of the second substrate of about 74 μm.

The glazing device was constructed using spacers to assist in defining the interpane spacing. The spacers were sprinkled over the tungsten oxide coated surface of the first substrate and an epoxy was applied inward from the peripheral edge of the HW-ITO coated second substrate using a silk-screening technique. While the epoxy was still uncured, the first substrate and the second substrate were off-set from one another by a lateral displacement and a perpendicular displacement. The weather barrier of the electrochromic glazing device was then formed by thermal curing using a vacuum bagging technique (as is known in the laminating art) at a reduced atmospheric pressure of about 10" of mercury and a temperature of about 140° C. for a period of time of about 1 hour in order to maintain a substantially even pressure when curing the epoxy into a weather barrier.

We prepared a formulation of starting components containing ferrocene [about 0.3% (w/w)], phenothiazine [about 0.8% (w/w)], lithium perchlorate [about 0.4% (w/w)], "SARBOX" acrylate resin (500E50) [about 27.9% (w/w)], propylene carbonate (as a plasticizer) [about 67.3% (w/w)] and "IRGACURE" 184 (as a photoinitiator) [about 3.3% (w/w)]. We dispensed this formulation into the electrochromic glazing device using the vacuum backfilling method [as described in Varaprasad IV].

We then in situ polymerized the formulation by exposing it to ultraviolet radiation to form a solid-phase electrolyte.

We then affixed bus bars along the peripheral edges of the electrochromic glazing device, and connected electrical leads to the bus bars.

We introduced an applied potential of about 1.5 volts to the electrochromic glazing for a period of time of about 2 minutes, with the positive polarity applied at the second substrate (the surface of which having tungsten oxide overcoated onto its HW-ITO-coated surface) and observed it to have a high transmittance of about 73.0%. Thereafter, we reversed the polarity, and observed the transmission to dim to a low transmittance of about 17.8% when a potential of about 1.5 volts was applied thereto.

We made and recorded these observations using the SAE procedure referred to in Example 1, supra, except that the reflectometer was set in transmittance mode.

Example 11

In this example, we constructed an electrochromic mirror device having the same shape described in Example 1, supra, with an interpane spacing of about 74 μm and using a solid-phase electrolyte.

We prepared a formulation of starting components containing ferrocene [about 0.2% (w/w)], phenothiazine [about 0.5% (w/w)], lithium perchlorate [about 0.3% (w/w)], polyethylene glycol dimethacrylate (600) (PEGDMA-600) [about 17.9% (w/w)], propylene carbonate (as a plasticizer) [about 76.5% (w/w)], "IRGACURE" 184 (as a photoinitiator) [about 2.1% (w/w)] and "UVINUL" 400 [about 2.5% (w/w)].

The mirror was constructed using spacers to assist in defining the interpane spacing. The spacers were sprinkled over the HW-ITO coated inward surface of the first substrate (whose opposite, non-inward surface had been coated with a layer of silver using conventional wet chemical silver line deposition) and the formulation, which would be transformed into a solid-phase electrolyte, was dispensed thereover. The second substrate, whose inward surface was coated with tungsten oxide at a thickness of about 5,000 Å, was positioned over the spacer-sprinkled HW-ITO coated surface of the first substrate to allow the formulation to spread evenly across and between the coated surfaces of the first substrate and the second substrate.

We temporarily held the first substrate and the second substrate together using clamps and in situ polymerized the formulation located therebetween through exposure to ultraviolet radiation to form a solid-phase electrolyte. Specifically, we placed the mirror onto the conveyor belt of a Fusion UV Curing System F-450 B, with the belt advancing at a rate of about fifteen feet per minute and being subjected to ultraviolet radiation generated by the D fusion lamp of the F-450 B. We passed the mirror under the fusion lamp fifteen times pausing for two minute intervals between every fifth pass.

We then affixed bus bars along the peripheral edges of the device, and attached electrical leads to the bus bars.

We introduced an applied potential of about 1.5 volts to the electrochromic mirror for a period of time of about 2 minutes, with the positive polarity applied at the second substrate (the surface of which having tungsten oxide overcoated onto its HW-ITO-coated surface) and observed it to have a high reflectance of about 73.2%. Thereafter, we reversed the polarity, and observed the reflection to dim to a low reflectance of about 7.1% when a potential of about 1.5 volts was applied thereto.

We made and recorded these observations using the SAE procedure referred to in Example 1, supra.

Example 12

In this example, we constructed an electrochromic mirror cell having the same shape described in Example 4, supra.

We formulated an electrolyte containing ferrocene (about 0.025M), phenothiazine (about 0.06M), lithium perchlorate (about 0.05M) and "UVINUL" 400 [about 5% (w/v)] in a solvent combination of 1,2-butylene carbonate and propylene carbonate [in a ratio of about 50:50 (v/v)]. We dispensed this electrolyte into the mirror cell using the vacuum backfilling method [as described in Varaprasad IV].

Upon introduction of an applied potential of about 1.4 volts to the mirror, we observed the high reflectance change from about 72.0% to a low reflectance of about 6.8%.

We also cycled the mirror for about 50,000 cycles at a temperature of about 50° C., and observed it to cycle well.

Example 13

In this example, we again constructed an electrochromic mirror cell having the same shape described in Example 1, supra.

For this mirror cell, we formulated an electrolyte containing ferrocene (about 0.025M), phenothiazine (about 0.06M), lithium perchlorate (about 0.05M) lithium tetrafluoroborate (about 0.05M) and "UVINUL" 400 [about 5% (w/v)] in propylene carbonate, and dispensed it into the mirror cell using the vacuum backfilling method [as described in Varaprasad IV].

Upon introduction of an applied potential of about 1.4 volts to the mirror, we observed the high reflectance to change from about 72.0% to a low reflectance of about 6.7%.

The mirror demonstrated excellent cycle stability and stability to ultraviolet light.

Example 14

In this example, we constructed an electrochromic mirror cell having the same shape described in Example 1, supra, with an on demand display. For illustrative purposes, see FIG. 9.

To provide the on demand display to this mirror cell, a display window (with dimensions of about 7/16"×3/4") was laser-etched through an overcoating of silver/copper/paint on the rearmost (opposite, non-inward) surface of the second substrate of the mirror cell.

Over and within the display window, we applied an optical adhesive ["IMPRUV" LV potting compound (commercially available from Loctite Corporation, Newington, Conn.)] so that a glass cover sheet, having a thickness of about 0.075", may be disposed over and affixed thereto.

The glass cover sheets suitable for use in this context were prepared by previously exposing a larger glass sheet to a vacuum evaporation process in which a thin film layer of silver was coated onto one of its surfaces. The thin film layer of silver was substantially reflecting (having a reflectance of about 93%) and partially transmitting (having a transmittance of about 5%). The silver-coated glass cover sheet was then cut to size—e.g., about 1"×¾"—, and the silvered-surface disposed over, and affixed to using the optical adhesive, the display window. Over the opposite, non-silvered surface of the glass cover sheet, we placed a layer of epoxy [UV15-74RI (commercially available from Master Bond Incorporated, Hackensack, N.J.)] and affixed thereto a vacuum fluorescent display [Part No. FIP2QM8S (NEC Electronics Incorporated, Mountain View, Calif.)].

Into this mirror cell, we dispensed the electrolyte of Example 1, supra.

Example 15

In this example, we constructed an electrochromic mirror cell having the same shape described in Example 1, supra, with an on demand display. For illustrative purposes, see FIG. 10.

In this mirror cell, like the mirror cell of Example 14, supra, a display window (with dimensions of about 7/16"×¾") was laser-etched through the silver/copper/paint overcoating of the rearmost (opposite, non-inward) surface of the second substrate of the mirror cell.

A thin film layer of silver was then coated over the display window so formed by electron beam evaporation in a vacuum chamber as described supra. The thin film layer of silver was substantially reflecting (having a reflectance of about 90%) and partially transmitting (having a transmittance of about 8%).

Over and within the silvered-display window, we applied a layer of epoxy [UV15-74RI (Master Bond)] and affixed thereto a vacuum fluorescent display [Part No. FIP2QM8S (NEC Electronics)].

Into this mirror cell, we dispensed the electrolyte of Example 1, supra.

Example 16

In this example, we constructed an electrochromic mirror cell using as the first substrate and second substrate clear HW-ITO-coated glass. Over the inward surface of the second substrate, we coated a layer of chromium at a thickness of about 100 Å as an adhesion promoter. We then coated a thin film of silver at a thickness of about 450 Å onto the layer of chromium as a reflective element, and a layer of tungsten oxide at a thickness of about 5,800 Å over the layer of silver as an electrochromic solid film. The first substrate and the second substrate were positioned in spaced-apart relationship to form an 88 μm interpane spacing between the coated inward surfaces of the substrates.

We placed an opaque tape on the rearmost surface of the second substrate with apertures provided therein at appropriate locations to accommodate vacuum fluorescent displays and other information indicia.

A vacuum fluorescent display was affixed to this mirror cell as described in Example 14, supra, but dispensing with the reflector coated cover sheet. The display provided compass directional information and, dependent on the vehicle direction when driving, displayed N, NE, E, SE, S, SW, W or NW when any one of which coordinates was activated by compass circuitry included in the mirror housing and assembly into which the electrochromic mirror element was mounted for driving in a vehicle, and such as described in commonly assigned U.S. Pat. No. 5,255,442 (Schierbeek). Turn signal indicia [JKL NEO-Wedge Lamps T2-1/4 (commercially available from JKL Components Corporation, Paloina, Calif.)] were also located behind the rearmost surface of the second substrate, with appropriately shaped apertures cut into the opaque tape at the location of the turn signal indicia. The turn signal indicia was activated through a triggering mechanism from the particular turn signal. For an illustration of the use of turn signal indicia 21 in an electrochromic mirror, see FIG. 12.

Into this mirror cell, we dispensed the electrolyte of Example 1, supra.

Upon introduction of an applied potential of about 1.4 volts to the mirror, we observed the high reflectance to change from about 74.1% to a low reflectance of about 7.0%. We also observed the transmittance to be about 4.5% in the clear state.

This mirror was installed in a vehicle and tested under a variety of actual day and night driving conditions, and was found to operate for its intended purpose.

Example 17

In this example, we constructed an electrochromic mirror suitable for use as an interior rearview mirror for a motor vehicle.

The mirror was constructed from clear ITO-coated glass as the first substrate (having a sheet resistance of about 80 ohms per square). As the second substrate of the mirror cell we used ordinary soda-lime glass. Both substrates were sized and shaped to identical dimensions. A notch was cut in the middle of the top edge of the first substrate and another notch was cut in the middle of the bottom edge of the second substrate. A thin metal film busbar was formed along the edges of the first substrate by first affixing a mask over the central region leaving most of the perimeter region unmasked, and then depositing by a vacuum evaporation process a thin film of chromium having a thickness of about 2000 Å followed by a thin film of silver having a thickness of about 5000 Å.

A layer of chromium at a thickness of about 1000 Å was coated directly onto the inward surface of the second glass substrate as an adhesion promoter. A thin film of silver at a thickness of about 1000 Å was then deposited onto the layer of chromium as a reflective element and tungsten oxide at a thickness of about 5000 Å was then coated over the layer of silver as an electochromic solid film.

The first substrate and the second substrate were then positioned in a spaced-apart relationship so that the edges of the substrates were flush and a seal was applied to form a cavity between the substrates. In this flush design, the interpane spacing between the coated inward surfaces of the substrates was 88 μm.

For this flush design interior mirror, we formulated an electrolyte as in Example 1, supra. We dispensed this electrolyte into the mirror cell using the vacuum backfilling method [as described in Varaprasad I].

Electrical leads were then attached to the mirror. The notch in the second substrate permitted an electrical lead to be attached at a point contact on the thin metal film busbar on the bottom edge of the first substrate. Similarly, the notch in the first substrate caused a portion of the top edge of the inward surface of the second substrate to be exposed, permitting an electrical lead to be attached at a point contact on the chromium/silver/tungsten oxide coating.

Upon introduction of an applied potential of about 1.5 volts to the mirror, we observed a reflectance change from a high reflectance of about 85.3% to a low reflectance of about 7.5%.

These examples are provided for illustrative purposes only, and it will be clear to those of ordinary skill in the art that changes and modifications may be practiced within the spirit of the claims which define the scope of the present invention. Thus, the art-skilled will recognize or readily ascertain using no more than routine experimentation, that equivalents exist to the embodiments of the invention described herein. And, it is intended that such equivalents be encompassed by the claims which follow hereinafter.

What we claim is:

1. An electrochromic rearview mirror for a motor vehicle comprising:

(a) a substantially transparent substrate with a substantially transparent conductive electrode coating on its inward surface;

(b) a substrate with a conductive electrode coating on its inward surface, said substrate positioned in spaced-apart relationship with said substrate of (a);

(c) a layer of reflective material coated onto a surface of said substrate of (b);

(d) an electrochromic solid film coated onto said substantially transparent conductive electrode coating of (a) or onto said conductive electrode coating of (b);

(e) a sealing means positioned toward a peripheral edge of each of said substrate of (a) and said substrate of (b) and sealingly forming a cavity therebetween;

(f) an electrolyte comprising redox reaction promoters, wherein said redox reaction promoters comprise a metallocene in combination with a phenothiazine, and wherein said electrolyte is located within said cavity to form an electrochromic element; and

(g) a means for introducing an applied potential to said electrochromic element to controllably cause a variation in the amount of light reflected from said mirror.

2. The electrochromic mirror according to claim 1, wherein said layer of reflective material is silver.

3. The electrochromic mirror according to claim 1, wherein said electrochromic solid film is an inorganic transition metal oxide.

4. The electrochromic mirror according to claim 3, wherein said electrochromic solid film is tungsten oxide.

5. The electrochromic mirror according to claim 1, wherein said redox reaction promoters comprise ferrocene.

6. The electrochromic mirror according to claim 1, wherein said redox reaction promoters comprise phenothiazine.

7. The electrochromic mirror according to claim 1, wherein said electrolyte further comprises an ultraviolet stabilizing agent.

8. An electrochromic rearview mirror for a motor vehicle comprising:

(a) a substantially transparent substrate coated with a substantially transparent conductive electrode coating on its inward surface;

(b) a substrate positioned in spaced-apart relationship with said substrate of (a);

(c) a layer of reflective material coated onto the inward surface of said substrate of (b) or onto a thin film or stack of thin films coated onto the inward surface of said substrate of (b);

(d) an electrochromic solid film coated onto said layer of reflective material of (c);

(e) a sealing means positioned toward the peripheral edge of each of said substrate of (a) and said substrate of (b) and sealingly forming a cavity therebetween;

(f) an electrolyte comprising a redox reaction promoter, wherein said electrolyte is located within said cavity to form an electrochromic element; and

(g) a means for introducing an applied potential to said electrochromic element to controllably cause a variation in the amount of light reflected from said mirror.

9. The electrochromic mirror according to claim 8, further comprising an adhesion promoter coated between said layer of reflective material of (c) and

(i) the inward surface of said substrate of (b) or

(ii) the thin film or stack of thin films coated on the inward surface of said substrate of (b).

10. The electrochromic mirror according to claim 9, wherein said adhesion promoter is selected from the group consisting of a metal, a metal oxide and a conducting metal oxide.

11. The electrochromic mirror according to claim 10, wherein said metal is selected from the group consisting of chromium, stainless steel, nickel-based alloys, titanium, monel, nichrome and molybdenum.

12. The electrochromic mirror according to claim 10, wherein said metal oxide is selected from the group consisting of silver oxide, aluminum oxide and chromium oxide.

13. The electrochromic mirror according to claim 10, wherein said conducting metal oxide is selected from the group consisting of indium oxide, indium tin oxide, tin oxide, doped tin oxide, and doped zinc oxide.

14. The electrochromic mirror according to claim 8, wherein said layer of reflective material is silver.

15. The electrochromic mirror according to claim 8, wherein said electrochromic solid film is an inorganic transition metal oxide.

16. The electrochromic mirror according to claim 15, wherein said electrochromic solid film is tungsten oxide.

17. The electrochromic mirror according to claim 8, wherein said redox reaction promoter comprises a metallocene.

18. The electrochromic mirror according to claim 8, wherein said redox reaction promoter comprises a phenothiazine.

19. The electrochromic mirror according to claim 8, wherein said electrolyte further comprises an ultraviolet stabilizing agent.

20. An electrochromic rearview mirror for a motor vehicle comprising:

(a) a substantially transparent substrate with a substantially transparent conductive electrode coating on its inward surface;

(b) a substrate with a conductive electrode coating on its inward surface, said substrate positioned in spaced-apart relationship with said substrate of (a);

(c) a layer of reflective material coated onto a surface of said substrate of (b);

(d) an electrochromic solid film coated onto said substantially transparent conductive electrode coating of (a) or onto said conductive electrode coating of (b);

(e) a sealing means positioned toward, but inward from, a peripheral edge of each of said substrate of (a) and said substrate of (b) and sealingly forming a cavity therebetween;

(f) an electrolyte comprising:

(1) redox reaction promoters, wherein said redox reaction promoters comprise a metallocene in combination with a phenothiazine,

(2) an ultraviolet stabilizing agent and

(3) an organic solvent,

wherein said electrolyte is located within said cavity to form an electrochromic element; and

(g) a means for introducing an applied potential to said electrochromic element to controllably cause a variation in the amount of light reflected from said mirror.

21. An electrochromic rearview mirror for a motor vehicle comprising:

(a) a substantially transparent substrate with a substantially transparent conductive electrode coating on its inward surface;

(b) a substrate positioned in spaced-apart relationship with said substrate of (a);

(c) an adhesion promoter coated onto the inward surface of said substrate of (b);

(d) a layer of reflective material coated over said adhesion promoter of (c);

(e) an electrochromic solid film coated onto said layer of reflective material of (d);

(f) a sealing means positioned toward, but inward from, a peripheral edge of each of said substrate of (a) and said substrate of (b) and sealingly forming a cavity therebetween;

(g) an electrolyte comprising:

(1) a redox reaction promoter,

(2) an ultraviolet stabilizing agent and

(3) an organic solvent,

wherein said electrolyte has been dispensed into and is confined within said cavity to form an electrochromic element; and

(h) a means for introducing an applied potential to said electrochromic element to controllably cause a variation in the amount of light reflected from said mirror.

22. An electrochromic rearview mirror for a motor vehicle comprising:

(a) a substantially transparent substrate with a substantially transparent conductive electrode coating on its inward surface;

(b) a substrate positioned in spaced-apart relationship with said substrate of (a);

(c) a layer of reflective material coated onto the inward surface of said substrate of (b) or onto a thin film or stack of thin films coated onto the inward surface of said substrate of (b);

(d) an electrochromic solid film coated onto said layer of reflective material of (c);

(e) a sealing means positioned toward a peripheral edge of each of said substrate of (a) and said substrate of (b) and sealingly forming a cavity therebetween;

(f) an electrolyte comprising:

(1) a redox reaction promoter,

(2) an ultraviolet stabilizing agent, and

(3) an organic solvent,

wherein said electrolyte is located within said cavity to form an electrochromic element; and

(g) a means for introducing an applied potential to said electrochromic element to controllably cause a variation in the amount of light reflected from said mirror.

23. An electrochromic rearview mirror for a motor vehicle comprising:

(a) a substantially transparent substrate with a substantially transparent conductive electrode coating on its inward surface;

(b) a substrate positioned in spaced-apart relationship with said substrate of (a);

(c) an adhesion promoter coated onto the inward surface of said substrate of (b);

(d) a layer of reflective material coated over said adhesion promoter of (c);

(e) a sealing means positioned toward, but inward from, a peripheral edge of each of said substrate of (a) and said substrate of (b) and sealingly forming a cavity therebetween;

(f) an electrochromic medium positioned between said substrate of (a) and said substrate of (b); and

(g) a means for introducing an applied potential to said electrochromic medium to controllably cause a variation in the amount of light reflected from said mirror.

24. The electrochromic mirror according to claim 23, wherein said adhesion promoter is selected from the group consisting of a metal, a metal oxide and a conducting metal oxide.

25. The electrochromic mirror according to claim 24, wherein said metal is selected from the group consisting of chromium, stainless steel, nickel-based alloys, titanium, monel, nichrome and molybdenum.

26. The electrochromic mirror according to claim 24, wherein said metal oxide is selected from the group consisting of silver oxide, aluminum oxide and chromium oxide.

27. The electrochromic mirror according to claim 24, wherein said conducting metal oxide is selected from the group consisting of indium oxide, indium tin oxide, tin oxide, doped tin oxide, and doped zinc oxide.

28. The electrochromic mirror according to claim 23, wherein said layer of reflective material is silver.

29. The electrochromic mirror according to claim 23, wherein said electrochromic medium comprises an electrochromic solid film.

30. The electrochromic mirror according to claim 29, wherein said electrochromic solid film is an inorganic transition metal oxide.

31. The electrochromic mirror according to claim 30, wherein said electrochromic solid film is tungsten oxide.

32. The electrochromic mirror according to claim 23, further comprising an electrolyte comprising redox reaction promoters, and wherein said electrolyte has been dispensed into and is confined within said cavity.

33. The electrochromic mirror according to claim 32, wherein said redox reaction promoters comprise a metallocene in combination with a phenothiazine.

34. The electrochromic mirror according to claim 33, wherein said redox reaction promoters comprise ferrocene.

35. The electrochromic mirror according to claim 33, wherein said redox reaction promoters comprise phenothiazine.

36. The electrochromic mirror according to claim 32, wherein said electrolyte further comprises an ultraviolet stabilizing agent.

37. The electrochromic mirror according to claim 23, wherein said electrochromic medium comprises an electrochromic solution.

38. The electrochromic mirror according to claim 37, wherein said electrochromic solution further comprises an ultraviolet stabilizing agent.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 5,668,663 Page 1 of 2

DATED : September 16, 1997

INVENTOR(S) : Desaraju V. Varaprasad, et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

TITLE PAGE

Item: [56] In "T. Alfrey, Jr. et al.," "Fulms", should read --Films",--;

In "I.F. Chang," "Nonemissi" should read --Nonemissive--

and "(1995)." should read --(1976).--;

In "N.R. Lynam," "Electrochramic" should read --Electrochromic--;

and "0870636," should read --870636,--.

Col. 30, line 13, "0.043"" should read --0.043".--

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 5,668,663 Page 2 of 2

DATED : September 16, 1997

INVENTOR(S) : Desaraju V. Varaprasad, et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Col. 39, Table II(a), "630 5.3 5.2 5.2 5.1 6.0 ... etc. should read --630 5.4 5.2 5.2 5.1 5.0 ... ect.--.

Col. 40, line 63, "201%" should read --20%--

Col. 42, line 27, Close up right margin;
line 28, Close up left margin.

Col. 48, line 49, "electochromic" should read --electrochromic--.

Signed and Sealed this

Sixth Day of October, 1998

Attest:

Bruce Lehman

BRUCE LEHMAN

Attesting Officer

Commissioner of Patents and Trademarks

PTO-1683
(Rev. 7-96)

IW 7655477

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APPLICATION NUMBER: ***09/478,315***
FILING DATE: ***January 06, 2000***
PATENT NUMBER: ***6,522,451***
ISSUE DATE: ***February 18, 2003***

By Authority of the
Under Secretary of Commerce for Intellectual Property and Director of the United States Patent and Trademark Office

SYLVIA HOLLEY
Certifying Officer

PART (2) OF (3) PARTS

US005550677A

United States Patent [19]

Schofield et al.

[11] **Patent Number: 5,550,677**

[45] **Date of Patent: Aug. 27, 1996**

[54] **AUTOMATIC REARVIEW MIRROR SYSTEM USING A PHOTOSENSOR ARRAY**

[75] Inventors: **Kenneth Schofield**, Holland; **Mark Larson**, Grand Haven, both of Mich.

[73] Assignee: **Donnelly Corporation**, Holland, Mich.

[21] Appl. No.: **23,918**

[22] Filed: **Feb. 26, 1993**

[51] **Int. Cl.**^{6} **G02B 5/08**; G02B 27/00

[52] **U.S. Cl.** **359/604**; 359/267; 359/601; 359/603

[58] **Field of Search** 359/264–267, 359/601–610, 38, 264–272; 250/204–205, 206.1–206.2, 208.2, 210

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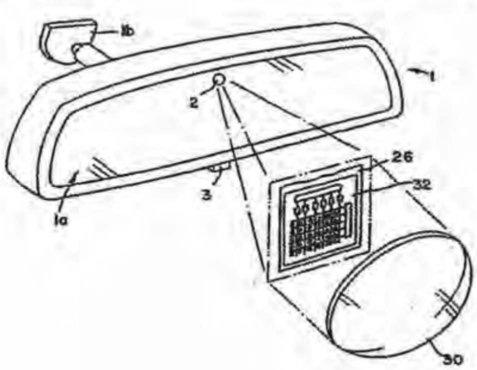
Primary Examiner—Thong Q. Nguyen
Attorney, Agent, or Firm—Fitzpatrick, Cella, Harper & Scinto

[57] **ABSTRACT**

A system apparatus, structure and method for controlling a plurality of variable reflectance mirrors (or mirror segments), including a rearview mirror and side view mirrors, which change their reflectance level in response to a plurality of drive voltages applied thereto, for an automotive vehicle. The system includes a light sensing device and a control circuit formed as a single VLSI CMOS circuit. The light sensing device comprises a photosensor array having a field of view encompassing a rear window area and at least a portion of at least one side window area of the vehicle. The logic and control circuit determines a background light signal from photosensor element signals generated by the photosensor elements in the photosensor array indicative of light levels incident on the photosensor elements. The circuit also determines a peak light signal in three different zones or sub-arrays of the photosensor array. The zones or sub-arrays may correspond to three mirrors or mirror segments. The peak light signals in each of the zones and a common background light signal are used to determine independent and separate control signals, which are then output to separate mirror drive circuits for independently controlling the reflectance level of the rearview mirror and the left and right side view mirrors, or alternatively the segments of a mirror.

87 Claims, 12 Drawing Sheets



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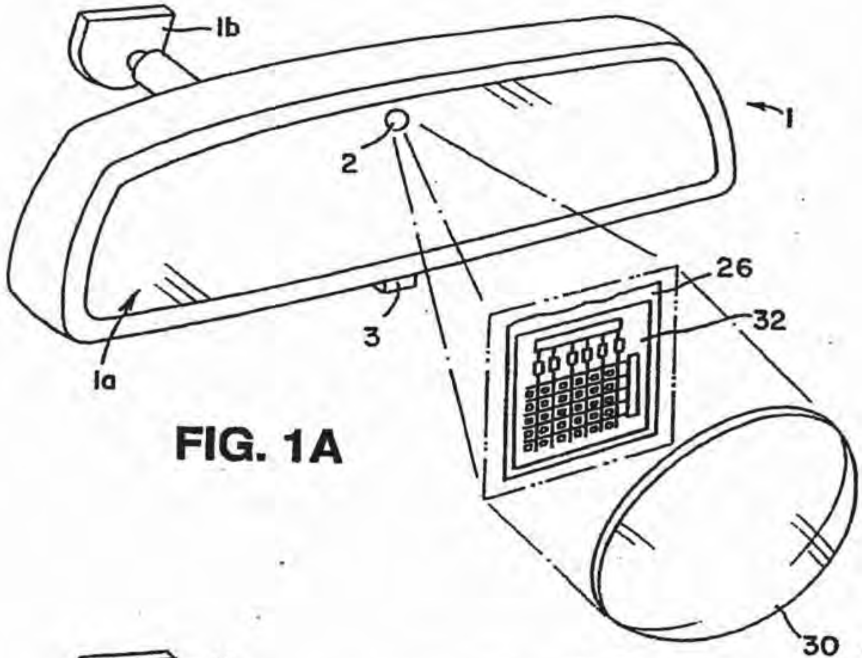


FIG. 1A

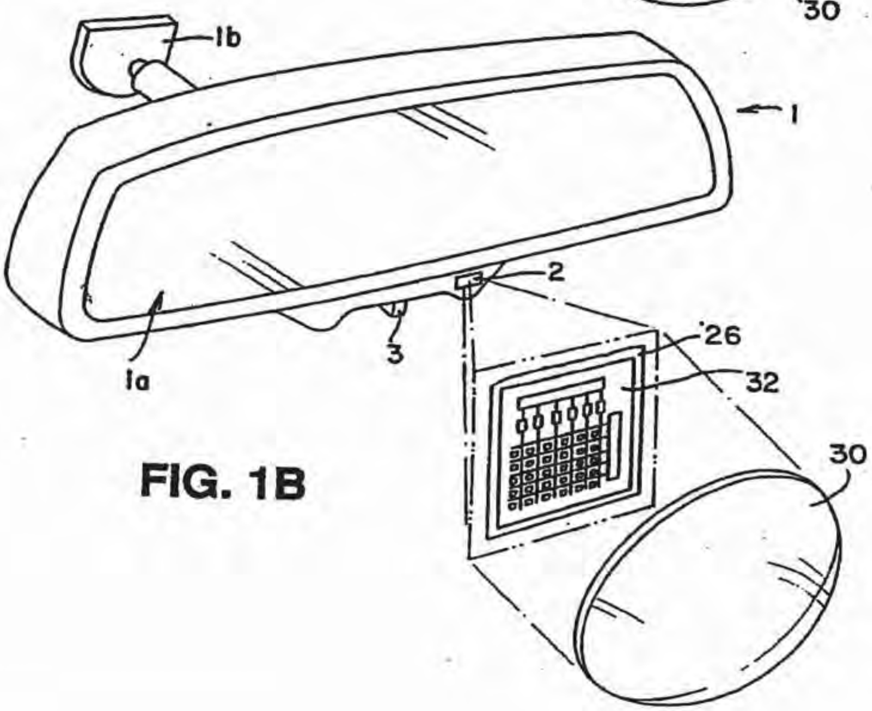
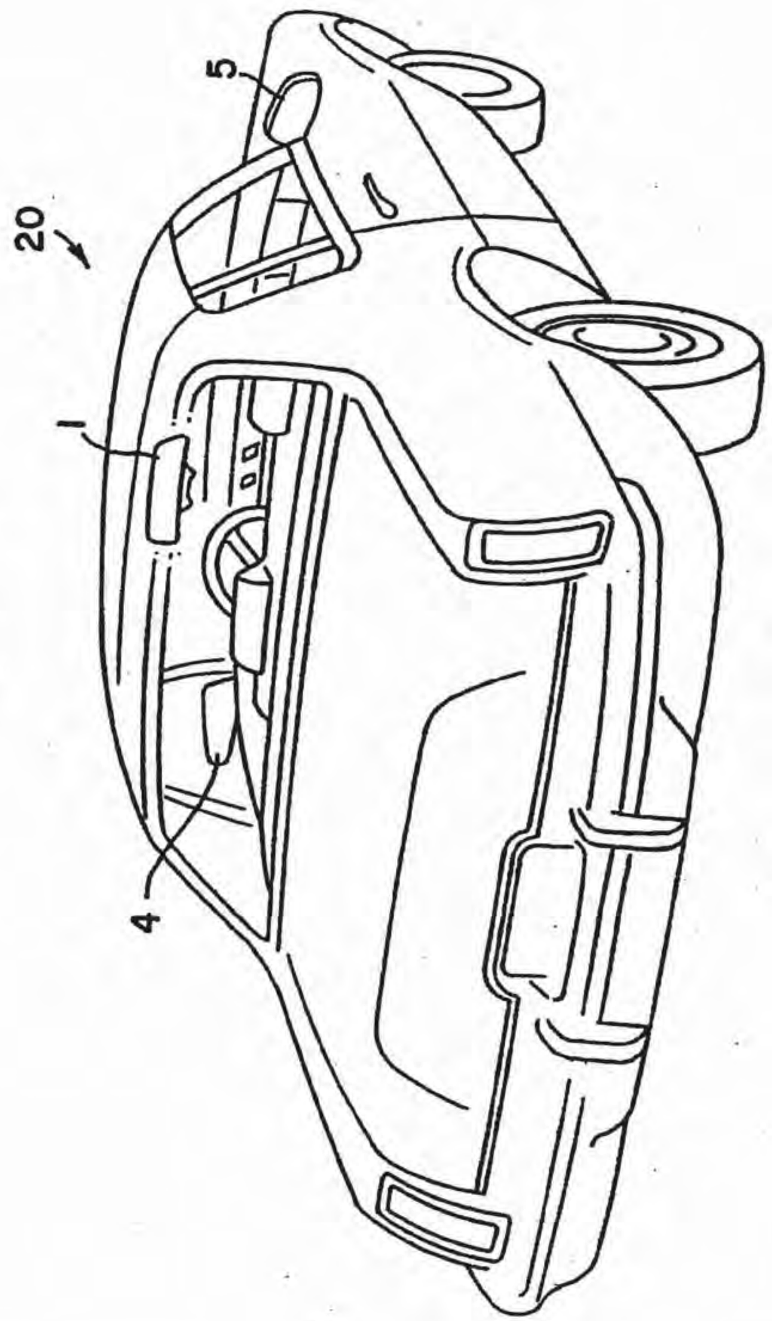


FIG. 1B

FIG. 2



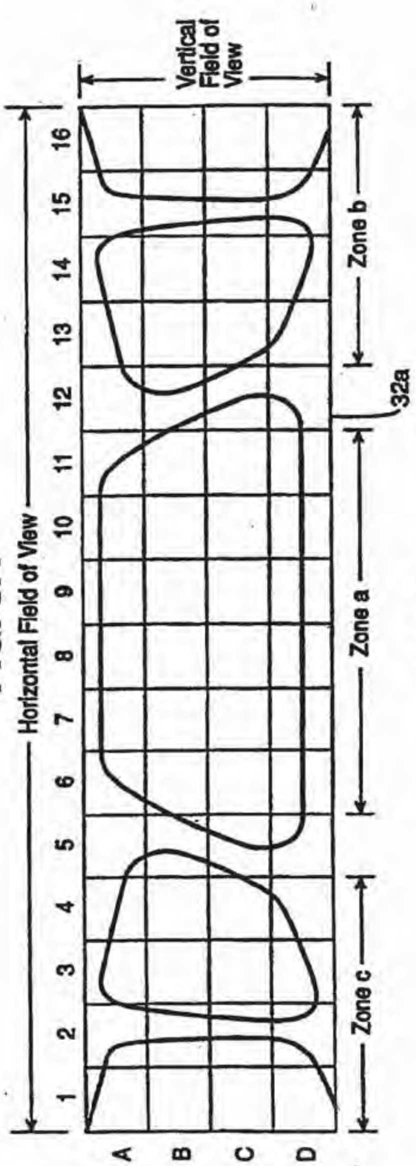

Vertical Field of View
Horizontal Field of View
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
A
B
C
D
Zone a
Zone b
Zone c
32a

FIG. 3A

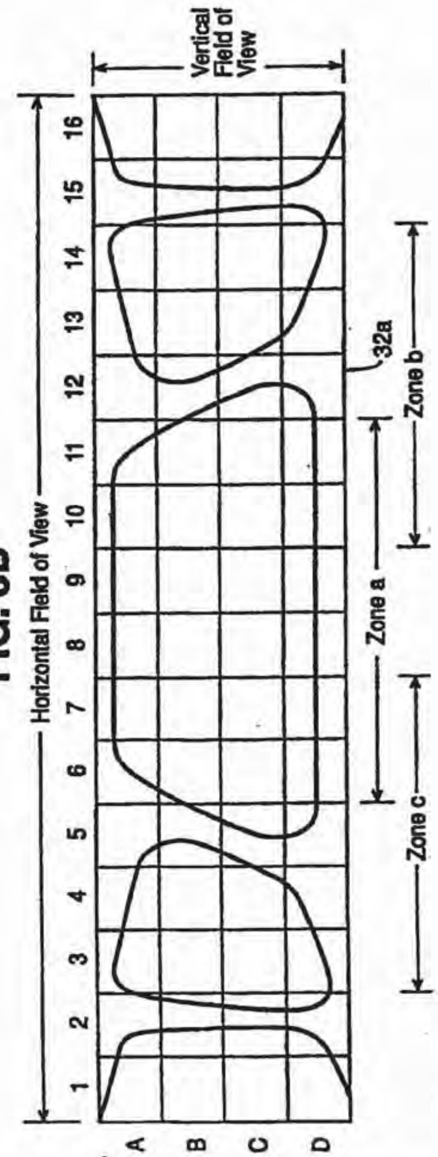

Vertical Field of View
Horizontal Field of View
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
A
B
C
D
Zone a
Zone b
Zone c
32a

FIG. 3B

FIG. 4A

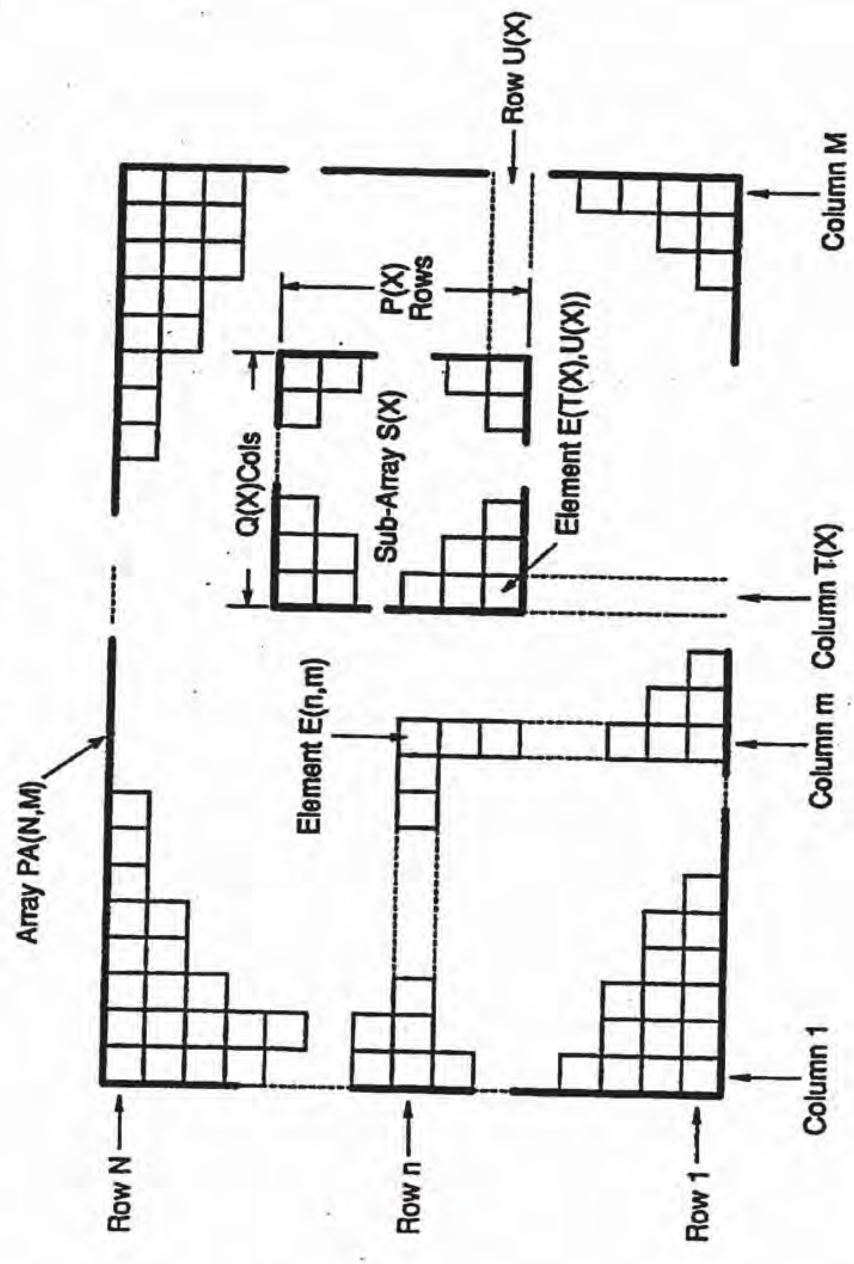

Row U(X)
Column M
P(X) Rows
Q(X)Cols
Sub-Array S(X)
Element E(T(X),U(X))
Column T(X)
Array PA(N,M)
Element E(n,m)
Column m
Column 1
Row N
Row n
Row 1

FIG. 4B

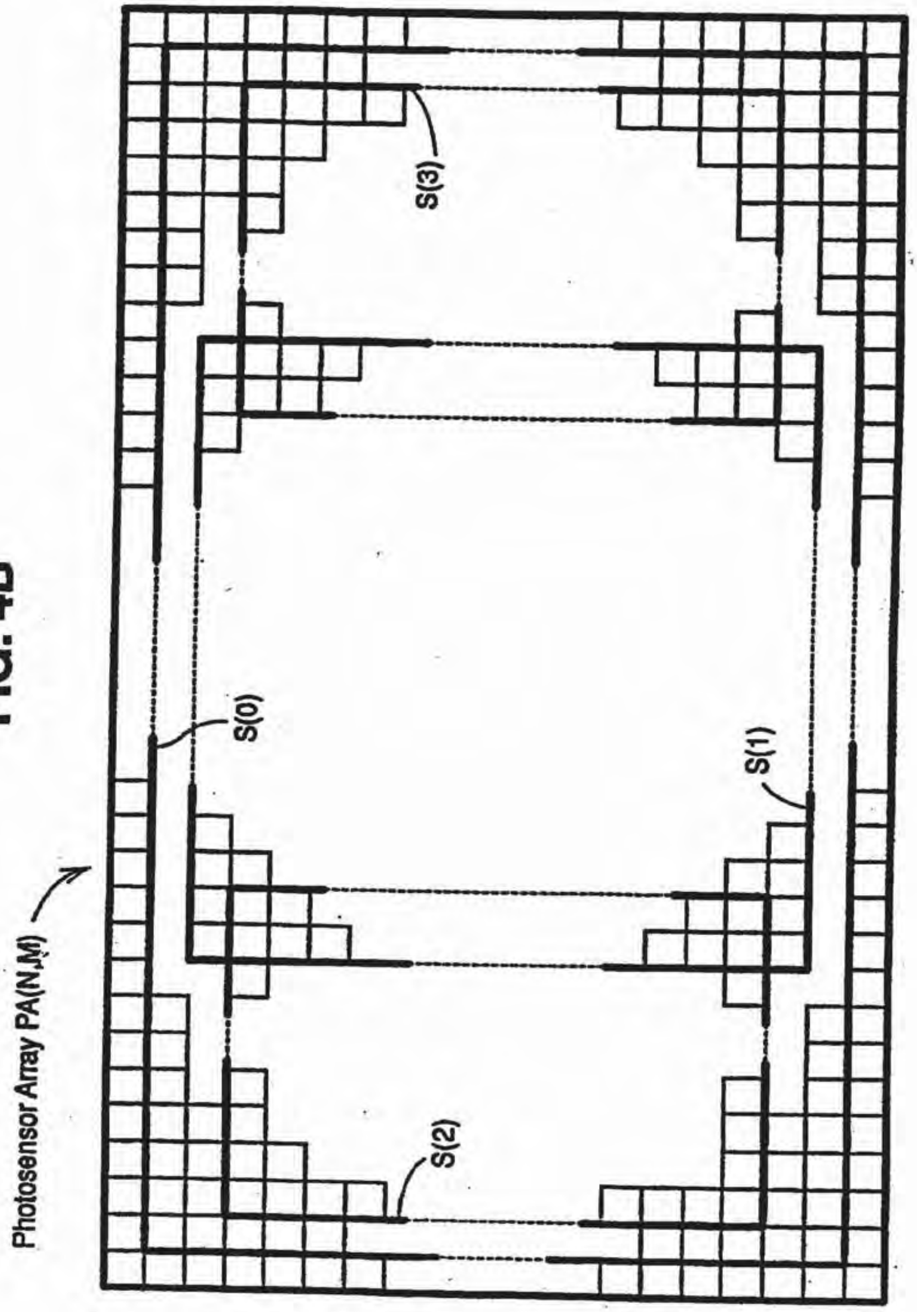


FIG. 5

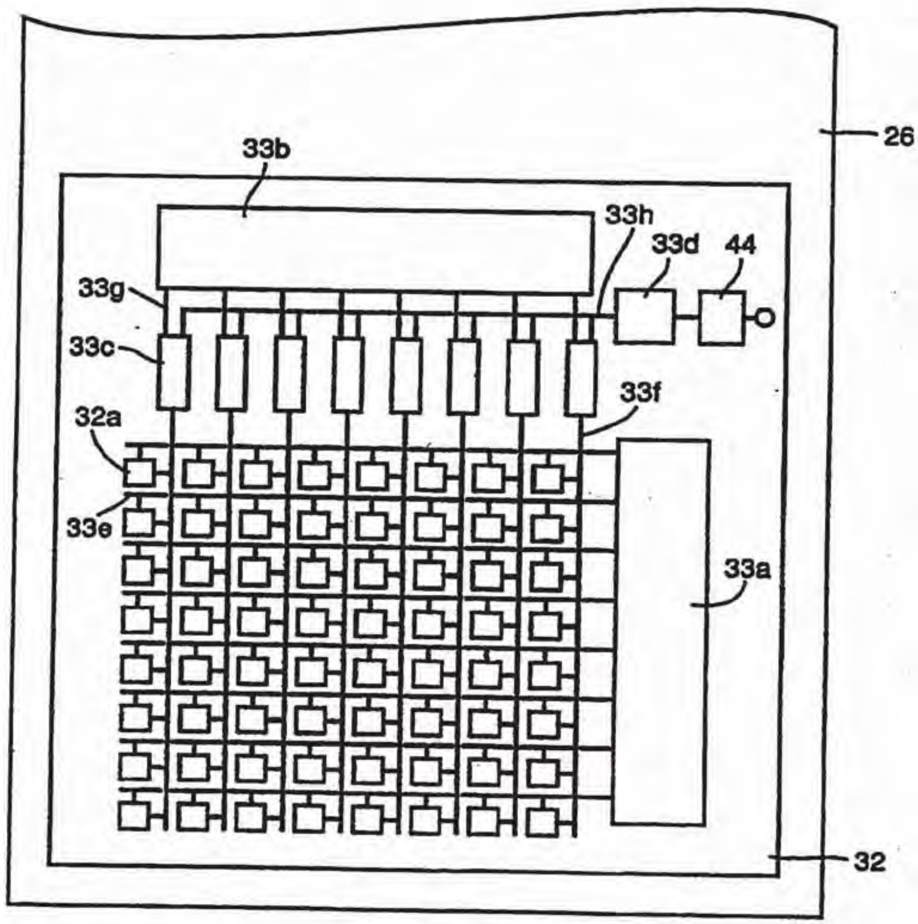


FIG. 6

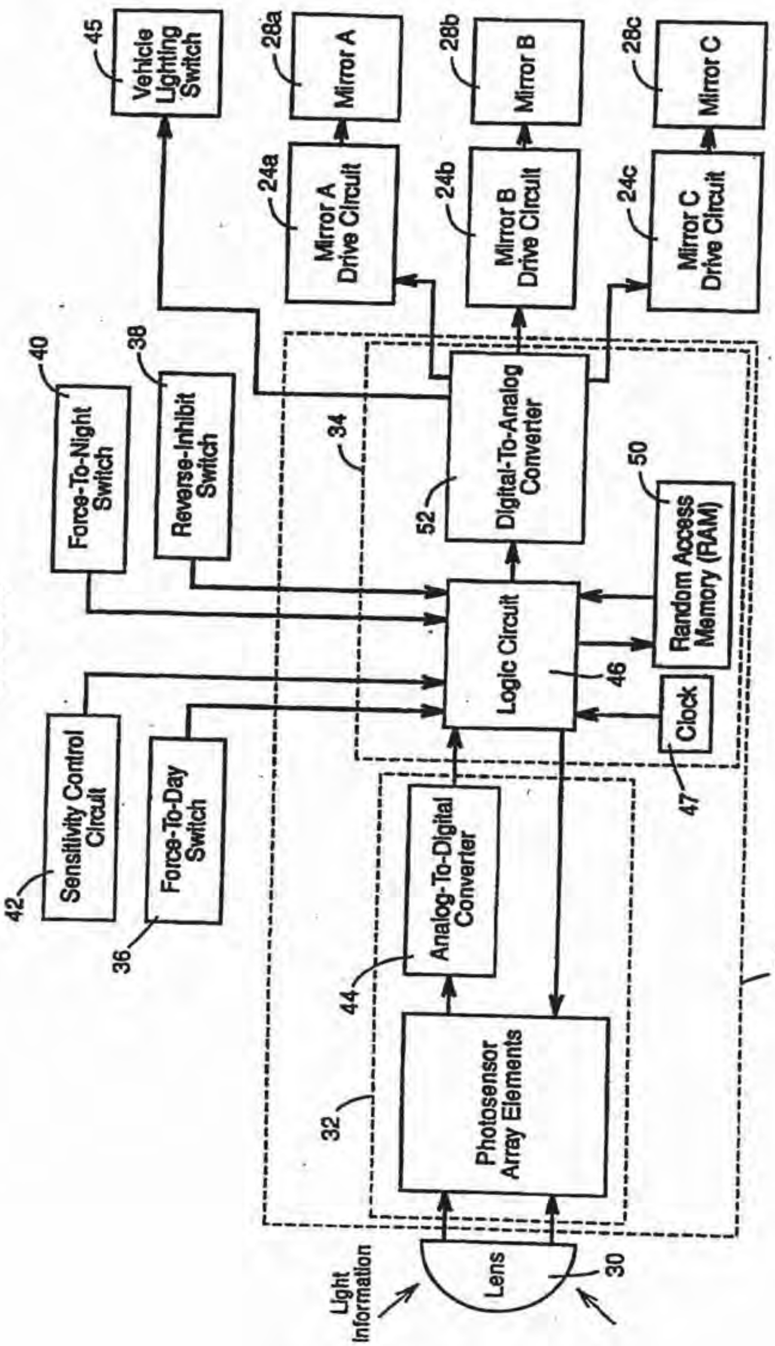

Vehicle Lighting Switch
45
Mirror A
28a
Mirror B
28b
Mirror C
28c
Mirror A Drive Circuit
24a
Mirror B Drive Circuit
24b
Mirror C Drive Circuit
24c
Force-To-Night Switch
40
Reverse-Inhibit Switch
38
Digital-To-Analog Converter
52
34
Random Access Memory (RAM)
50
Logic Circuit
46
Clock
47
Sensitivity Control Circuit
42
Force-To-Day Switch
36
Analog-To-Digital Converter
44
Photosensor Array Elements
32
26
Lens
30
Light Information

FIG. 7

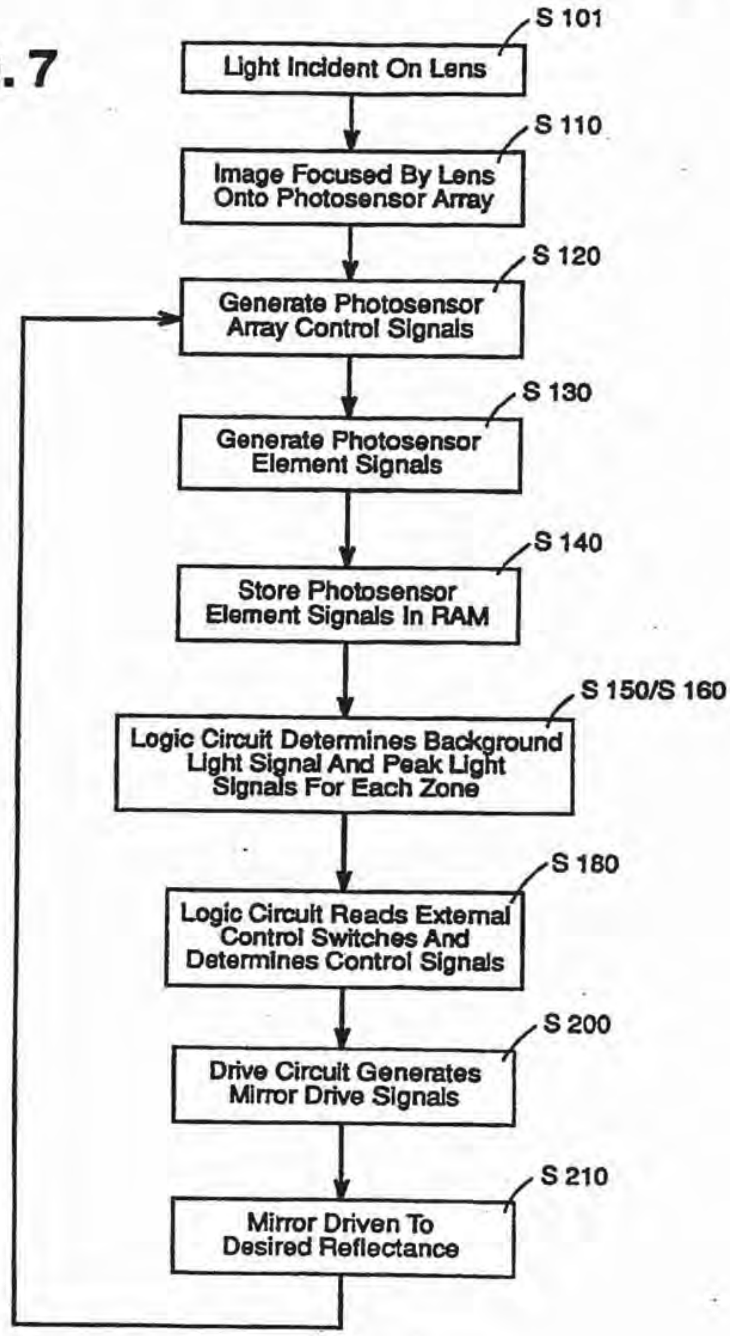

S 101
Light Incident On Lens
S 110
Image Focused By Lens Onto Photosensor Array
S 120
Generate Photosensor Array Control Signals
S 130
Generate Photosensor Element Signals
S 140
Store Photosensor Element Signals In RAM
S 150/S 160
Logic Circuit Determines Background Light Signal And Peak Light Signals For Each Zone
S 180
Logic Circuit Reads External Control Switches And Determines Control Signals
S 200
Drive Circuit Generates Mirror Drive Signals
S 210
Mirror Driven To Desired Reflectance

FIG. 8A

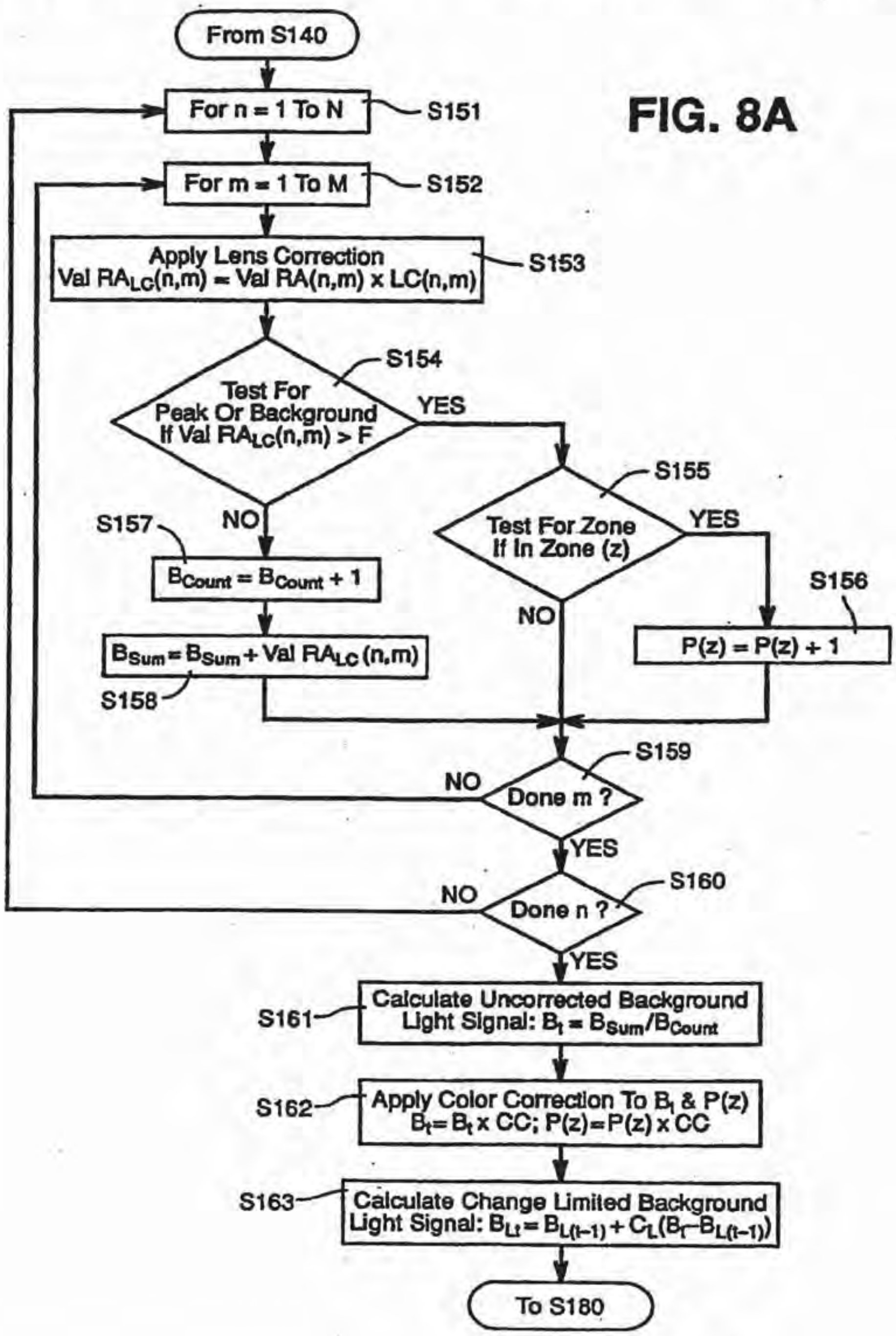

From S140
For n = 1 To N
S151
For m = 1 To M
S152
Apply Lens Correction
Val RA_LC(n,m) = Val RA(n,m) x LC(n,m)
S153
S154
Test For
Peak Or Background
If Val RA_LC(n,m) > F
YES
NO
S155
Test For Zone
If In Zone (z)
YES
NO
S156
P(z) = P(z) + 1
S157
B_Count = B_Count + 1
B_Sum = B_Sum + Val RA_LC (n,m)
S158
S159
NO
Done m ?
YES
S160
NO
Done n ?
YES
S161
Calculate Uncorrected Background
Light Signal: B_t = B_Sum/B_Count
S162
Apply Color Correction To B_t & P(z)
B_t = B_t x CC; P(z) = P(z) x CC
S163
Calculate Change Limited Background
Light Signal: B_Lt = B_L(t-1) + C_L(B_t - B_L(t-1))
To S180

FIG. 8B

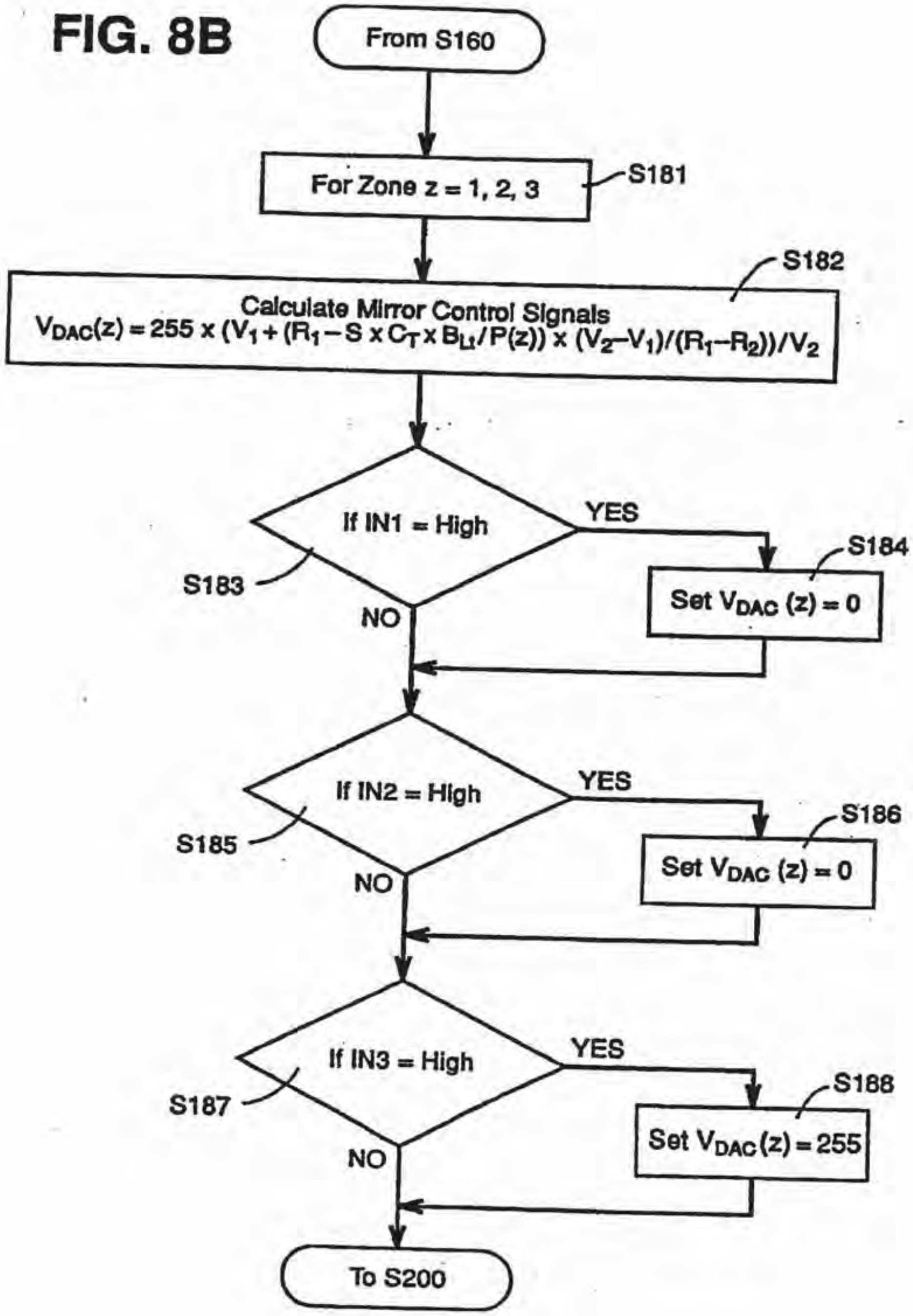
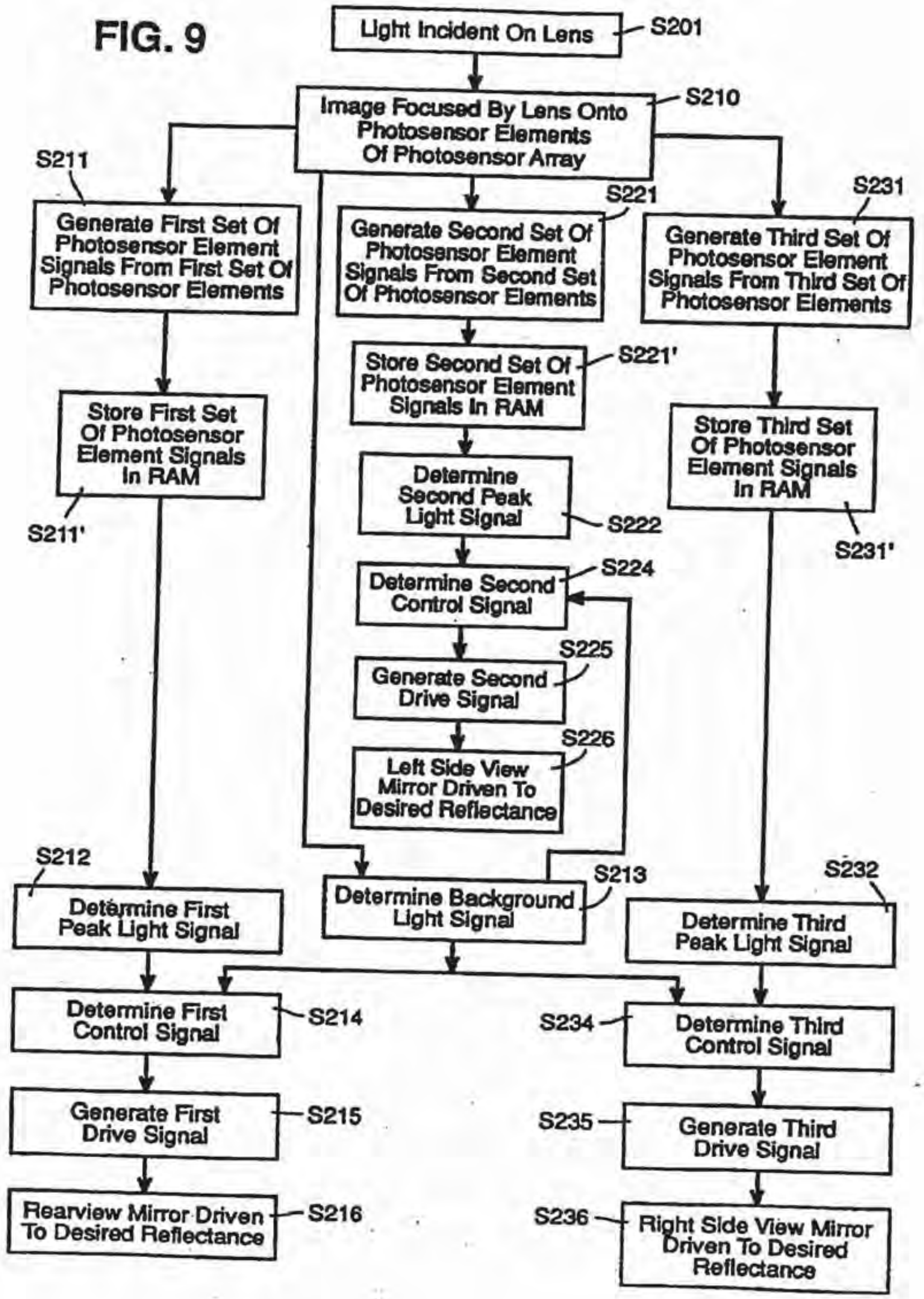

From S160
For Zone z = 1, 2, 3
S181
S182
Calculate Mirror Control Signals
$V_{DAC}(z) = 255 \times (V_1 + (R_1 - S \times C_T \times B_{Lt} / P(z)) \times (V_2 - V_1)/(R_1 - R_2))/V_2$
If IN1 = High
YES
NO
S183
S184
Set V_{DAC} (z) = 0
If IN2 = High
YES
NO
S185
S186
Set V_{DAC} (z) = 0
If IN3 = High
YES
NO
S187
S188
Set V_{DAC}(z) = 255
To S200

FIG. 9


Light Incident On Lens
S201
Image Focused By Lens Onto Photosensor Elements Of Photosensor Array
S210
S211
Generate First Set Of Photosensor Element Signals From First Set Of Photosensor Elements
S221
Generate Second Set Of Photosensor Element Signals From Second Set Of Photosensor Elements
S231
Generate Third Set Of Photosensor Element Signals From Third Set Of Photosensor Elements
Store Second Set Of Photosensor Element Signals In RAM
S221'
Store First Set Of Photosensor Element Signals In RAM
S211'
Determine Second Peak Light Signal
S222
Store Third Set Of Photosensor Element Signals In RAM
S231'
Determine Second Control Signal
S224
Generate Second Drive Signal
S225
Left Side View Mirror Driven To Desired Reflectance
S226
S212
Determine First Peak Light Signal
Determine Background Light Signal
S213
S232
Determine Third Peak Light Signal
Determine First Control Signal
S214
S234
Determine Third Control Signal
Generate First Drive Signal
S215
S235
Generate Third Drive Signal
Rearview Mirror Driven To Desired Reflectance
S216
S236
Right Side View Mirror Driven To Desired Reflectance

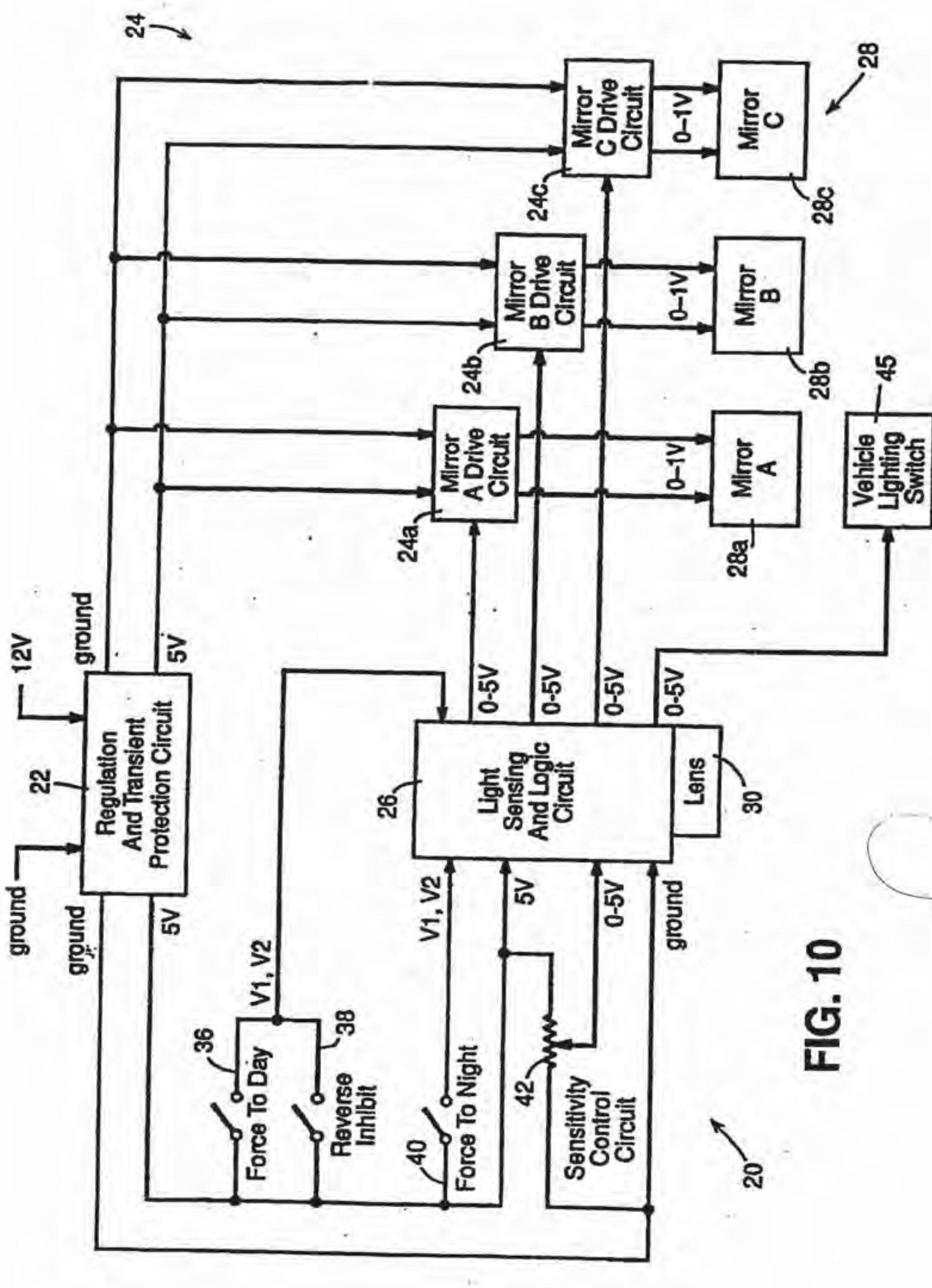

24
28
Mirror C Drive Circuit
Mirror C
24c
28c
0–1V
Mirror B Drive Circuit
Mirror B
24b
28b
0–1V
Mirror A Drive Circuit
Mirror A
24a
28a
0–1V
Vehicle Lighting Switch
45
12V
ground
5V
22
Regulation And Transient Protection Circuit
ground
ground
5V
0-5V
0-5V
0-5V
0-5V
26
Light Sensing And Logic Circuit
Lens
30
V1, V2
V1, V2
5V
0-5V
ground
36
Force To Day
38
Reverse Inhibit
40
Force To Night
42
Sensitivity Control Circuit
20

FIG. 10

AUTOMATIC REARVIEW MIRROR SYSTEM USING A PHOTOSENSOR ARRAY

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to an automatic rearview mirror system for automotive vehicles which automatically changes reflectance level in response to glare causing light, and more particularly relates to an improved automatic rearview mirror system using only a rearwardly facing sensor.

2. Description of Related Art

Automatic rearview mirrors and mirror systems have been devised for varying the reflectance level of a variable reflectance rearview mirror by reducing the reflectance automatically in response to annoying glare light, as seen rearwardly of the rearview mirror or mirrors by a driver of the vehicle, and by increasing automatically the reflectance to a normal or maximum reflectance level when the annoying glare light subsides. These automatic mirrors have been changed over the years in an effort to improve their performance characteristics and associated level of glare protection.

Early automatic rearview mirrors used a rearwardly facing sensor and control circuit to change mirror reflectance. One example of such a "single-sensor" type mirror is described in U.S. Pat. No. 4,266,856. In these prior art single-sensor type mirrors, the rear glare light was incident on a rearwardly facing sensor or photocell, such as a photodiode, photoresistor or phototransistor. These mirrors suffered from various problems, however, including the problem that these mirrors would become increasingly sensitive and even "lock-up" in their minimum reflectance level or state as the driver encountered significantly higher light levels in town or city driving. This required the driver to repeatedly adjust the mirror's sensitivity control to prevent such problems.

To overcome the problems of single-sensor type mirrors, a non-rearwardly facing photocell for sensing "ambient" light was added. It was believed that the desired reflectance necessary to relieve the driver from glare depended not only on glare light but also on ambient light. Accordingly, these "two-sensor" type mirrors used two separate photocells, one generally facing rearwardly and one generally facing forwardly (or other non-rearwardly facing direction) of the mirror or vehicle. The signals from these two photocells were then compared in some fashion, and when, for example, the glare light from the rear was comparatively high with respect to the "ambient" light, a control circuit would apply a control signal to reduce mirror reflectance. Some examples are described in German Laid-Open Patent No. 3,041,612; Japanese Laid-Open Patent No. 58-19941; and U.S. Pat. Nos. 3,601,614; 3,612,666; 3,680,951; 3,746,430; 4,443,057; 4,580,875; 4,690,508; and 4,917,477. In many of these prior art automatic rearview mirrors, light generally forward of the mirror or vehicle was incident on the second photocell.

These arrangements, however, also had problems. In some of these mirrors the forwardly facing or "ambient" light sensor was inaccurate because it did not correctly measure ambient light levels since it did not include light generally rearward of the mirror or vehicle. Some examples include the devices described in U.S. Pat. Nos. 4,443,057 and 4,917,477. Other prior art devices overcame these deficiencies by providing a control circuit which correctly measured ambient light as a combination of both the forward and rear light levels. Examples of this significantly different approach are described in U.S. Pat. Nos. 4,793,690 and 4,886,960.

The prior art two-sensor type systems generally provided improved performance over prior art single-sensor type systems but were also more complex and costly. In part, this was because using separate forwardly and rearwardly facing photocells required that the performance characteristics of the two separate photocells, such as photoresistors, be matched appropriately to ensure consistent performance under various operating conditions. Matching photocells such as photoresistors, however, generally involves complex, expensive and time consuming operations and procedures.

Both the prior art single-sensor and two-sensor type mirrors presented additional problems when they were also used to control the exterior side view mirrors. This is because such prior art systems used a common control or drive signal to change the reflectance level of both the interior rearview mirror and the exterior left and/or right side view mirrors by substantially the same amount. In U.S. Pat. No. 4,669,826, for example, a single-sensor type mirror system used two rearwardly facing photodiodes to control both an interior rearview mirror and the left and/or right side view mirrors based on the direction of incident light from the rear. Another example includes the two-sensor type system described in U.S. Pat. No. 4,917,477.

In rearview mirror systems, however, each of the interior rearview and exterior side view mirrors may reflect different source light levels. More specifically, the inside rearview mirror, left side view mirror and right side view mirror each enable the driver to view a different portion or zone of the total rearward area. Of course, there may be some overlap of the image information contained in each of the three zones. The situation is further complicated with multi-lane traffic because each of the mirrors reflects different light levels caused by the headlights of the vehicles which are following, passing or being passed. As a result, in the prior art systems, when the reflectance level of the interior rearview mirror was reduced to decrease the glare of headlights reflected therein, the reflectance level of the exterior left and right side view mirrors was also reduced by substantially the same amount, even though, for example, the side view mirrors might not be reflecting the same level of glare light, if any. Accordingly, rear vision in the exterior left and right side view mirrors could be improperly reduced.

Other prior art two-sensor type systems used a common ambient light sensor and several rearwardly facing sensors, one for each of the mirrors. An example is the alternate system also described in U.S. Pat. No. 4,917,477. This approach is not satisfactory, however, because it reduces system reliability and increases complexity and cost.

Finally, some prior anti-glare mirrors used several sensors to control the segments of a variable reflectance mirror. One example is disclosed in U.S. Pat. No. 4,632,509, which discloses a single-sensor type mirror using three rearwardly facing photocells to control three mirror segments depending on the direction of incident light from the rear. See also U.S. Pat. No. 4,697,883. These prior mirror systems generally have the same problems as the other single-sensor type mirrors. Some other anti-glare mirrors are generally disclosed in U.S. Pat. Nos. 3,986,022; 4,614,415; and 4,672,457.

Consequently, there is a need for an automatic rearview mirror system for an automotive vehicle having improved reliability and low cost, which accurately determines or otherwise discriminates light levels that the driver will experience as glare without the need for a separate forwardly facing photocell. In addition, as noted above, there is also a need for an automatic rearview mirror system of high reliability and low cost, which accurately determines light levels that the driver will experience as glare, and which can control independently the reflectance of a plurality of mirrors according to the light levels actually reflected by each of the rearview and exterior side view mirrors without the need for additional and separate rearwardly facing photocells. There is also a need for an automatic rearview mirror system that can independently control the segments of a variable reflectance mirror while accurately determining light levels that the driver will experience as glare in each segment of the mirror without the need for additional and separate forwardly and rearwardly facing photocells.

SUMMARY OF THE INVENTION

It is an object of the present invention to overcome the problems of the prior art.

It is another object of the present invention to provide an automatic rearview mirror system of improved reliability.

It is yet another object of the present invention to provide an automatic rearview mirror system that accurately determines light levels that the driver will experience as glare without the need for a separate forward facing sensor or other non-rearwardly facing photocells.

It is another object of the present invention to provide an automatic rearview mirror system of high reliability that accurately determines light levels that the driver will experience as glare, and which can independently control a plurality of mirrors or mirror segments according to different fields of view without the need for additional and separate rearwardly facing photocells.

According to one aspect of the present invention, using a photosensor array and an appropriate control circuit allows the elimination of separate forwardly facing or other non-rearwardly facing photocells, thereby allowing for lower costs and increased reliability since it is not necessary to match two separate photocells such as photoresistors.

According to another aspect, the present invention which achieves one or more of these objectives relates to a control system for controlling a plurality of variable reflectance mirrors or mirror segments which change their reflectance in response to a signal from a drive circuit. The system comprises a plurality of variable reflectance mirrors, a photosensor array and a control circuit receiving signals from the photosensor array for controlling the mirrors. The photosensor array is mountable to view rearwardly of the mirror or vehicle. The photosensor array comprises a plurality of sets of photosensor elements corresponding to the plurality of variable reflectance mirrors. The photosensor elements in each set produce a plurality of photosensor element signals in response to light incident thereon. The control circuit determines control signals, indicative of a desired reflectance for each of the plurality of variable reflectance mirrors, in response to receiving photosensor element signals from the photosensor element set for each view or zone corresponding to the rearview mirror and exterior side view mirrors and also (or alternatively) the mirror segments. The control signals control the drive circuit to cause the plurality of variable reflectance mirrors or mirror segments to assume the desired reflectance.

According to another aspect, the present invention which achieves one or more of these objectives relates to an automatic rearview mirror system for an automotive vehicle comprising at least one variable reflectance rearview mirror, and an array of sensing elements to sense light levels in an area rearward of the at least one variable reflectance rearview mirror. Each of the sensing elements is adapted to sense light levels of light incident thereon and to output an electrical signal indicative of the sensed light levels. The system further comprises a signal processor, connected to the array of sensing elements, receiving and using the electrical signals indicative of the sensed light levels from the sensing elements to determine a first electrical signal indicative of a background light level in the area rearward of the at least one variable reflectance rearview mirror and to determine a second electrical signal indicative of at least one peak light level in the area rearward of the at least one variable reflectance rearview mirror. The signal processor determines at least one control signal indicative of the desired reflectance level of the at least one variable reflectance rearview mirror from the first electrical signal indicative of the background light level and the second electrical signal indicative of the at least one peak light level. The system further comprises at least one drive circuit connected to the signal processor and to the at least one variable reflectance rearview mirror for receiving the at least one control signal and generating and applying at least one drive signal to the at least one variable reflectance rearview mirror to drive the at least one variable reflectance mirror to the desired reflectance level.

According to another aspect, the present invention which achieves one or more of these objectives relates to a control system for controlling a plurality of variable reflectance mirrors, each of which change their reflectance level in response to a drive signal from an associated drive circuit, for an automotive vehicle. The system comprises a plurality of variable reflectance mirrors, and a photosensor array mountable to face substantially towards a rear area. The photosensor array comprises a plurality of photosensor element sets. Each set comprises a plurality of photosensor elements. Each of the photosensor elements generates a photosensor element signal indicative of a light level of light incident thereon, and each of the sets corresponds to one of the plurality of variable reflectance mirrors. The system further comprises a control circuit, connected to the photosensor array, for determining and applying a plurality of control signals. Each of the control signals is indicative of a desired reflectance level for each of the plurality of variable reflectance mirrors in response to receiving the photosensor element signals from each of the plurality of photosensor element sets. The system further comprises a plurality of drive circuits connected to the control circuit and to different ones of the plurality of variable reflectance mirrors associated therewith. Each of the control signals is output to the drive circuit associated therewith, to generate and apply a drive signal to each of the plurality of variable reflectance mirrors causing each of the mirrors to assume a desired reflectance level.

According to another aspect, the present invention which achieves one or more of these objectives relates to a control system for controlling at least one variable reflectance mirror for an automotive vehicle. The system comprises photosensor array means for sensing light levels in an area rearward of the at least one variable reflectance mirror and generating photosensor array signals, means for determining a background light signal from the photosensor array signals, means for determining a peak light signal from the photosensor array signals, and means for controlling a reflectance level of the at least one variable reflectance mirror using the background and peak light signals.

According to another aspect, the present invention which achieves one or more of these objectives relates to a method of controlling the reflectance of at least one variable reflectance mirror comprising the steps of sensing light levels in an area rearward of the at least one variable reflectance mirror with an array of sensing elements, determining a background light level from the sensed light levels, determining a peak light level from the sensed light levels, and controlling a reflectance level of the at least one variable reflectance mirror using the determined background and peak light levels.

By using a plurality of photosensor element sets or sub-arrays on a photosensor array to control a plurality of mirrors and also (or alternatively) mirror segments, the mirrors may be controlled independently to vary their reflectance in accordance with the view associated with each of the photosensor element sets or sub-arrays.

These and other objects, advantages and features of the present invention will be readily understood and appreciated with reference to the detailed description of preferred embodiments discussed below together with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1A is a drawing of an automatic rearview mirror of the present invention, including an expanded view of a rearwardly facing photosensor array located in the upper center area of the mirror surface;

FIG. 1B is another drawing of an automatic rearview mirror of the present invention, including an expanded view of the rearwardly facing photosensor array alternatively located in a bezel or chin of the mirror;

FIG. 2 is a drawing of an automotive vehicle with the automatic rearview mirror system of the present invention;

FIGS. 3A and 3B are illustrative diagrams of a rearward area as viewed by the photosensor elements of the photosensor array;

FIG. 4A is a generalized diagram of a photosensor array PA(N,M) having a sub-array S(X);

FIG. 4B is a generalized diagram of the photosensor array PA(N,M) and sub-arrays S(0), S(1), S(2) and S(3);

FIG. 5 is another schematic diagram of the photosensor array commonly located on a light sensing and logic circuit;

FIG. 6 is a schematic block diagram of the automatic rearview mirror system;

FIG. 7 is a flow chart illustrating the method of the present invention for controlling the reflectance of a rearview mirror or mirrors;

FIGS. 8A and 8B are detailed flow charts for steps S150, S160 and S180 of FIG. 7;

FIG. 9 is a flow chart of the general logic flow of FIGS. 7, 8A and 8B for controlling the reflectance of three mirrors; and

FIG. 10 is another schematic block diagram of the automatic rearview mirror system of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENT

I. The Automatic Rearview Mirror system

FIG. 1A illustrates an automatic rearview mirror 1 comprising a variable reflectance mirror element la and a single rearwardly facing photosensor 2. The photosensor 2 is mounted facing rearwardly of the rearview mirror 1 so that its field of view encompasses an area comprising a rear window area and at least a portion of either or both side window areas. Also shown is a switch 3 to allow a driver to manually control several possible mirror functions, such as an on-off control switch, a sensitivity adjustment and a force-to-day or a force-to-night switch (i.e., forced maximum or minimum reflectance levels, respectively). An expanded view of the photosensor 2, which is preferably located in an upper center area of the variable reflectance mirror element la as shown, shows a light sensing and logic circuit 26 comprising a photosensor array 32 and a logic and control circuit 34 (which is not shown in FIG. 1A but is shown in FIG. 6 as discussed below). A photosensitive surface of each of the photosensor elements 32*a* (shown in FIG. 5) of the photosensor array 32 senses light levels or image information in a predetermined field of view encompassing an area located rearwardly of the rearview mirror 1. A lens 30 images or otherwise focuses the light information from the predetermined field of view onto the photosensor array 32.

The rearview mirror 1 further comprises a channel mount 1*b* or other mounting means used to fixedly attach the mirror 1 to the windshield or headliner area of the vehicle. The rearview mirror 1 is generally adjustable with respect to the channel mount la to allow a driver to position the mirror for correct viewing of the rearward area or scene so that the driver's sightline through the rearview mirror 1 is aligned approximately with the vehicle's centerline.

Preferably, the photosensor 2 is fixedly mounted on the adjustable portion of the rearview mirror 1 as shown in both FIGS. 1A and 1B so that the viewing axis of the photosensor 2 is generally aligned with the viewing axis of the mirror 1 which is perpendicular to the glass surface of the mirror 1. This approach is preferable both because of packaging concerns and because it provides a guaranteed sightline. It is, however, within the scope of the present invention to mount the photosensor array 32 so that it is movable with respect to the variable reflectance mirror element 1*a* of the rearview mirror 1.

More preferably, as shown in FIG. 1A, the photosensor 2 is located in the upper center area of the variable reflectance mirror element 1*a*. This may be required, for example, if it is necessary to reduce the bezel size of the rearview mirror 1. If the photosensor 2 is located behind a glass surface of the variable reflectance mirror element 1*a*, an appropriately sized hole is provided in the protective and reflective materials of the variable reflectance mirror element 1*a*. Additionally, a corresponding area within an active layer of the variable reflectance mirror element 1*a* may be removed or otherwise rendered inactive to enable the photosensor 2 to view directly the rearward scene. Alternatively, for manufacturing reasons, the photosensor 2 may view the rearward scene through the active layer of the variable reflectance mirror element 1*a*, in which case it is preferable to compensate for or otherwise negate the effects of reducing reflectance and correspondingly the transmittance of the variable reflectance mirror element 1*a* so that the photosensor 2 effectively views the rearward scene directly as will be described later.

Most preferably, a reflective surface is maintained within the hole to both preserve the cosmetic appearance of the assembly as viewed by the driver and to maximize the reflective surface. This can be achieved by providing a very thin metal reflective layer (100 Å thickness or lower) of aluminum, stainless steel, chromium, or silver, etc., so as to be sufficiently transmitting for incident light to enable proper operation of the photosensor array 32 but also sufficiently reflective to appear mirror-like in the area of the hole. Alternatively, a reflective tape, which is both sufficiently transmitting and reflective to achieve the objectives described herein, may be adhered at the hole region using suitable means such as an optical adhesive and the photosensor array 32 may then be mounted behind the optical adhesive. Additionally, thin film stacks such as a solid state tri-layer of ¼ wave TiO_2, ¼ wave SiO_2 and ¼ wave TiO_2 or some other single thin film of a high index material may be mounted behind or coated upon the area of the hole. Finally, since the preferred photosensor array 32 is responsive to both visible light and near infrared, it is preferable to select a material which reflects a significant proportion of visible light while being essentially transparent to infrared.

As shown in FIG. 1B, the photosensor 2 may also be located in the bezel or chin of the rearview mirror 1 to view the rearward area directly without any compensation. Although not shown, the photosensor 2 may also be located on or near the channel mount 1*b* so that the axis of the photosensor 2, which is perpendicular to the plane of the photosensor array 32, is in fixed alignment with the vehicle's centerline regardless of the adjusted position of the rearview mirror 1.

For other vehicles, such as trucks, the photosensor 2 may also be located with each of the external side view mirrors as will be described later.

The lens 30 is preferably a single molded plastic lens approximately 2 millimeters in diameter and is preferably bonded to or in close contact with the photosensor array 32. The lens 30 may, however, include any appropriate image focusing means such as conventional single component optics, holographic lens type optics, binary optics or a microlens. The lens 30 preferably is also designed to focus an image of the rearward scene within a field of view defined by a cone. The cone's centerline is perpendicular to the plane of the photosensor array 32 and the cone preferably has an included angle of approximately 100 degrees. Thus, the image is focused onto a circular area of the plane of the photosensor array 32. Of course, the photosensor array 32 could be positioned in other than a rearwardly facing direction so long as appropriate lenses or other optics are used to direct the light or image information from the rearward area onto the photosensitive surface of the photosensor array 32.

The pre-positioning of the photosensor array 32 in the rearview mirror 1 depends on whether the automatic rearview mirror system 20 is being used in a left hand or a right hand drive vehicle. In either case, the photosensor array 32 is preferably pre-positioned within the circular area of the focused image so that for either a left or right hand drive vehicle and with only driver adjustment of the rearview mirror 1, the rearward scene imaged onto the photosensitive surface of the photosensor array 32 includes the rear window area and at least a portion of the left and right side window areas of the vehicle.

If a sufficiently large photosensor array 32 is used, then the pre-positioning of the photosensor array 32 is not vehicle specific as described above, and a system 20 using a larger photosensor array 32 may be used for both left and right hand drive vehicles. The larger photosensor array 32 is positioned symmetrically within the circular area of the focused image described above. Using the larger photosensor array 32 involves using a pattern recognition means to determine the approximate vehicle centerline so that the appropriate portion of the larger photosensor array 32 may be selected depending on whether the automatic rearview mirror system 20 is installed in a left or right hand drive vehicle.

FIG. 2 illustrates an automatic rearview mirror system 20 for an automotive vehicle, comprising the rearview mirror 1, a left side view mirror 4 and a right side view mirror 5. As will be discussed below, either or both of the side view mirrors 4 and 5 may be connected to a control circuit of the rearview mirror 1. The mirrors 1, 4 and 5 may be constructed according to any of the methods known to those skilled in the art and are generally constructed according to the styling preferences and specifications of the automotive vehicle manufacturers. The means for mounting the rearview mirror 1, such as the channel mount 1*b*, and the electrical connectors used to connect the mirrors 4 and 5 to the control circuit of the rearview mirror 1 and the vehicle's electrical system may include any one of the many configurations known to those having ordinary skill in the art. The variable reflectance mirror element 1*a* of the mirrors 1, 4 and 5 may be any device having more than one reflectance level corresponding to a specific control or drive signal. Preferably, however, the variable reflectance mirror element 1*a* is an electrochromic mirror.

As discussed, the photosensor 2 is mounted facing rearwardly of the rearview mirror 1 so that its field of view encompasses an area comprising the rear window area and at least a portion of both the left side window area and the right side window area. The horizontal and vertical fields of view of the rearward area as seen by the photosensor 2, and more particularly by the photosensor array 32, are illustratively shown in FIGS. 3A and 3B.

As shown in FIG. 3A, the photosensor array 32 senses a field of view divided into three separate zones: a center zone a, a left zone b (generally corresponding to the left side window area) and a right zone c (generally corresponding to the right side window area). Each zone is sensed by a separate set or sub-array S(X) of photosensor elements 32*a* (described with respect to FIGS. 4A and 4B) within the photosensor array 32. The center zone, zone a, generally receives light from the rear window area of the vehicle. This rear window area is depicted by a trapezoidally shaped rear window figure superimposed on a first set or sub-array S(1) of photosensor elements 32*a* used to sense light levels in zone a. Zone b includes light from at least a portion of a left side window area. This is depicted by a trapezoidally shaped left rear side window figure and a partially shown left front side window figure superimposed on a second set or sub-array S(2) of photosensor elements 32*a* used to sense light levels in zone b. Similarly, zone c includes light from at least a portion of a right side window area. This is depicted by a trapezoidally shaped right rear side window figure and a partially shown right front side window figure superimposed on a third set or subarray S(3) of photosensor elements 32*a* used to sense light levels in zone c. Additionally, all three zones include light reflected from whatever fixed body work and interior trim, head rests, vehicle occupants or other objects that are within the zones a, b and c.

Also as illustratively shown in FIG. 3A, the photosensor elements 32*a* in columns 1 to 4 comprise the third photosensor element set in zone c, the photosensor elements 32*a* in columns 6–11 comprise the first photosensor element set in zone a and the photosensor elements 32*a* in columns 13 to 16 comprise the second photosensor element set in zone b. Null zones are provided between the zones a and b and between the zones a and c to allow for driver adjustment of the rearview mirror 1. These null zones also ensure that the center zone a does not include light or other image information from the side window areas of zones b and c.

As will be discussed in more detail below, the logic and control circuit 34 selects photosensor element signals from the first photosensor element set or subarray S(1) (shown in FIG. 4B) corresponding to zone a to control the reflectance level of the rearview mirror 1. Similarly, the control circuit 34 selects photosensor element signals from the second photosensor element set or sub-array S(2) (shown in FIG. 4B) corresponding to zone b to control the reflectance level of the left side view mirror 4, and further selects photosensor element signals from the third photosensor element set or sub-array S(3) (shown in FIG. 4B) corresponding to zone c to control the reflectance level of the right side view mirror 5. Additionally, for a variable reflectance mirror element 1*a* having segments, such as a center, left and right segment, appropriately defined zones a, b and c, i.e., sub-arrays S(1), S(2) and S(3), corresponding to the mirror segments may be used by the logic and control circuit 34 to control independently the individual mirror segments.

FIG. 3B illustratively shows the preferred embodiment for the zones of the photosensor array 32. In this embodiment, the logic and control circuit 34 selects photosensor element signals from three overlapping sets or sub-arrays S(1), S(2) and S(3) of photosensor elements 32*a* corresponding to the three overlapping zones a, b and c to control, respectively, the reflectance level of the mirrors 1, 4 and 5. More specifically, the control circuit 34 selects photosensor element signals from the photosensor elements 32*a* in columns 6 to 11 (zone a) to control the reflectance level of the rearview mirror 1. The control circuit 34 also selects photosensor element signals from photosensor elements 32*a* in columns 10 to 14 (zone b) to control the reflectance level of the left side view mirror 4, and further selects photosensor element signals from photosensor elements 32*a* in columns 3 to 7 (zone c) to control the reflectance level of the right side view mirror 5.

Additionally, in the FIG. 3B embodiment, the lens 30 focuses or images light information from: (1) the rear window area onto zone a; (2) at least a portion of the rear window and left side window areas onto zone b; and (3) at least a portion of the rear window and right side window areas onto zone c. Contrastingly, in the FIG. 3A embodiment, the lens 30 focuses light from: (1) the rear window area onto zone a; (2) the left side window area onto zone b; and (3) the right side window area onto zone c. The overlapping zones in the FIG. 3B embodiment are advantageous because each set of overlapping photosensor elements 32*a* in zones a and b and each set of overlapping photosensor elements 32*a* in zones a and c, as well as the logic and control circuit 34, is able to "preview" the light information that may, for example, first appear in the rear window area (and correspondingly in the rearview mirror 1), but which may appear shortly thereafter in the left or right side view mirrors 4 and 5. By examining at least a portion of the rear window area, the automatic rearview mirror system 20 is able to more quickly respond to annoying glare light from approaching vehicles or other sources. Overlapping zones are also generally preferred because a glare light source located in a common or overlapping area of the rearview mirror 1 and one of the side view mirrors 4 or 5 can influence both mirrors.

II. The Light Sensing Device

The light sensing device of the light sensing and logic circuit 26 is preferably the photosensor array 32 shown in FIG. 5. The photosensor array 32 has sufficient resolution to view the real image of a scene but may also use a spatial distribution of light intensities as an approximation of the imaged scene. An example of such a photosensor array is the VLSI Vision Limited (VVL) Single Chip Video Camera Model #ASIS 1011.

Since a photosensor array 32 of the type described, namely a VVL Single Chip Video Camera, is capable of providing image information having sufficient resolution for displaying an actual image or for some other purpose, it will be readily understood that additional features or functions may be incorporated by adding circuitry to provide video output from the photosensor array 32 in addition to the primary control functions described herein. For example, the video output may be output to a CRT, flat LC panel display or other appropriate display device, located within the vehicle, to provide a display of the imaged scene for viewing by the driver.

The photosensor array 32 may be located in any of the mirrors 28 or in any other appropriate location, whether local or remote, such as on the vehicle's rear bumper, thereby extending significantly the effective field of view normally available to the driver either directly or through the vehicle's mirrors 28. Additionally, the photosensor array 32 may even replace one or more of the side view mirrors 4 and 5 of the automatic rearview mirror system 20, thereby reducing the aerodynamic drag on the vehicle while providing sufficient information to the driver comparable to that available through the side view mirrors 4 and 5.

A video signal from the photosensor array 32 may also be used by the logic and control circuit 34 to determine the presence of a vehicle or other object within the field of view of the photosensor array 32 to provide a visual signal warning such as through a display panel, or even an audible warning, based on certain parameters, such as distance and speed of the object. Additionally, if the photosensor array 32 is located in the rearview mirror 1, the video signal may be used to monitor the vehicle's interior to detect unauthorized intrusion into the vehicle. This may be achieved by providing electrical power to the mirror's logic and control circuit 34 from a vehicle power supply and by activating a vehicle intrusion monitoring mode when a signal indicates that the vehicle's door and trunk locks have been activated. The logic and control circuit 34 may be used to continuously monitor the image from the vehicle's interior thereby allowing detection of objects or persons moving within the vehicle, and if movement is detected, another signal from the logic and control circuit 34 may then activate an intrusion alarm.

It is, however, within the scope of the present invention for the light sensing device to comprise any similarly appropriate image or array sensor. When the light sensing and logic circuit 26 is formed as a very-large-scale-integrated (VLSI) complementary-metal-oxide-semiconductor (CMOS) device, as is known to those skilled in the art, the light sensing device will share a common semiconductor substrate with the logic and control circuit 34.

Preferably, for the described three mirror system, the photosensor array 32 comprises a plurality of photosensor elements 32*a* arranged in 160 columns and 40 rows (a 160×40 array) providing a horizontal field of view of approximately 100 degrees and a vertical field of view of approximately 30 degrees. As discussed, FIGS. 3A and 3B illustratively show a 16×4 photosensor array 32. The photosensor array 32 may, however, comprise any appropriately sized array having an appropriate field of view. For example, the field of view may be narrower when controlling the segments of only one mirror. Each photosensor element 32*a* is preferably about 10 microns square.

As shown in FIG. 4A, the photosensor array 32 generally comprises a plurality of photosensor elements 32*a* arranged in a photosensor array PA(N,M) having N rows of M columns. When viewing the photosensitive surface of the photosensor array PA(N,M) in a vertical plane, the lower row is row 1, the top row is row N, the left hand column is column 1, and the right hand column is column M. A specific photosensor element is identified as E(n,m) and the signal indicative of a light level incident thereon is L(n,m). Also, the sub-array S(X), where X=0, 1, 2, . . . , Z, is a rectangular array having P(X) rows of Q(X) columns of photosensor elements **32***a* and is located such that its lower left hand element is photosensor element E(T(X)), U(X)).

As shown in FIG. **4B**, a background sub-array S(X) designated S(0) is used to determine a general background light level B. Signals from the photosensor elements **32***a* of each peak sub-array S(X), designated S(1), S(2), . . . , S (Z), are used to determine a peak light level P(z) incident on each peak sub-array S(1), S(2), . . . , S(Z). The general background light level B for background sub-array S(0) and the peak light level P(z) for each peak sub-array S(X) are then used to determine a mirror control signal $V_c(z)$ for controlling at least one mirror or mirror segments associated with each zone.

FIG. **5** generally illustrates a logic layout of the photosensor array **32**. The logic and control circuit **34** generates array control signals to control the photosensor array **32**. As is well known in the art, the photosensor array **32** is typically accessed in scan-line format, with the array **32** being read as consecutive rows, and within each row as consecutive columns or pixels. Each photosensor element **32***a* is connected to a common word-line **33***e*. To access the photosensor array **32**, a vertical shift register **33***a* generates word-line signals for each word-line **33***e* to enable each row of photosensor elements **32***a*. Each column of photosensor elements **32***a* is connected to a bit-line **33***f* which is connected to a charge-to-voltage amplifier **33***c*. As each word-line **33***e* is accessed, a horizontal shift register **33***b* uses a line **33***g* to output the bit-line signals on consecutive bit-lines **33***f* to an output line **33***h* connected to the logic and control circuit **34**. Also shown is a voltage amplifier **33***d* used to amplify the resulting analog photosensor element signals. The analog photosensor element signals are then output on line **33***h* to the analog-to-digital converter **44** and converted to digital photosensor element signals.

III. The Logic and Control Circuit

FIG. **6** shows the light sensing and logic circuit **26** comprising the photosensor array **32** and the logic and control circuit **34**. The logic and control circuit **34** comprises a logic circuit **46**, a clock **47**, a random-access-memory (RAM) **50**, or other appropriate memory, and a digital-to-analog converter **52**. The logic circuit **46** is preferably a dedicated configuration of digital logic elements constructed on the same semiconductor substrate as the photosensor array **32**. Alternatively, the logic circuit **46** may also be a microprocessor comprising a central processing unit (CPU) and a read-only-memory (ROM). The logic circuit **46** may also be implemented using gate array technology or any other appropriate hardwired logic circuit technology.

The logic circuit **46** interfaces with the clock **47**, provides array control signals to the photosensor array **32**, manages data flow to and from the RAM **50** and converters **44** and **52**, and performs all computations for determining a digital mirror control signal $V_{DAC}(Z)$ for causing the variable reflectance mirror element **1***a* to assume a desired reflectance level. As discussed, the analog-to-digital converter **44** converts the analog photosensor element signals to the digital photosensor element signals processed by the logic circuit **46**. It has been found that an eight-bit analog-to-digital converter **44** provides adequate data resolution for controlling the mirrors **1**, **4** and **5**. Preferably, the analog-to-digital converter **44** is constructed on the same semiconductor substrate as the photosensor array **2** as shown in FIG. **5**.

The digital photosensor element signals output to the logic and control circuit **34** are generally stored in the RAM **50** for processing. The values of the digital photosensor element signals for the photosensor array PA(N,M) are correspondingly stored in an array in the RAM **50** designated RA(N,M). The logic circuit **46** processes the values of each of the digital photosensor element signals, which are designated Val RA(n,m), to determine an instantaneous or substantially real-time background light signal B, for a time period t and at least one peak light signal P(z). The logic circuit **46** uses these signals, which may also be temporarily stored in the RAM **50**, to determine a digital control signal $V_{DAC}(Z)$ to cause at least one mirror or mirror segment to assume a desired reflectance level. The digital mirror control signal $V_{DAC}(Z)$ is then output to the digital-to-analog converter **52**, which outputs a corresponding analog mirror control signal Vc(z) to a mirror drive circuit **24**. Alternatively, the digital-to-analog converter **52** need not be used if the logic circuit **46** generates a pulse-width-modulated (PWM) mirror control signal to control the mirror drive circuit **24**.

The mirror drive circuit **24** comprises mirror drive circuits **24***a*, **24***b* and **24***c*. The drive circuit **24** drives mirrors **28**, which comprises a rearview mirror **28***a* (mirror A), a left side view mirror **28***b* (mirror B) and a right side view mirror **28***c* (mirror C). Mirrors A, B and C correspond, respectively, to the rearview mirror **1**, the left side view mirror **4** and the right side view mirror **5** shown in FIG. **2**. It is, of course, within the scope of the present invention for the mirror A to be a mirror other than the rearview mirror **1**. It is similarly within the scope of the present invention for the mirror B to be a mirror other than the left side view mirror **4**, and for the mirror C to be a mirror other than the right side view mirror **5**. It is also within the scope of the invention for the mirrors A, B and C to be mirror segments or zones of the variable reflectance mirror element **1***a* where the peak sub-array S(X) for each zone corresponds to a segment of the variable reflectance mirror element **1***a*. Thus, for example, S(1) may correspond to a center mirror segment, S(2) may correspond to a left mirror segment and S(3) may correspond to a right mirror segment. Any other appropriate mirror segmentation scheme may also be used.

A sensitivity control circuit **42** is used to input a sensitivity signal S to the logic and control circuit **34**. In addition, signals from a force-to-day (maximum reflectance) switch **36**, a reverse-inhibit (maximum reflectance) switch **38** and a force-to-night (minimum reflectance) switch **40** may also be input to the logic and control circuit **34**. The switch **3** of FIGS. **1A** and **1B** may include the sensitivity control circuit **42**, as well as the force-to-day switch **36** and the force-to-night switch **40**.

The switches **36**, **38** and **40** each generate a signal causing the logic circuit **46** to override its normal operation, as will be described with respect to FIGS. **7**, **8A** and **8B**, and to output mirror control signals $V_c(z)$ to the mirror drive circuit **24** causing the variable reflectance mirror **28** to assume a maximum or minimum reflectance level in accordance with the appropriate signals from the switches **36**, **38** or **40**. Finally, the logic and control circuit **34** may also be used to control a vehicle lighting switch **45** to automatically turn on and off a vehicle's headlights and sidelights. This feature will be further described later.

IV. Operation of the Invention

FIG. **7** shows an overview of the logic flow chart and method for controlling the reflectance levels of any one or all of the mirrors or mirror segments **28a**, **28b** or **28c**. It should be understood that the reflectance level of each of the mirrors **28a**, **28b** and **28c** in the automatic rearview mirror system of the present invention may be commonly or independently controlled. FIGS. 8A, 8B and 9 provide more detail on the logic and method of FIG. 7.

In step **S101** of FIG. 7, light information seen rearwardly of the rearview mirror **1** is incident on the lens **30**. In step **Si10**, light passing through the lens **30** is refracted such that the light information is imaged or focused onto the photosensitive surface of the photosensor array **32**. In step **S120**, the logic circuit **46** generates and outputs the array control signals to the photosensor array **32**. In step **S130**, photosensor element signals indicative of the light levels incident on each of the photosensor elements **32a** are generated. In step **S140**, these photosensor element signals are temporarily stored in RAM or any other appropriate memory. In steps **S150** and **S160**, the logic circuit **46** determines values for the background light signal and the peak light signal for each zone corresponding to each of the mirrors **28**. In step **S180**, the logic circuit **46** uses the background and peak light signals of step **S150** to determine the control signals required to cause each of the mirrors **28** to achieve a desired reflectance level. Also, the logic and control circuit **34** in step **S180** reads and processes the states of the optional sensitivity control circuit **42**, force-to-day switch **36**, force-to-night switch **40** and reverse-inhibit switch **38**. In step **S200**, the mirror drive circuits **24** use the control signals determined in step **S180** to generate drive signals to cause the mirrors **28** to assume the desired reflectance levels in step **S210**.

In one embodiment of the invention, the logic circuit **46** determines the background light signal B_t in steps **S150** and **S160** by calculating the average value of the photosensor element signals, previously stored in RAM in step **S140**, for the photosensor elements **32a** in a lowest row or rows of the photosensor array **32** corresponding to an area below the rear window. With respect to FIGS. 3A and 3B, this means that the background light signal B_t is determined from photosensor element signals generated by the photosensor elements **32a** located in row D of the photosensor matrix array **32**. The logic circuit **46** may then output B_t to the RAM **50** for later processing. The logic circuit **46** may also determine B_t by calculating an average value of all of the photosensor element signals in the entire photosensor array **32**. More generally, the background light signal B_t for the rearward scene may be determined by calculating the average value of X percent of the lowest photosensor element signal values in the RAM array RA(N,M), where X is preferably 75, but typically may be in the range of 5 to 100.

Additionally, the background light signal B_t is preferably change-limited to determine a limited background light signal B_{Lt}. The signal B_t may be change-limited, for example, by limiting changes in the background light signal B_t to 2% per time frame. A time frame may be, for example, 250 milliseconds or any other time relating to the rate at which the logic circuit **46** samples the photosensor element signals from the photosensor array **32**. The logic circuit **46** determines the change-limited value B_{Lt} used to determine the digital mirror control signal $V_{DAC}(z)$ as follows: $B_{Lt}=B_{L(t-1)}+C_L\times(B_t-B_{L(t-1)})$, where B_{Lt}=the change-limited background light signal for a current time frame t, B_t=the actual or substantially real-time background light signal for the current time frame t, $B_{L(t-1)}$=the change-limited background light signal for a previous time frame (t−1) and C_L=the change-limit value. Additionally, the background light signal B_t from step **S150** may be processed by the logic circuit **46** to determine whether the change limited background light signal B_{Lt} is less than or greater than $B_{L(t-1)}$. If B_{Lt} is greater than $B_{L(t-1)}$, then the logic circuit **46** may use a higher change-limit value C_{LH} to determine B_{Lt}. If the background light signal B_{Lt} is less than or equal to $B_{L(t-1)}$, then the logic circuit **46** may use a lower change-limit value C_{LL} to determine B_{Lt}. The values C_{LH} and C_{LL} are in the range of 0.01 to 2, but are preferably on the order of about 0.02 or 2%.

The logic circuit **46** in step **S150** also determines the peak light signal P(z) for each zone or sub-array S(X) of the photosensor matrix array **32**. The peak light signal P(z) used to determine the appropriate mirror control signal $V_C(z)$ for the mirror **28** may be determined by counting or summing the number of occurrences where the digital value for a photosensor element signal is greater than a peak threshold value F for each zone or sub-array S(X). For the preferred analog-to-digital converter having eight-bit data resolution, the logic circuit **46** generates digital values indicative of light levels of light incident on each photosensor element **32a** in the range of 0 to 255 ($2^8-1=255$), with headlights resulting in values in the range of about 200 to 255, so that the peak threshold value F is selected to be in the range of about 200 to 255 but is preferably 245. The resulting count or sum P(z) provides a measure of the peak light level for the following reasons.

One design objective of the lens **30** and the photosensor array **32** combination is to be able to measure background light levels in the approximate range of 0.01 to 0.1 lux when driving on sufficiently dark roads. This is achieved by ensuring that the lens **30**, photosensor elements **32a** and charge-to-voltage amplifiers **33c** are able to measure such light levels and by providing a maximum exposure time. The maximum exposure time determines the operating frequency or sampling rate of the system **20**. In the case of the described system, 1.5 MHz has been found to be appropriate.

By varying the exposure time relative to a general background light level B and using a substantially constant sampling rate, a wide range of background light levels in the range of 0.01 to 1000 lux can be measured. Thus, when the background light level is low, the exposure time is relatively long such that headlights within the rearward area cause the affected photosensor elements **32a** to saturate. Correspondingly, for higher background light levels, the exposure time is reduced. Saturation occurs when the incident light charges the photosensor element **32a** to capacity so that any excess charge will leak or transfer to adjacent photosensor elements **32a**. This charge leakage effect is commonly referred to as "blooming." It has been found that a count of the number of photosensor elements **32a** at or near saturation, i.e., those having digital values greater than the peak threshold value F, provides an excellent approximation of the peak light levels and is further described in FIG. 8A. The above described method effectively extends the range of measurable light levels for the photosensor array **32**.

Alternatively, if an anti-blooming device is incorporated in the photosensor array **32**, such as is well known to those skilled in the art, then the peak light signal P(z) may be determined by calculating an average value of Y percent of the highest photosensor element signal values for each zone, where Y is preferably 10, but may be in the range of 1 to 25. When using this approach for determining P(z), it is also preferable to include logic to adjust the sampling rate or operating frequency of the logic circuit **46** to an appropriate value depending on B_{Lt}.

The general background light signal B, whether B_t or B_{Lt}, and the peak light signal P(z) for each zone of the photosensor array 32, as determined in steps S150 and S160, are then used by the logic circuit 46 to determine a mirror control signal $V_C(z)$ as a function of the ratio of B^n (n preferably has a value of one but may typically range from 0.8 to 1.3) to P(z), i.e., $V_C(z)=f(B^n/P(z))$. The control signal $V_C(z)$ is then output to the mirror drive circuits 24 in step S180 to drive the mirrors 28 or segments thereof to their desired reflectance level in the steps S200 and S210.

V. The Preferred Embodiment

The general lighting conditions of the rearward scene can be defined as follows: the background light level of the viewed rearward scene is B and the peak light level for each zone or sub-array S(X) is P(z). A contrast ratio C(z) may be defined as the ratio of the peak light level P(z) for each zone to the general background light level B; thus, C(z)=P(z)/B. Given the background light level B, the human eye can tolerate varying peak light levels in the viewed rearward scene up to a particular contrast ratio tolerance C_T. Contrast ratios greater than C_T initially cause discomfort and are generally known as glare. As the eye adjusts its light sensitivity to protect itself from the discomforting peak or glare light levels, vision is reduced and the glare may become disabling. Thus, the maximum tolerable peak light level P_T of the viewed rearward scene is equal to the product of the contrast ratio tolerance C_T and the background light level B, i.e., $P_T=C_T \times B$.

The desired reflectance $R_d(z)$ of a variable reflectance mirror for each zone is that reflectance level which reduces a peak light level P(z) to a value equal to the maximum tolerable peak light level P_T, i.e., $P_T=R_d(z) \times P(z)$ or $R_d(z)=P_T/P(z)$, and substituting the expression for P_T, $R_d(z)=(C_T \times B)/P(Z)$. However, the maximum tolerable contrast ratio C_T varies across the population due to aging and other factors; accordingly, a sensitivity factor S may be used to account for this variation in contrast tolerance sensitivity so that $R_d(z)=(S \times C_T \times B)/P(z)$. Selecting the desired reflectance $R_d(z)$ for each zone provides maximum information from the rearward scene viewed in each mirror or mirror segment while reducing discomforting or disabling peak light levels to tolerable levels.

The mirror control signal $V_C(Z)$ required to obtain the desired reflectance $R_d(z)$ depends on the particular variable reflectance mirror element that is used. For electrochromic mirrors, a voltage-reflectance relationship can be approximated and generally defined. In general, an electrochromic mirror has a reflectance level R having a maximum value of R_1 with an applied voltage V_{app} of 0 volts. As the applied voltage V_{app} is increased, the reflectance level R perceptually remains on the order of R_1 until V_{app} reaches a value of approximately V_1. As V_{app} is further increased, the reflectance level R decreases approximately linearly until a minimum reflectance of approximately R_2 is reached at a voltage V_2. Thus, the applied voltage V_{app} can be approximately defined as:

$$V_{app}=V_1-(R_1=R)\times(V_2-V_1)/(R_1-R_2)$$

Substituting desired reflectance $R_d(z)$ for the reflectance R results in the mirror control signal, the voltage of which is determined as follows:

$$V_C(z)=V_1+(R_1-S\times C_T\times B/P(z)\times(V_2-V_1)/(R_1-R_2).$$

To obtain a digital value $V_{DAC}(z)$, $V_C(z)$ is scaled by a factor that is the ratio of the maximum digital value to the value V_2; thus, for eight-bit data resolution $V_{DAC}(z)=255\ V_C(z)/V_2$, and substituting for $V_c(Z)$:

$$V_{DAC}(z)=255(V_1+(R_1-S\times C_1\times B/P(z)\times(V_2-V_1)/(R_1-R_2))/V_2.$$

FIG. 8A provides further detail on the steps S150 and S160 where the logic circuit 46 determines the background and peak light signals. More particularly, steps S151, S152, S159 and S160 provide two processing loops for sequentially determining the digital values indicative of the photosensor element signals, Val RA(n,m), in the RAM array RA(N,M) for each of the photosensor elements 32a of the photosensor array PA(N,M).

In step S153, a lens correction factor LC(n,m) is applied to each digital value indicative of the photosensor element signal, Val RA(n,m), to correct for the effects of lens 30, which results in a lens corrected digital value of the photosensor element signal Val $RA_{LC}(n,m)$. These effects are typically referred to as cosine effects or Lambert's Law effects. The lens correction factor LC(n,m) depends on the radial distance of the photosensor element 32a from a central axis of the lens 30, and is typically in the range of 1 to 15 but will depend on the geometry of the lens and the selected photosensor array. The lens correction factor LC(n,m) applied to each Val RA(n,m) may be calculated according to Lambert's Law each time Val RA(n,m) is processed. More preferably, the logic circuit 46 initially stores an array of values LC(n,m) in the RAM 50 for each photosensor element 32a of the photosensor array PA(n,m) during an initialization routine. Alternatively, the size of the photosensor elements 32a of the photosensor array 32 may be adjusted to correct for the lens effects at each photosensor element 32a.

As discussed, it has been found that light levels for headlights generally result in an eight-bit digital value greater than a peak threshold value F having a value of about 245. Correspondingly, during non-daylight operation of the automatic rearview mirror system 20, background light levels generally result in eight-bit digital values indicative of the light levels incident on the photosensor elements 32a that are less than or equal to the peak threshold value F.

Accordingly, the lens corrected value Val $RA_{LC}(n,m)$ is compared in step S154 to the peak threshold value F. If Val $RA_{LC}(n,m)$ is less than or equal to F it is used to increment a counter B_{Count}, in the logic circuit 46, by 1 in step S157 (thereby indicating that a value less than or equal to F has been identified) and by increasing a value B_{Sum} by the value of Val $RA_{LC}(n,m)$ in step S158, where B_{Sum} is the sum of all the values of Val $RA_{LC}(n,m)$ which are less than or equal to F. The background light signal B_t is then determined in step S161 as follows: $B_t=B_{Sum}/B_{Count}$. If Val $RA_{LC}(n,m)$ is greater than F in step S154, then the logic circuit 46 uses a counter P(z) indicative of the peak light levels for each of the zones or sub-arrays S(X) of the photosensor array PA(N,M) which is incremented by 1 as previously described. More particularly, Val $RA_{LC}(n,m)$ is tested in step S155 to determine whether it originates from a particular zone or sub-array S(X), where X=1 to Z. If Val $RA_{LC}(n,m)$ does not fall within a defined zone or sub-array S(X), then P(z) is not incremented; otherwise, P(z) is incremented in step S156 for the appropriate zone.

If the photosensor array 32 is arranged to view the rearward area through the active layer of the variable reflectance element 1a, then a color correction factor CC is applied in step S162 to B, and P(z) to compensate for any reduction in transmittance when the reflectance level (and transmittance) of the rearview mirror 1 is reduced. The value of CC is determined from the last calculated value indicative of the digital mirror control signal $V_{DAC}(z)$ applied to the rearview mirror 1. In step S163, a change-limited background light signal B_{Lt} is determined as has been described previously.

FIG. 8B provides further detail on step S180 where the logic circuit 46 determines the appropriate digital mirror control signal $V_{DAC}(z)$ for each zone or sub-array S(X) and corresponding mirror 28. In steps S181 and S182, $V_{DAC}(z)$ is calculated for each mirror 28. In step S183, the logic circuit 46 reads a state IN1 of the reverse-inhibit switch 38 and if the vehicle is in reverse gear so that IN1 is high, then all digital mirror control signals $V_{DAC}(z)$ are set to 0 in step S184 forcing the mirror 28 to its maximum reflectance level. In step S185, a state IN2 of the force-to-day switch 36 is read and if IN2 is high, then all digital mirror control signals $V_{DAC}(z)$ are set to 0 in step 186 forcing the mirror 28 to its maximum reflectance level.

Finally, in step S187, a state IN3 of the force-to-night switch 40 is read and if IN3 is high, then all digital mirror control signals $V_{DAC}(z)$ are set to 255 (the maximum digital value for eight-bit data resolution) in step S188 forcing the mirror 28 to its minimum reflectance level.

FIG. 9 shows another view of the logic flow whereby the rearview mirror, the left side view mirror and the right side view mirror (or alternatively three mirror segments) are independently driven to their desired reflectance levels by the independent and separate control and drive signals using photosensor element signals from three photosensor element sets (i.e., the sub-arrays S(1), S(2) and S(3) of photosensor elements 32a in the photosensor array PA(n,m)). The specific subroutines shown in FIGS. 8A and 8B corresponding to the general steps shown in FIG. 7 are also used with the general steps shown in FIG. 9.

In step S201, light incident on the lens 30 is focused in step S210 onto the photosensor array 32 comprising the first, second and third sets of photosensor elements 32a in zones a, b and c, respectively. Next, in step S211, the light incident on the first photosensor element set in zone a generates a first set of photosensor element signals, which, in step S211', are then stored in RAM and later used by the logic circuit 46 to determine a first peak light signal in step S212.

In step S221, the light incident on the second photosensor element set in zone b generates a second set of photosensor element signals, while in step S231, the light incident on the third photosensor element set in zone c generates a third set of photosensor element signals. The second set of photosensor element signals, generated in step S221 are also stored in step 221' in RAM and then used by the logic circuit 46 to determine a second peak light signal in step S222. Similarly, the third set of photosensor element signals, generated in step S231, is next stored in step S231' in RAM and then used by the logic circuit 46 to determine a third peak light signal in step S232.

In step S213, photosensor element signals generated from selected photosensor elements on which light is incident in step S210 are used to determine the background light signal.

In step S214, the logic circuit 46 uses the background light signal determined in step S213 and the first peak light signal determined in step S212 to determine a first control signal. Similarly, the logic circuit 46 uses the background light signal of step S213 and the second peak light signal determined in step S222 to determine a second control signal in step S224. In the same manner, the background light signal of step S213 and the third peak light signal of step S232 are used by the logic circuit 46 to determine a third control signal in step S234.

The first control signal determined in step S214 is used by the drive circuit 24a to generate a first drive signal in step S215. This first drive signal drives the rearview mirror 28a to a desired reflectance level in step S216. Likewise, the second control signal determined by the logic circuit 46 in step S224 is used by the drive circuit 24b to generate a second drive signal in step S225, which is then used to drive the left side view mirror 28b to a desired reflectance level in step S226. Finally, the third control signal determined by the logic circuit 46 in step S234 is used by the drive circuit 24c to generate a third drive signal to drive the right side view mirror 28c to a desired reflectance level in step S236. Of course, the first, second and third control signals may also be used to control the segments of a mirror 28.

Finally, as previously discussed, one advantage of the present invention is that it is able to use a single photosensor array 32 to determine both a background light level and a peak light level for controlling the reflectance level of a mirror. This is especially advantageous where the sensor must be placed outside the interior of the vehicle to view the rearward scene. This may be required, for example, in certain truck type vehicles where only exterior side view mirrors may be used and automatic operation is desired. Accordingly, the photosensor array 32 may be located with each side view mirror. The other electronics for the automatic rearview mirror system 20, described previously, may be located either with the photosensor array 32 in each side view mirror, inside the vehicle cab or elsewhere in or on the vehicle. A desired reflectance level for each exterior side view mirror may then be accurately determined using both the determined background light level and peak light level using only a single photosensor array 32 for each mirror.

VI. Integrated Headlight Control System

It is generally important for driver safety reasons that the headlights and sidelights of operating vehicles are turned on as night approaches or when background lighting levels fall below approximately 500 lux. More particularly, it is desirable to have the vehicle's headlights and sidelights automatically turn on when background lighting levels fall to a sufficiently low level and automatically turn off when background lighting levels rise sufficiently.

While there are other automatic headlight control systems, such systems require that the photocells, which are used to control the headlights, be located and positioned so that they generally face upward either to avoid the effects of oncoming headlights for generally forward facing photocells or to avoid the effects of following headlights for generally rearward facing photocells.

An advantage of the automatic rearview mirror system 20 is that the background light signal B_{Lt} may be used to automatically turn on and off a vehicle's headlights and sidelights by controlling the vehicle lighting switch 45. Importantly, since B_{Lt} is determined regardless of the presence of peak light sources, such as oncoming or following headlights, the directional constraints on how and where the sensor is located or positioned are avoided. Accordingly, using the photosensor array 32 of the present invention to provide additional vehicle lighting control functions results in lower costs and improved reliability over other headlight control systems.

The limited background light signal B_{Lt} has been described for the purpose of controlling the reflectance levels of an automatic rearview mirror system 20. Additionally, the logic circuit 46 may use B_{Lt} to generate a vehicle lighting control signal to control the vehicle lighting switch 45 to turn on and off automatically the vehicle's headlights and sidelights. The ability to use B_{Lt} is important because the vehicle lighting switch 45 should not be responsive to rapid or small fluctuations in background light levels in the region of the desired point at which the vehicle lighting switch is turned on or off, i.e., the switch point. Such fluctuations can be caused by the shadowing effect of overhanging trees or structures or the lighting differences between the eastern and western skylines at dawn and dusk which may be encountered when turning the vehicle.

Additionally, hysteresis is also provided between the switch-on and switch-off conditions of the vehicle lighting switch **45** to further stabilize operation of the switch **45** in such fluctuating light conditions. More specifically, if the required switch point for falling light levels is SP, then the switch point for rising light levels is SP×(1+H), where H is a hysteresis factor typically in the range of about 0.005 to 0.5, but is preferably 0.2. Thus, if B_{L_l} is less than SP, then the vehicle lighting control signal to the vehicle lighting switch **45** is set high to turn on the vehicle's headlights and sidelights. If B_{L_l} is greater than SP×(1+H), then the vehicle lighting control signal to the vehicle lighting switch **45** is set low to turn off the vehicle's headlights and sidelights.

Additionally, if the photosensor array **32** and logic circuit **46** are both powered directly by the vehicle's electrical system through the ignition switch, then a time delay t_d may be provided such that if the ignition switch is turned off when the headlight control signal is set high, the vehicle lighting control signal will remain high for a time t_d and thereafter fall to a low value to turn off the vehicle's headlights and sidelights. A manual control may also be provided to allow the driver to adjust the time delay t_d.

Finally, the vehicle lighting control signal and, more specifically, the lighting control switch **45** may also be used to inhibit automatic control of the automatic rearview mirror system **20**. For example, if the vehicle lighting control signal indicates that the vehicle lighting should be turned off, then the logic and control circuit **34** may be used to enable sensitivity switch **42** or some other switch allowing the driver to manually adjust the reflectance level of the mirrors **28**. Thus, the driver may manually select a lower reflectance level during daylight conditions to provide protection against peak light sources, such as a bright setting sun. As background light levels fall or during non-daylight conditions, the vehicle lighting control signal would indicate non-daylight conditions and the logic and control circuit **34** may then be used to disable manual control and return the automatic rearview mirror system **20** to full automatic control.

VII. The Automatic Rearview Mirror System

FIG. **10** also shows the automatic rearview mirror system **20** of the present invention. The system **20** is powered by the vehicle's electrical system (not shown) to which the system **20** is connected. A voltage regulation and transient protection circuit **22** regulates power and protects the system **20** from voltage transients as is well known in the art. The circuit **22** is connected to the vehicle's electrical system and to ground, and outputs a voltage of up to about 5 volts to power the mirror drive circuits **24** and the light sensing and logic circuit **26**. The circuit **22** also has a ground line connected to the light sensing and logic circuit **26**.

The 5 volt line is also connected to the force-to-day switch **36** and the reverse-inhibit switch **38** (connected in parallel to the light sensing and logic circuit **26**) which are used to force the mirrors **28** to their maximum reflectance level. More particularly, when either of these switches is closed, they generate a high level signal V_H such as a 3 volt signal, which is input to the light sensing and logic circuit **26**. This high level signal overrides the normal operation of the light sensing and logic circuit **26** causing it to output a control signal to the drive circuits **24** to drive the mirrors **28** to their maximum reflectance level. Conversely, when these switches are open, they each generate a low level signal V_L such as a signal of less than 3 volts, thereby permitting normal operation of the light sensing and logic circuit **26**, as has been discussed with respect to FIGS. **7**, **8A** and **8B**. The force-to-day switch **36** and the reverse-inhibit switch **38** may be alternatively configured to generate a low level signal when closed and a high level signal when open. The force-to-day switch **36** is a manually operated switch and is preferably placed on the rearview mirror **28a** and may be switch **3**. The reverse-inhibit switch **38** is connected to a reverse inhibit line in the vehicle's electrical system (not shown) so that the reverse-inhibit switch **38** is actuated automatically whenever the vehicle is in reverse gear.

The force-to-night switch **40**, used to force the mirrors **28** to their minimum reflectance level, generates a high level signal V_H when closed and a low level signal V_L when opened. The signal V_H or V_L is then input to the light sensing and logic circuit **26**. The high level signal may, for example, be between 3 to 5 volts and the low level signal may be below 3 volts. The high level signal overrides the normal operation of the light sensing and logic circuit **26**, as discussed with respect to FIGS. **7**, **8A** and **8B**, causing the circuit **26** to output a control signal to the drive circuits **24** to drive the mirrors **28** to their minimum reflectance level. The low level signal, on the other hand, permits normal operation of the light sensing and logic circuit **26**. Alternatively, the force-to-night switch **40** may be configured to generate a low level signal when closed and a high level signal when open. The force-to-night switch **40** is also a manually operable switch, preferably located on the rearview mirror **28a**, and may also be switch **3**.

The light sensing and logic circuit **26** is also connected to the sensitivity control circuit **42**. The circuit **42** enables the operator to manually adjust the sensitivity of the mirrors **28** using the switch **3** (shown in FIGS. **1A** and **1B**). The sensitivity control circuit **42** (switch **3**) may comprise a potentiometer whose voltage may be varied from zero to five volts. Alternatively, a single resistor may be used to provide a single preset sensitivity setting that cannot be changed by the driver.

As previously discussed with respect to FIGS. **5** and **6**, the light sensing and logic circuit **26** comprises the photosensor array **32** (or other light sensing device) and the logic and control circuit **34**. These two devices may be either separate or commonly located on a single semiconductor substrate. The light sensing and logic circuit **26** is preferably a single VLSI CMOS circuit.

Also shown in FIG. **10**, the light sensing and logic circuit **26** outputs analog mirror control signals having voltages varying from zero to approximately 5 volts to the mirror drive circuits **24** and a vehicle lighting control signal of 0 to 5 volts to the vehicle lighting switch **45**. Alternatively, as previously discussed the light sensing and logic circuit **26** may output a 5 volt pulse-width-modulated (PWM) signal to the mirror drive circuits **24**. The mirror drive circuits **24** then generate and apply drive voltages varying from a low voltage on the order of 0 volts to a high voltage on the order of 1 volt to drive the mirrors **28**. The actual driving voltage (or current) may, of course, be significantly lower or higher depending on the variable reflectance mirror element **1a** used.

Each of the mirrors **28** preferably comprises a reflective electrochromic (EC) cell whose reflectance level may be varied from a maximum of anywhere from approximately 50 to 90 percent to a minimum of approximately 4 to 15 percent, and having a maximum driving voltage on the order of about 1 to 2 volts. As is well known in the art, electrochromic devices change their reflectance level when a voltage or other appropriate drive signal is applied to the electrochromic device. The mirrors **28** alternatively may comprise any other suitable variable reflectance mirror.

As previously discussed, it is also within the scope of the present invention for the light sensing and logic circuit **26** to be located remotely from the mirrors **28** of the system **20**. However, it is preferred that the light sensing and logic circuit **26** be integral with the rearview mirror **28***a* such that: (1) the center line of the field of view of the photosensor array **32** is substantially perpendicular to the reflective surface of the rearview mirror **28***a*; and (2) the horizontal field of view of the photosensor array **32** is aligned with the horizontal axis of the rearview mirror **28***a*. As a result, the photosensor array **32** receives the light that will be incident on the rearview mirror **28***a* as shown in FIG. **6**.

The individual components represented by the blocks shown in the schematic block diagrams of FIGS. **6** and **10** are well known in the art relating to automatic rearview mirrors, and their specific construction and operation is not critical to the invention or the best mode for carrying out the present invention. Moreover, the logic flow charts discussed in the specification and shown in FIGS. **7**, **8A** and **8B** may be implemented in digital hardwired logic or programmed into well-known signal processors, such as microprocessors, by persons having ordinary skill in the art. Since such digital circuit construction or programming per se is not part of the invention, no further description thereof is deemed necessary.

While the present invention has been described in connection with what are the most practical and preferred embodiments as currently contemplated, it should be understood that the present invention is not limited to the disclosed embodiments. Accordingly, the present invention is intended to cover various modifications and equivalent arrangements, methods and structures that are within the spirit and scope of the claims.

What is claimed is:

1. An automatic rearview mirror system for an automotive vehicle comprising:

at least one variable reflectance rearview mirror;

an array of sensing elements to sense light levels in an area rearward of said at least one variable reflectance rearview mirror, each of said sensing elements adapted to sense light levels of light incident thereon and to output an electrical signal indicative of said sensed light levels;

a signal processor, connected to said array of sensing elements, receiving and using the electrical signals indicative of the sensed light levels from said sensing elements to determine a first electrical signal indicative of a background light level in the area rearward of said at least one variable reflectance rearview mirror and to determine a second electrical signal indicative of at least one peak light level in the area rearward of said at least one variable reflectance rearview mirror,

wherein said signal processor determines at least one control signal indicative of a desired reflectance level of the at least one variable reflectance rearview mirror from the first electrical signal indicative of the background light level and the second electrical signal indicative of the at least one peak light level; and

at least one drive circuit connected to said signal processor and to said at least one variable reflectance rearview mirror for receiving said at least one control signal and generating and applying at least one drive signal to said at least one variable reflectance rearview mirror to drive said at least one variable reflectance mirror to the desired reflectance level.

2. The automatic rearview mirror system defined by claim 1, further comprising an imaging system to focus an image of the area rearward of said at least one variable reflectance rearview mirror onto said array.

3. The automatic rearview mirror system defined by claim 2, wherein said imaging system comprises a lens.

4. The automatic rearview mirror system defined by claim 3, further comprising a semiconductor substrate on which said array of sensing elements is formed.

5. The automatic rearview mirror system defined by claim 4, wherein said imaging system is constructed integrally with said array of sensing elements.

6. The automatic rearview mirror system defined by claim 5, wherein said array of sensing elements and said signal processor are constructed on said semiconductor substrate as an integrated circuit.

7. The automatic rearview mirror system defined by claim 1, wherein said at least one variable reflectance rearview mirror is an electrochromic mirror.

8. The automatic rearview mirror system defined by claim 1, wherein said signal processor is an integrated circuit.

9. The automatic rearview mirror system defined by claim 1, further comprising a memory, connected to said array and to said signal processor, receiving and storing the electrical signals output by said sensing elements, wherein said signal processor receives the electrical signals stored in said memory.

10. The automatic rearview mirror system defined by claim **9**, wherein said memory is a random-access-memory.

11. The automatic rearview mirror system defined by claim **1**, wherein said signal processor is a microprocessor.

12. The automatic rearview mirror system defined by claim **1**, further comprising a memory that is connected to said array and said signal processor, wherein said memory receives and stores the electrical signals output by said sensing elements and outputs the electrical signals to the signal processor,

wherein said signal processor uses the electrical signals output from said memory to determine the first and second electrical signals and stores the first and second electrical signals in said memory,

wherein said signal processor uses the first and second electrical signals output from said memory to determine the at least one control signal.

13. The automatic rearview mirror system defined by claim **1**, wherein said signal processor determines said second electrical signal indicative of at least one peak light level in at least one zone of said area rearward of said at least one variable reflectance rearview mirror.

14. The automatic rearview mirror system defined by claim **13**,

wherein said signal processor determines a plurality of the second electrical signals indicative of a plurality of peak light levels, wherein each of the second electrical signals correspond to at least one zone of the area rearward of said at least one variable reflectance mirror, and

wherein said signal processor determines and outputs a corresponding plurality of the control signals based on the first and the plurality of second electrical signals.

15. The automatic rearview mirror system defined by claim **1**, wherein said signal processor samples the electrical signals indicative of the sensed light levels at a substantially constant sampling rate and varies the exposure time relative to the background light level.

16. The automatic rearview mirror system defined by claim **1**, wherein said array of sensing elements is a photosensor array and said sensing elements are photosensor elements arranged in a two-dimensional array of rows and columns, wherein each of said photosensor elements generates a photosensor element signal indicative of the light levels of light incident thereon.

17. The automatic rearview mirror system defined by claim 16, wherein said signal processor determines the first electrical signal indicative of the background light level by calculating an average of the photosensor element signals indicative of the light levels of light incident on said photosensor elements in the lowest X rows of said photosensor array, wherein X is a positive integer less than the number of rows in said photosensor array.

18. The automatic rearview mirror system defined by claim 16, wherein said signal processor determines the first electrical signal indicative of the background light level by using X percent of the photosensor element signals indicative of the light levels of light incident on said photosensor elements, wherein X is a positive number not greater than 100, and averaging said X percent of the photosensor element signals.

19. The automatic rearview mirror system defined by claim 18 wherein X is approximately 100.

20. The automatic rearview mirror system defined by claim 16, wherein said signal processor determines the first electrical signal indicative of the background light level by using X percent of the photosensor element signals indicative of the lowest light levels of light incident on said photosensor elements, wherein X is a positive number not greater than 100, and averaging said X percent of the photosensor element signals.

21. The automatic rearview mirror system defined by claim 20, wherein X is between approximately 5 and 100.

22. The automatic rearview mirror system defined by claim 20, wherein X is approximately 75.

23. The automatic rearview mirror system defined by claim 16, wherein said signal processor determines the second electrical signal indicative of the at least one peak light level by using Y percent of the photosensor element signals indicative of the highest light levels of light incident on a predetermined set of said photosensor elements, wherein Y is a positive number not greater than 100, and averaging said Y percent of the photosensor element signals.

24. The automatic rearview mirror system defined by claim 23, wherein Y is in the range of from approximately 1 to 25.

25. The automatic rearview mirror system defined by claim 23, wherein Y is approximately 10.

26. The automatic rearview mirror system defined by claim 16, wherein said signal processor determines said control signal according to the formula:

$$V_C(z)=V_1+(R_1-S\times C_T\times B/P(z))\times(V_2-V_1)/(R_1-R_2),$$

wherein V_C is the voltage of the at least one control signal determined by said signal processor, V_1 is the approximate voltage which, when applied to said at least one variable reflectance rearview mirror, causes said at least one variable reflectance rearview mirror to begin perceptibly decreasing its reflectance from its maximum reflectance level R_1, S is a sensitivity factor, C_T is the maximum contrast ratio of the peak light level to the background light level, B is the background light level, P(z) is the at least one peak light level, and V_2 is the approximate voltage which, when applied to said at least one variable reflectance rearview mirror, causes said at least one variable reflectance rearview mirror to decrease its reflectance to approximately its minimum reflectance level R_2.

27. The automatic rearview mirror system defined by claim 16, wherein said signal processor tests the photosensor element signal output from each photosensor element to determine whether the photosensor element signal output from each photosensor element is indicative of a peak light level or a background light level.

28. The automatic rearview mirror system defined by claim 27, further comprising an imaging system comprising a lens to focus an image of the area rearward of said at least one variable reflectance rearview mirror onto said photosensor array of photosensor elements, wherein said system further comprises means for applying a lens correction factor to each photosensor element signal output from each photosensor element.

29. The automatic rearview mirror system defined by claim 28, wherein the lens correction factor is in the range of approximately 1 to 15.

30. The automatic rearview mirror system defined by claim 27, wherein said signal processor determines a value indicative of the light level sensed by each photosensor element and compares each determined value with a predetermined peak threshold value to determine whether the photosensor element signal output from each photosensor element is indicative of a peak light level or a background light level.

31. The automatic rearview mirror system defined by claim 1,

wherein said signal processor determines that a photosensor element signal output from one of said photosensor elements is indicative of a background light level when the determined value indicative of the sensed light level of said one of said photosensor elements is not greater than the peak threshold value, and

wherein said signal processor determines that a photosensor element signal output from said one of said photosensor elements is indicative of a peak light level when the determined value indicative of the sensed light level of said one of said photosensor elements is greater than the peak threshold value.

32. The automatic rearview mirror system defined by claim 31, wherein the peak threshold value is in the range of approximately 200 to 255.

33. The automatic rearview mirror system defined by claim 31, wherein said signal processor counts the number of determined values greater than the peak threshold value in a predetermined set of determined values corresponding to a predetermined set of photosensor elements and determines the second electrical signal indicative of the at least one peak light level in the area rearward of said at least one variable reflectance rearview mirror as a function of the number of determined values greater than the peak threshold value in the predetermined set of determined values.

34. The automatic rearview mirror system defined by claim 30, wherein said signal processor determines the first electrical signal, indicative of a background light level by summing the determined values determined to be not greater than the peak threshold value and dividing the resulting sum by the number of determined values determined to be not greater than the peak threshold value.

35. The automatic rearview mirror system defined by claim 30,

wherein said photosensor array means is located in said at least one variable reflectance rearview mirror so as to receive light through an active layer of said at least one variable reflectance rearview mirror from the area rearward of said at least one variable rearview reflectance,mirror, and

wherein said signal processor applies a color correction factor to each value indicative of the sensed light level for each photosensor element to compensate for the reduction in transmitted light levels when the reflectance level of said at least one variable reflectance rearview mirror is reduced.

36. The automatic rearview mirror system defined by claim 16,

wherein said signal processor uses the first electrical signal to determine a third electrical signal indicative of a change-limited background light level in the area rearward of said at least one variable reflectance rearview mirror, and

wherein said signal processor determines the at least one control signal from the second and third electrical signals.

37. The automatic rearview mirror system defined by claim 36,

wherein the automotive vehicle further comprises vehicle lighting,

wherein said signal processor determines a vehicle lighting control signal using the third electrical signal,

wherein said system further comprises at least one vehicle lighting switch, connected to said signal processor and to the vehicle lighting, receiving the vehicle lighting control signal from said signal processor and turning on or turning off the vehicle lighting in response thereto.

38. The automatic rearview mirror system defined by claim 1, wherein said at least one variable reflectance rearview mirror comprises a plurality of segments each of whose reflectance is independently controllable by said signal processor, and wherein said signal processor controls each of the segments of said at least one variable reflectance rearview mirror using the electrical signals from a corresponding set of sensing elements of said array.

39. The automatic rearview mirror system defined by claim 1, wherein the light levels in the area rearward of said at least one variable reflectance rearview mirror comprise light levels from a rear window area, at least a portion of a right side window area and at least a portion of a left side window area, and

wherein said photosensor array has a two-dimensional field of view comprising said rear window area, said at least a portion of a right side window area and said at least a portion of a left side window area.

40. The automatic rearview mirror system defined by claim 39, wherein said photosensor array comprises 40 rows of said photosensor elements, each row comprising 160 of said photosensor elements.

41. The automatic rearview mirror system defined by claim 1, wherein the system comprises a plurality of said drive circuits and the variable reflectance rearview mirrors,

wherein said signal processor determines and outputs a plurality of the control signals to said plurality of said drive circuits, each of the control signals corresponding to a desired reflectance for each of said plurality of variable reflectance rearview mirrors, and

wherein said plurality of said drive circuits, in response to the control signals, generate and apply a plurality of said drive signals to said plurality of variable reflectance rearview mirrors causing each of said variable reflectance rearview mirrors to assume a desired reflectance level associated therewith.

42. The automatic rearview mirror system defined by claim 41, wherein said photosensor array comprises a plurality of photosensor element sets, each of said sets corresponding to each of said plurality of variable reflectance rearview mirrors,

wherein said signal processor determines and outputs a plurality of said second electrical signals indicative of the at least the one peak light level,

wherein said signal processor uses the first electrical signal indicative of the background light level and the plurality of said second electrical signals to determine and output the control signal for each of said plurality of said drive circuits and said variable reflectance rearview mirrors associated therewith.

43. The automatic rearview mirror system defined by claim 41, wherein said photosensor array comprises a first photosensor element set and a second photosensor element set, and a lens for focusing light from a rear window area and from at least a portion of a side window onto said photosensor array,

wherein said signal processor determines a first peak light signal indicative of a peak light level of light incident on the first photosensor element set,

wherein said signal processor determines a second peak light signal indicative of a peak light level of light incident on the second photosensor element set,

wherein said signal processor determines and outputs a first control signal indicative of a desired reflectance level for one of said plurality of variable reflectance rearview mirrors using the first peak light signal and the first electrical signal indicative of the background light level,

wherein said signal processor determines and outputs a second control signal indicative of a desired reflectance level for another of said plurality of variable reflectance rearview mirrors using the second peak light signal and the first electrical signal indicative of the background light level,

wherein said first control signal is received by one of said plurality of drive circuits which generates and applies a first drive signal to one of said plurality of variable reflectance rearview mirrors causing it to assume the desired reflectance level associated therewith, and

wherein said second control signal is received by another of said plurality of drive circuits which generates and applies a second drive signal to another of said plurality of variable reflectance rearview mirrors causing it to assume the desired reflectance level associated therewith.

44. The automatic rearview mirror system defined by claim 43, wherein said plurality of variable reflectance rearview mirrors comprise a rearview mirror, a left side view mirror and a right side view mirror,

wherein said photosensor array further comprises a third photosensor element set,

wherein said light focused from said at least a portion of a side window area comprises light from at least a portion of a left side window area and light from at least a portion of a right side window area,

wherein said signal processor determines a first peak light signal indicative of a peak light level incident on the first photosensor element set,

wherein said signal processor determines a second peak light signal indicative of a peak light level incident on the second photosensor element set,

wherein said signal processor determines a third peak light signal indicative of a peak light level incident on the third photosensor element set,

wherein said signal processor determines and outputs first, second and third control signals indicative of a desired reflectance for said rearview mirror, said left side view mirror and said right side view mirror, respectively, using each of the first, second, and third peak light signals and the first electrical signal indicative of the background light level, wherein each of the first, second and third control signals are output to each of said drive circuits associated therewith to generate and apply a first, second and third drive signal to said rearview mirror, said left side view mirror, and said right side view mirror, respectively, causing said mirrors to assume the desired reflectance level associated therewith.

45. The automatic rearview mirror system defined by claim 1, wherein said array of sensing elements comprises an analog photosensor array of photosensor elements, each of said photosensor elements generating analog photosensor element signals in response to light incident thereon,

wherein said system further comprises an analog-to-digital converter connected to said analog photosensor array and said signal processor to convert the analog photosensor element signals to digital photosensor element signals,

wherein said signal processor determines the first electrical signal indicative of the background light level using the digital photosensor element signals,

wherein said signal processor determines the second electrical signal indicative of at least one peak light level using the digital photosensor element signals,

wherein the control signal determined by said signal processor is a digital control signal,

wherein said system further comprises a digital-to-analog converter connected to said signal processor and to said at least one drive circuit to convert the digital control signal to an analog control signal, and

wherein said at least one drive circuit receives the analog control signal and in response thereto generates and applies a drive signal to said at least one variable reflectance rearview mirror to vary its reflectance level.

46. A control system for controlling a plurality of variable reflectance mirrors, each of which change their reflectance level in response to a drive signal from an associated drive circuit, for an automotive vehicle, comprising:

a plurality of variable reflectance mirrors;

a photosensor array mountable to face substantially towards a rearward area, wherein said photosensor array comprises a plurality of photosensor element sets, each set comprising a plurality of photosensor elements, each of said photosensor elements generating a photosensor element signal indicative of a light level of light incident thereon, and each of the sets corresponding to one of said plurality of variable reflectance mirrors,

a control circuit, connected to said photosensor array, for determining and applying a plurality of control signals, each of the control signals indicative of a desired reflectance level for each of said plurality of variable reflectance mirrors in response to receiving the photosensor element signals from each of the plurality of photosensor element sets,

a plurality of drive circuits connected to said control circuit, each of said plurality of drive circuits being connected to different ones of said plurality of variable reflectance mirrors associated therewith,

wherein each of the control signals is output to said drive circuit associated therewith, to generate and apply a drive signal to each of said plurality of variable reflectance mirrors causing each of said mirrors to assume a reflectance level.

47. The control system defined by claim 46, wherein said control circuit determines a background light signal indicative of a background light level in response to receiving the photosensor element signals from at least one of the photosensor element sets,

wherein said control circuit determines a plurality of peak light signals, each of said peak light signals being indicative of a peak light level incident on each of the photosensor element sets,

wherein said control circuit determines a plurality of control signals, each of the control signals determined by using the background light signal and one of the plurality of peak light signals, associated with each of the plurality photosensor element sets,

wherein said control circuit applies each of the plurality of control signals to a drive circuit associated therewith, each of said drive circuits generating and applying a drive signal to each of said variable reflectance mirrors associated therewith.

48. The control system defined by claim 47, wherein said photosensor array comprises a first set and a second set of photosensor elements, and a lens for focusing light from a rearward area onto said photosensor array,

wherein said control circuit determines a first peak light signal indicative of a peak light level incident on the first photosensor element set in response to receiving photosensor element signals from the first photosensor element set,

wherein said control circuit determines another peak light signal indicative of another peak light level incident on the second photosensor element set in response to receiving photosensor element signals from the second photosensor element set,

wherein said control circuit determines a first control signal indicative of a desired reflectance for one of said plurality of variable reflectance mirrors using the first peak light signal and the background light signal,

wherein said control circuit determines a second control signal indicative of another desired reflectance for another of said plurality of variable reflectance mirrors using the another peak light signal and the background light signal,

wherein the first control signal controls a first drive circuit to generate a first drive signal in response to which said one of said plurality of variable reflectance mirrors is driven to the desired reflectance associated therewith, and

wherein said second control signal controls a second drive circuit to generate a second drive signal in response to which said another of said plurality of variable reflectance mirrors is driven to the desired reflectance associated therewith.

49. The control system defined by claim 48, wherein said plurality of variable reflectance mirrors comprise a rearview mirror, a left side view mirror and a right side view mirror,

wherein said light from said rearward area comprises light from a rear window area, light from a left side window area and light from a right side window area,

wherein said photosensor array further comprises a third photosensor element set, each of said photosensor elements generating a photosensor element signal indicative of a light level incident thereon,

wherein said control circuit determines a first peak light signal indicative of a peak light level incident on the first photosensor element set in response to receiving photosensor element signals from the first photosensor element set, wherein said control circuit determines a second peak light signal indicative of a second peak light level incident on the second photosensor element set in response to receiving photosensor element signals from the second photosensor element set,

wherein said control circuit determines a third peak light signal indicative of a third peak light level incident on the third photosensor element set in response to receiving photosensor element signals from the third photosensor element set,

wherein said control circuit determines a first control signal indicative of a desired reflectance level of said rearview mirror using the first peak light signal, and the background light signal,

wherein said control circuit determines a second control signal indicative of a desired reflectance level of said left side view mirror using the second peak level signal and the background light signal,

wherein said control circuit determines a third control signal indicative of a desired reflectance level of said right side view mirror using the third peak light signal and the background light signal,

wherein said first control signal controls a first drive circuit to generate a first drive signal in response to which said rearview mirror is driven to the desired reflectance level associated therewith,

wherein said second control signal controls a second drive circuit to generate a second drive signal in response to which said left side view mirror is driven to the desired reflectance level associated therewith, and

wherein said third control signal controls a third drive circuit to generate a third drive signal in response to which said right side view mirror is driven to the desired reflectance level associated therewith.

50. A control system for controlling at least one variable reflectance mirror for an automotive vehicle, comprising:

photosensor array means for sensing light levels in an area rearward of said at least one variable reflectance mirror and generating photosensor array signals,

means for determining a background light signal from the photosensor array signals;

means for determining a peak light signal from the photosensor array signals; and

means for controlling a reflectance level of the at least one variable reflectance mirror using the background and peak light signals.

51. The control system defined by claim **50**, wherein said controlling means comprises:

desired reflectance level determining means for determining a desired reflectance level for the at least one variable reflectance mirror by using said background and peak light signals; and

desired reflectance control means for controlling the reflectance level of the at least one variable reflectance mirror using the determined desired reflectance level.

52. The control system defined by claim **51**,

wherein said photosensor array means comprises a plurality of photosensor elements arranged in a two-dimensional array of rows and columns, each of said plurality of photosensor elements generating a photosensor element signal indicative of a light level incident thereon,

wherein said means for determining a background light signal determines the background light signal by calculating an average of the photosensor element signals corresponding to the light levels incident on said photosensor elements in the lowest X rows of said photosensor array means, wherein X is a positive integer less than the number of rows in said photosensor array means.

53. The control system defined by claim **51**,

wherein said photosensor array means comprises a plurality of photosensor elements, each photosensor element generating a photosensor element signal indicative of a light level of light incident thereon,

wherein said means for determining a background light signal determines a background light signal by using X percent of the photosensor element signals, wherein X is a positive number not greater than 100, and averaging said X percent of the photosensor element signals.

54. The control system defined by claim **53**, wherein X is approximately 100.

55. The control system defined by claim **51**, wherein said photosensor array means comprises a plurality of photosensor elements, each photosensor element generating a photosensor element signal indicative of a light level of light incident thereon,

wherein said means for determining a background light signal determines a background light signal by using X percent of the photosensor element signals indicative of the lowest light levels incident on said photosensor elements, wherein X is a positive number not greater than 100, and averaging said X percent of the photosensor element signals.

56. The control system defined by claim **55**, wherein X is between approximately 5 and 100.

57. The control system defined by claim **55**, wherein X is approximately 75.

58. The control system defined by claim **51**, wherein said photosensor array means comprises a plurality of photosensor elements for sensing light levels in an area rearward of said at least one variable reflectance mirror, each photosensor element generating photosensor element signals indicative of a light level incident thereon,

wherein said means for determining a peak light signal determines a peak light signal by determining the average value of Y percent of the photosensor element signals indicative of the highest light levels of light incident on a predetermined set of said photosensor elements, wherein Y is a positive number not greater than 100, and averaging said Y percent of the photosensor element signals.

59. The control system defined by claim **58**, wherein Y is in the range of approximately 1 to 25.

60. The control system defined by claim **58**, wherein Y is approximately 10.

61. The control system defined by claim **51**, wherein said desired reflectance level determining means determines a control signal indicative of the desired reflectance level according to the formula:

$$V_C(z)=V_1+(R_1-S\times C_T\times B/P(z))\times(V_2-V_1)/(R_1-R_2)$$

wherein V_C is the voltage of the at least one control signal determined by said signal processor, V_1 is the approximate voltage which, when applied to said at least one variable reflectance mirror, causes said at least one variable reflectance mirror to begin perceptibly decreasing its reflectance from its maximum reflectance level R_1, S is a sensitivity factor, C_T is the maximum contrast ratio of the peak light level to the background light level, B is the background light level, P(z) is the at least one peak light level, and V_2 is the approximate voltage which, when applied to said at least one variable reflectance mirror, causes said at least one variable reflectance mirror to decrease its reflectance to approximately its minimum reflectance level R_2.

62. The control system defined by claim **51**, wherein said means for determining a peak light signal tests the photosensor array signals to determine whether each photosensor array signal is indicative of a peak light level, and

wherein said means for determining a background light signal tests the photosensor array signals to determine whether each photosensor array signal is indicative of a background light level.

63. The control system defined by claim **62**, further comprising an imaging system comprising a lens to focus an image of the area rearward of said at least one variable reflectance mirror onto said photosensor array means, and means for applying a lens correction factor to each photosensor array signal.

64. The control system defined by claim **63**, wherein the lens correction factor is in the range of approximately 1 to 15.

65. The control system defined by claim **62**, wherein said means for determining a peak light signal determines a value indicative of the second light level corresponding to each photosensor array signal and compares each determined value with a predetermined peak threshold value to determine whether each photosensor array signal is indicative of a peak light level, and

wherein said means for determining a background light signal determines a value indicative of the sensed light level corresponding to each photosensor array signal and compares each determined value with a predetermined peak threshold value to determine whether each photosensor array signal is indicative of a background light level.

66. The control system defined by claim **65**,

wherein said means for determining a background light signal determines that a photosensor array signal is indicative of a background light level when the determined value indicative of the sensed light level corresponding to one of the photosensor array signals is not greater than the peak threshold value, and

wherein said means for determining a peak light signal determines that a photosensor array signal is indicative of a peak light level when the determined value indicative of the sensed light level corresponding to the one of the photosensor array signals is not less than the peak threshold value.

67. The control system defined by claim **66**, wherein the peak threshold value is in the range of approximately 200 to 255.

68. The control system defined by claim **66**, wherein said means for determining the background light signal determines the background light signal by summing the determined values determined to be not greater than the peak threshold value and dividing the resulting sum by the number of determined values determined to be not greater than the peak threshold value.

69. The control system defined by claim **66**, wherein said means for determining the peak light signal counts the number of determined values not less than the peak threshold value in a predetermined set of determined values corresponding to a predetermined set of photosensor elements of said photosensor array means and determines the peak light signal in the area rearward of the at least one variable refelctance mirror as a function of the number of

determined values not less than the peak threshold value in the predetermined set of determined values.

70. The control system defined by claim **65**, further comprising a means for applying a color correction factor,

wherein said photosensor array means is located in the at least one variable reflectance mirror so as to receive light through an active layer of said at least one variable reflectance mirror from the area rearward of said at least one variable reflectance mirror, and

wherein said means for applying a color correction factor applies a color correction factor to each value indicative of the sensed light level for each photosensor array signal to compensate for the reduction in transmitted light levels when the reflectance level of the at least one variable reflectance mirror is reduced.

71. The control system defined by claim **51**,

wherein said desired reflectance level determining means uses the background light signal to determine a change-limited background light signal, and

wherein said desired reflectance level determining means uses the change-limited background signal to determine the desired reflectance level.

72. The control system defined by claim **51**, further comprising means for determining a plurality of peak light signals, wherein said means for determining a desired reflectance determines the desired reflectance for a plurality of variable reflectance mirrors using the background light signal and the plurality of the peak light signals, and

wherein said desired reflectance control means controls each of said plurality of variable reflectance mirrors using the desired reflectance for each of said plurality of variable reflectance mirrors.

73. The control system defined by claim **72**, wherein said photosensor array means comprises a first set and a second set of photosensor elements, and a lens for focusing light from a rear window area and from at least a portion of a side window onto said photosensor array means, each photosensor element generating a photosensor element signal indicative of a light level incident thereon,

wherein said means for determining a plurality of peak light signals determines a peak light signal indicative of a peak light level of light incident on the first photosensor element set from photosensor element signals of the first set and determines another peak light signal indicative of another peak light level of light incident on the second photosensor element set from photosensor element signals of the second set,

wherein said means for determining a desired reflectance determines the desired reflectance for one of said variable reflectance mirrors using the peak light signal corresponding to the first photosensor element set and the background light signal, and

wherein said means for determining a desired reflectance determines the desired reflectance for another of said variable reflectance mirrors using the peak light signal corresponding to the second photosensor element set and the background light level.

74. The control system defined by claim **73**, wherein the plurality of variable reflectance mirrors comprises a rearview mirror, a left side view mirror and a right side view mirror, wherein said light from a side window area comprises light from at least a portion of a left side window area and light from at least a portion of a right side window area,

wherein said photosensor array means comprises a third set of photosensor elements, each of said photosensor elements generating a photosensor element signal indicative of a light level incident thereon, wherein said means for determining a plurality of peak light signals determines a first peak light signal indicative of a peak light level of light incident on the first photosensor element set, a second peak light signal indicative of a peak light level of light incident on the second photosensor element set and a third peak light signal indicative of a peak light level of light incident on said third photosensor element set from photosensor element signals associated, respectively, with the first, second and third photosensor element sets,

wherein said means for determining a desired reflectance determines a desired reflectance of said rearview mirror using the first peak light signal and the background light signal,

wherein said means for determining a desired reflectance determines a desired reflectance of said left side mirror using the second peak light signal and the background light signal,

wherein said means for determining a desired reflectance determines a desired reflectance of said right side mirror using the third peak light signal and the background light signal, and

wherein said desired reflectance control means controls the rearview mirror, the left side mirror, and the right side mirror, respectively, using the desired reflectance of the rearview mirror, the left side mirror, and the right side mirror.

75. The control system defined by claim **51**, wherein said photosensor array signals are analog signals,

wherein said system further comprises analog-to-digital conversion means for converting the analog photosensor array signals to digital photosensor array signals,

wherein said means for determining a background light signal determines a background light signal from the digital photosensor array signals, and

wherein said means for determining a peak light signal determines a peak light signal from the digital photosensor array signals,

wherein said desired reflectance level determining means determines the desired reflectance level and produces a digital control signal indicative thereof,

wherein said system further comprises digital-to-analog conversion means to convert the digital control signal to an analog control signal, and

wherein said desired reflectance control means controls the reflectance level of the at least one variable reflectance mirror using the analog control signal.

76. A method of controlling the reflectance of at least one variable reflectance mirror comprising the steps of:

sensing light levels in an area rearward of the at least one variable reflectance mirror with an array of sensing elements;

determining a background light level from the sensed light levels;

determining a peak light level from the sensed light levels; and

controlling a reflectance level of the at least one variable reflectance mirror using the determined background and peak light levels.

77. The method defined by claim **76**,

wherein the array has a plurality of rows of sensing elements, and

wherein said step of determining a background light level comprises the step of determining the background light level by calculating an average of the sensed light levels in the lowest X rows of the array, wherein X is a positive integer less than the number of rows in the array.

78. The method defined by claim **76**, wherein said step of determining a background light level comprises the step of determining a background light level by using X percent of the sensed light levels, wherein X is a positive number not greater than 100, and averaging said X percent of the photosensor element signals.

79. The method defined by claim **76**, wherein said step of determining a background light level comprises the step of determining a background light level by using X percent of the lowest sensed light levels, wherein X is a positive number not greater than 100, and averaging said X percent of the photosensor element signals.

80. The method defined by claim **76**, wherein said step of determining a peak light level comprises the step of determining a peak light level by using Y percent of the sensed light levels indicative of the highest sensed light levels, wherein Y is a positive number not greater than 100, and averaging said Y percent of the photosensor element signals.

81. The method defined by claim **76**,

wherein the at least one variable reflectance mirror changes it reflectance in response to the application of a voltage thereto,

wherein said controlling step determines a desired reflectance level for the at least one variable reflectance mirror according to the formula:

$$V_C(z)=V_1+(R_1-S\times C_T\times B/P(z))\times(V_2-V_1)/(R_1-R_2),$$

wherein $V_C(z)$ is a voltage representing the desired reflectance level, V_1 is the approximate voltage which, when applied to the at least one variable reflectance mirror, causes the at least one variable reflectance mirror to begin perceptibly decreasing its reflectance from its maximum reflectance level R_1, S is a sensitivity factor, C_T is the maximum contrast ratio of the peak light level to the background light level B is the determined background light level, P(z) is the determined peak light level, and V_2 is the approximate voltage which, when applied to the at least one variable reflectance mirror, causes the at least one variable reflectance mirror to decrease its reflectance to approximately its minimum reflectance level R_2,

wherein said controlling step comprises the step of applying the voltage $V_C(z)$ to the at least one variable reflectance mirror to cause the at least one variable reflectance mirror to assume the determined desired reflectance level.

82. The method defined by claim **76**,

wherein said sensing step comprises the step of sensing the light level of light incident on each sensing element of the array, and

wherein said method further comprises the step of testing the light level sensed by each sensing element of the array to determine whether each light level is indicative of a peak light level or a background light level.

83. The method defined by claim **82**, wherein said testing step comprises the step of comparing each sensed light level of each sensing element of the array with a predetermined peak threshold value to determine whether each light level is indicative of a peak light level or a background light level.

84. The method defined by claim **83**,

wherein said testing step comprises the step of determining that a sensed light level of a sensing element is indicative of a background light level when the sensed light level is not greater than the peak threshold value, and

wherein said testing step further comprises the step of determining that a sensed light level of a sensing element is indicative of a peak light level when the sensed light level is greater than the peak threshold value.

85. The method defined by claim 84, wherein said background light level determining step comprises the step of determining a background light level by summing the sensed light levels sensed by each sensing element that are determined to be not greater than the peak threshold value and dividing the resulting sum by the number of sensed light levels determined to be not greater than the peak threshold value.

86. The method defined by claim 85, wherein said peak light level determining step comprises the steps of counting the number of sensed light levels greater than the peak threshold value in a predetermined set of sensed light levels corresponding to a predetermined set of sensing elements of the array, and determining a peak light level in the area rearward of the at least one variable reflectance mirror as a function of the number of sensed light levels greater than the peak threshold value in the predetermined set.

87. The method defined by claim 76, further comprising the step of:

determining a plurality of peak light levels for a plurality of areas rearward of the at least one variable reflectance mirror,

wherein said controlling step comprises the step of determining a desired reflectance for each of a plurality of variable reflectance mirrors using the determined background light level and the plurality of peak light levels, and

wherein said controlling step further comprises the step of controlling the reflectance of each of the plurality of variable reflectance mirrors using the determined desired reflectance for each of the plurality of variable reflectance mirrors.

* * * * *

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[45] Date of Patent: Aug. 24, 1993

[54] ELECTROCHEMICHROMIC SOLUTIONS, PROCESSES FOR PREPARING AND USING THE SAME, AND DEVICES MANUFACTURED WITH THE SAME

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[52] U.S. Cl. 359/272; 359/270; 359/265; 252/583; 252/586

[58] Field of Search 359/270, 272, 265; 252/586, 583

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[57] ABSTRACT

The present invention relates to electrochromic solutions and devices manufactured therefrom. More precisely, the invention relates to electrochemichromic solutions, and those devices manufactured with the same, that demonstrate superior responsiveness to those solutions known heretofore when an applied potential is introduced thereto. That is, the responsiveness observed in terms of solution coloring is of a greater rapidity, intensity and uniformity than those electrochemichromic solutions of the prior art. Preparation of these solutions involve the novel process of pre-treating at least one of the electrochemichromic compounds with a redox agent prior to placing it in contact with the other electrochemichromic compound. Moreover, the present invention relates to methods of preparing such novel solutions and processes for using these solutions to provide devices that exhibit and benefit from the aforementioned superior characteristics.

133 Claims, 1 Drawing Sheet

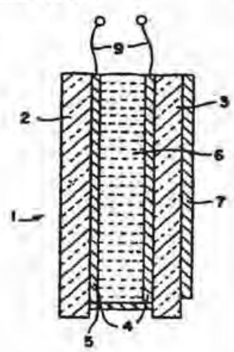

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FIG. 1

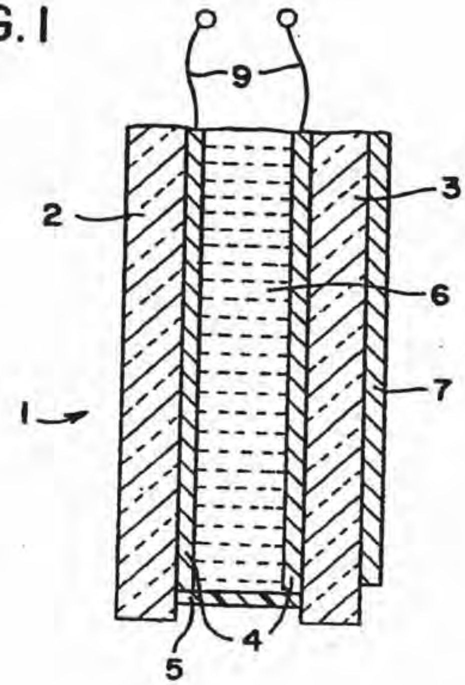
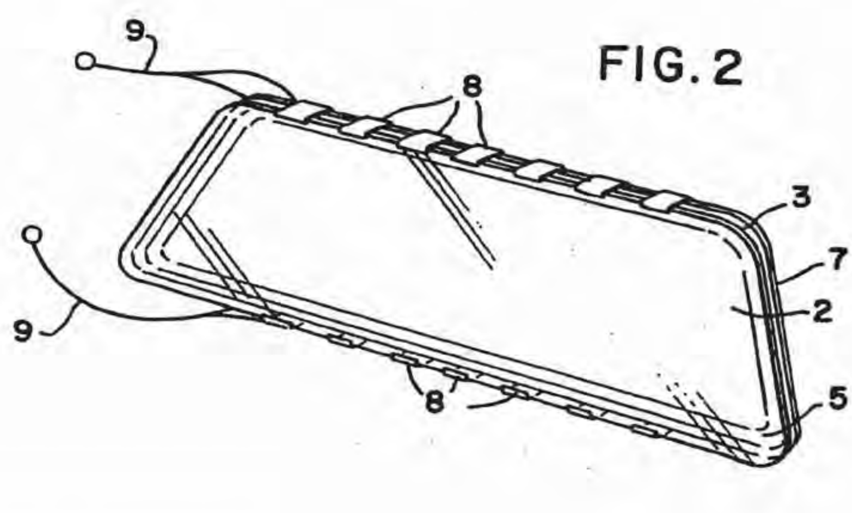


FIG. 2



ELECTROCHEMICHROMIC SOLUTIONS, PROCESSES FOR PREPARING AND USING THE SAME, AND DEVICES MANUFACTURED WITH THE SAME

BACKGROUND OF THE INVENTION

1. Technical Field of the Invention

The present invention relates to electrochromic solutions and devices manufactured therefrom. More particularly, the present invention relates to electrochemichromic solutions, and devices using the same, that demonstrate superior responsiveness to those solutions known heretofore when an applied potential is introduced thereto. That is, the responsiveness observed, in terms of solution coloring, is of a greater rapidity, intensity and uniformity than those prior art electrochemichromic solutions. In addition, the present invention relates to processes for preparing such novel solutions and processes for using these solutions to manufacture devices that exhibit the aforementioned superior characteristics and accordingly benefit therefrom.

2. Brief Description of the Prior Art

Such solutions, and the devices manufactured therefrom, are known [see, e.g. U.S. Pat. Nos. 3,806,229 (Schoot), 3,280,701 (Donnelly), 3,451,741 (Manos) and 4,902,108 (Byker), commonly assigned U.S. Pat. Nos. 5,140,455 (Varaprasad), 5,142,407 (Varaprasad) and 5,151,816 (Varaprasad), and I.V. Shelepin, *Electrokhimva*, 13(3), 404–08 (Mar. 1977)].

Typically, in the context of such devices, anodic compounds and cathodic compounds are placed together in a solvent to form a solution which is then placed within a cell housed by the device. When an applied potential is introduced to the device, the solution contained within colors thereby reducing the amount of light that is transmitted therethrough.

Although prior endeavors have proven satisfactory, an improvement in the rapidity, intensity and uniformity of the solution coloring would be advantageous inasmuch as the amount of light transmitted therethrough would further be decreased and the glare resulting from the face of those devices housing the solutions would also be decreased. Such an event would benefit those commercial applications currently employing solutions of this nature and would create new opportunities for commercial activity.

Thus, it would be desirable for an electrochemichromic solution to demonstrate an enhanced rapidity, intensity and uniformity of solution coloring when the solution is influenced by the introduction of an applied potential thereto. It would also be desirable to provide a process for preparing these solutions. It would further be desirable to provide a process for using these solutions. Finally, it would be desirable to provide a device manufactured with the electrochemichromic solutions of the present invention that benefits from the above-noted advantages of these solutions when employed therewith.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide electrochemichromic solutions that demonstrate enhanced rapidity, intensity and uniformity of solution coloring when the solution is influenced by the introduction of an applied potential thereto.

It is also an object of the present invention to provide processes for preparing these solutions.

It is a further object of the present invention to provide processes for using these solutions.

It is a final object of the present invention to provide devices manufactured with the electrochemichromic solutions of the present invention that benefit from the advantages provided by these solutions when employed therewith.

The present invention solves the aforementioned shortcomings of the prior art by providing for the first time electrochemichromic solutions capable of demonstrating enhanced rapidity, intensity and uniformity of solution coloring. Preparation of these novel solutions involve the process of pre-treating an electrochemichromic compound with a redox agent prior to use.

More specifically, the electrochemichromic solutions of this invention are comprised of an anodic compound—having been previously contacted with a redox agent to alter its valence state—, a cathodic compound and a solvent such that the redox potential of the anodic compound in an altered valence state is greater than the redox potential of the cathodic compound while each of these compounds is contacted with that solvent. In addition, ultraviolet stabilizing agents and electrolytic materials and the like may be optionally added thereto to modify the physical characteristics of these solutions.

The process for preparing these solutions comprises solubilizing the anodic compound in a solvent; contacting this solubilized anodic compound with a redox agent to alter its valence state; removing that amount (if any) of redox agent that has remained unreacted; introducing a cathodic compound to the solution containing the anodic compound having a valence state different to that when it was initially placed in solution; and introducing an applied potential to this solution to cause coloring thereof.

It is this initial pre-treatment of the anodic compound, which alters its valence state and its redox potential such that the pre-treated anodic compound bears a more positive redox potential than the cathodic compound with which it is to be placed in solution, wherein the point of novelty of the present invention lies.

Capitalizing on this, the electrochemichromic solutions of the present invention, and the processes for preparing and using the same, show utility in the manufacture of devices containing the solutions. The devices so manufactured benefit from the enhanced coloring capability of these solutions which not only affects the amount of light transmitted therethrough, but also the extent to which glare is reflected from such devices. This enhanced coloring capability may be continuously varied by controlling the magnitude, duration and polarity of the applied potential introduced thereto. Examples of such devices are mirrors—e.g., vehicular, architectural or specialty mirrors, such as those useful in periscopic or dental applications—, glazings—e.g., architectural, aeronautical or vehicular glazings like windows, sun roofs, sun visors or shade bands—, privacy or security partitions, information displays, optically attenuating contrast filters, lenses and the like.

Thus, the present invention exemplifies a further advance in the art that will become readily apparent and more greatly appreciated by a study of the detailed description taken in conjunction with the drawings which follow hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 depicts a sectional view of an electrochemichromic cell housing an electrochemichromic solution according to the present invention.

FIG. 2 depicts a perspective view of an electrochemichromic mirror assembly—i.e., an interior rearview automobile mirror—according to the present invention.

The depictions in these figures are for illustrative purposes and thus are not drawn to scale.

DETAILED DESCRIPTION OF THE INVENTION

In order to fully appreciate the teaching of the present invention, the following terms are defined herein. These terms and expressions employed herein are used as terms of expression only and are not meant to be construed to limit the instant teaching.

"Anodic Compound"—is meant to refer to a compound capable of undergoing a reversible color change when its valence state is altered due to oxidation.

"Bleaching"—is meant to refer to the affirmative steps of either (1) removing the applied potential, (2) applying zero potential or (3) momentarily reversing the polarity of the applied potential before performing either steps (1) or (2) so as to cause electrochemichromic compounds to revert back to their respective substantially colorless valence states.

"Cathodic Compound"—is meant to refer to a compound capable of undergoing reversible color change when its valence state is altered due to reduction.

"Color" or "Coloring"—is meant to refer to the ability of an electrochemichromic solution to decrease the amount of light transmitted therethrough thereby causing a color to form that is different than the color, or the lack of color, initially present in the solution. Thus, coloring may refer to color formation from an initially substantially colorless state or color change from one initially colored state to a substantially different colored state. It is of course to be understood that different anodic compounds and cathodic compounds, individually or in combination, may generate different color spectrums in the context of the present invention when their respective valence states are altered by an applied potential which is introduced to a solution containing those compounds.

"Electrochemichromic Compound"—is meant to refer to either an anodic compound or a cathodic compound, as defined hereinabove.

"Electrochemichromic Solution"—is meant to a solution comprising at least one electrochemichromic compound.

"Iris effect"—is meant to refer to the observation of non-uniform coloring or bleaching of an electrochemichromic solution when an applied potential is introduced to a cell housing that solution. This effect is typically due to the potential drop across the surface of the transparent conductive coatings present on the surfaces of the substrates of the electrochemichromic cell which results in the applied potential being highest adjacent to the bus bar and lowest at the center of this cell as the electrical current passes through the solution. Accordingly, it is not surprising that the solution will typically display non-uniform coloring by initially coloring the perimeter of the cell where the bus bars are located—i.e., closest to the point where the applied potential comes in contact with the electrochemichromic solution —and thereafter coloring toward the center of the cell.

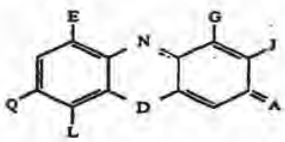
"Redox Agent"—is meant to refer to any material, or means, capable of altering the valence state of an electrochemichromic compound—e.g., a reducing agent or an oxidizing agent—that has a compatible redox potential to that electrochemichromic compound being acted upon. More specifically, when the redox agent is a reducing agent, this agent should possess a lower redox potential than that of the compound being reduced thereby driving the reduction process. Contrariwise, when the redox agent is an oxidizing agent, this agent should possess a higher redox potential than that of the compound being oxidized thereby driving the oxidation process. Regarding a means for altering the valence state of an electrochemichromic compound, an electrochemical means is suitable.

"Response Time"—is meant to refer to that period of time required for the electrochemichromic compound present in solution to change initially from a valence state that is substantially colorless to a valence state bearing color, or vice versa (see Bleaching). Alternatively, this time may refer to that period of time required for an electrochemichromic compound to change from a valence state bearing one color to a valence state bearing a substantially different color. This period of time will often vary depending on the specific physical characteristics and concentrations of the constituents present in the electrochemichromic solution and the operating conditions and physical construction of the electrochemichromic system. In addition, the response time may not be, and often is not, the same for the reverse processes of solution coloring and solution bleaching.

"Valence State"—is meant to refer to a state of oxidation or reduction of a given electrochemichromic compound. In that regard, an altered valence state is merely an alteration in valence state. The gain of one or more electrons (reduction) will lower the valence state whereas the loss of one or more electrons (oxidation) will raise the valence state of the electrochemichromic compound. "Self-erasing"—is meant to refer to the substantially spontaneous fading of solution color—i.e., an increase of light transmittance—hwen the applied potential is removed from the solution. This feature is provided by the spontaneous reactions of oxidized anodic compounds with reduced cathodic compounds to afford anodic compounds and cathodic compounds in their respective valence states—i.e., those valence states which display the least, or substantially no, color.

In accordance with the teaching of the present invention, the anodic compound and the cathodic compound may each comprise one pr more individual electrochemichromic compounds. Further, while the number of individual electrochemichromic compounds comprising the anodic compound is independent of the number of individual electrochemichromic compounds comprising the cathodic compound, that is not to say that the anodic compound and the cathodic compound may not comprise the same number of different individual electrochemichromic compounds. Rather, it merely indicates that the number of different individual electrochemichromic compounds comprising either the anodic compound or the cathodic compound does not depend on the identity of those individual electrochemichromic compounds chosen.

With this in mind, the anodic compound, prior to contacting with a redox agent, may be selected from the class of chemical compounds represented by the following formula



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wherein

A is O, NRR_1; wherein R and R may be the same or different and each may be selected from the group consisting of H or any straight-chain or branched alkyl constituent having from about one carbon atom to about six carbon atoms, such as CH_3, CH_2CH_3, $CH_2CH_2CH_3$, $CH(CH_3)_2$ and the like, provided that when A is NRR_1, Q is H or OH;

D is OS;

E is R , COOH, $CONH_2$, phenyl, 2,4-dihydroxyphenyl;

G is H;

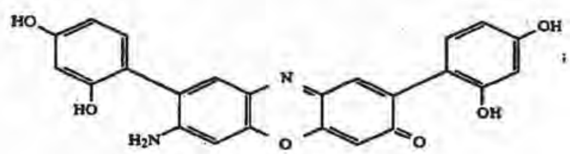
J is phenyl, 2,4-dihydroxyphenyl; or G and J, when taken together, represent an aromatic ring structure having six ring carbon atoms when viewed in conjunction with the ring carbon atoms to which they are attached;

L is H, OH; and

Q is H, OH, NRR , provided that when L and Q are OH, L and Q may also be any salt thereof.

Those salts include, but are not limited to, alkali metal salts, such as lithium, sodium, potassium and the like. In addition, when A is NRR_1, tetrafluoroborate (BF_4), perchlorate (ClO_4), trifluoromethane sulfonate ($CF_3SO_3^-$), hexafluorophosphate (PF_6^-) and any halogen may be associated therewith. Moreover, the ring nitrogen atom in this chemical formula may also appear as an N-oxide.

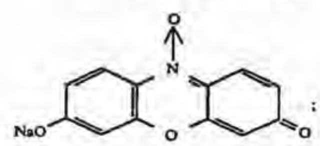
Preferably, the anodic compound represented by formula I, prior to contacting with a redox agent, may be selected from the group consisting of the class of chemical compounds represented by the following formulae



II

;

III



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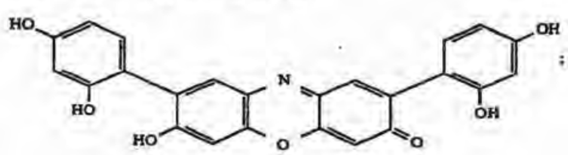

IV

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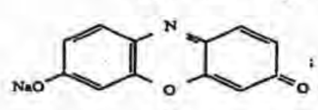

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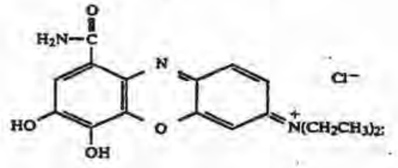
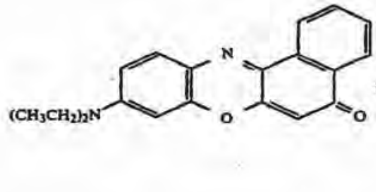
V

VI



VII



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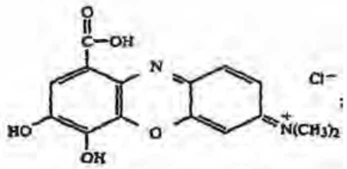
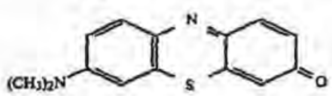


VIII



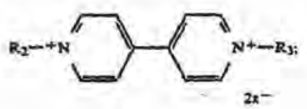
IX

methylene violet (Bernthsen) (MVTB)

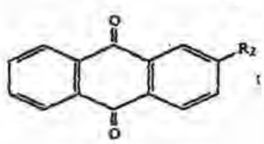
and any combination thereof.

Most preferably, the anodic compound, prior to contacting with a redox agent, is MVTB.

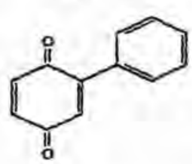
Similarly, a choice of cathodic compound should be made. The cathodic compound may be selected from the class of chemical compounds represented by the following formulae



X



XI



XII

wherein

R_2 and R_3 may be the same or different and each may be selected from the group consisting of H or any straight-chain or branched alkyl constituent having from about one carbon atom to about six carbon atoms; and

X is selected from the group consisting of BF_4, ClO_4, CF_3SO_3, PF_6, any halogen and any combination thereof.

Preferably, R_2 and R_3 in these chemical formulae which represent the cathodic compound are each CH_2CH_3. Thus, when X is ClO_4, a preferred cathodic compound is ethylviologen perchlorate ($EVClO_4$).

The redox agent that is employed in the present invention to pre-treat the anodic compound may be chosen from a host of materials that demonstrate the ability to alter the valence state of such an anodic compound. While not intending to be bound by theory, the redox agent should possess a compatible redox potential to that electrochemichromic compound with which it is to be placed in contact. Although the redox agents may be in any physical form—i.e., a solid, liquid or gaseous state—, a solid redox agent is typically preferred because of its ease of handling and use. Moreover, solid redox agents having a fine particle size—e.g., about 50 mesh to about 400 mesh —are also preferred because of the larger surface area provided. Alternatively, when in the gaseous state, the redox agent may advantageously be passed through a solution of an anodic compound by, for example, bubbling the gaseous redox agent through an airstone disperser.

When the chosen redox agent is a reducing agent, suitable materials that are representative candidates for use therefor may be drawn from the following non-exhaustive recitation including zinc, ascorbic acid, sodium hydrosulfite, vanadium (III) chloride, chromium (II) acetate, sulfur dioxide and any combination thereof. Preferred among these reducing agents, however, is zinc. When an electrochemical means is chosen as the reducing agent, a conventional electrochemical apparatus capable of providing a negative electrochemical potential may be used.

The redox agent for use in the instant invention may also be an oxidizing agent. In such a case, suitable materials include, but are not limited to, air, oxygen, sodium persulfate, MVTB and any combination thereof. Also, when an electrochemical means is chosen as the oxidizing agent, a conventional electrochemical apparatus capable of providing a positive electrical potential may be used.

The solvent of choice for solubilizing the aforementioned anodic compounds and cathodic compounds should remain substantially inert to those compounds, as well as to any other constituent initially present in the electrochemichromic solution, or formed as a by-product thereafter, so as not to interfere with the electrochemical reactions occurring with respect to those electrochemichromic compounds. To that end, the solvent chosen should be capable of solubilizing those anodic compounds and those cathodic compounds while each is in its ground valence state as well as when each is in its altered valence state, or for that matter, when the two electrochemichromic compounds are not in the same valence state—i.e., ground valence state, a high energy valence state or different high energy valence states. Thus, the different levels of solubility for different electrochemichromic compounds present in different valence states should be considered when choosing a solvent for the solutions of the subject invention. Further, the solvent should remain homogenous while preparing, using and storing the electrochemichromic solutions. Put another way, the solvent chosen should not encourage the constituents of the electrochemichromic solutions, or by-products thereof, to salt-out or precipitate from the solution, for such an event would interfere with the appearance and the effectiveness of the electrochemichromic cell and is thus obviously disadvantageous.

In that regard, any solvent that remains in its liquid form over the range of temperatures that the devices manufactured with the electrochemichromic solutions of the present invention will likely be subjected to is suitable for use as a solvent herein [for a nonexhaustive recitation of suitable materials, see, e.g. commonly assigned U.S. Pat. Nos. 5,142,407 (Varaprasad) and 5,151,816 (Varaprasad). Practically speaking, those solvents should be stable to electrolysis and other phenomena likely to be encountered during the practice of this invention.

Although any of those solvents identified above are suitable, preferable solvents may be selected from acetonitrile, 3-hydroxypropionitrile, methoxypropionitrile, 3-ethoxypropionitrile, 2-acetylbutyrolactone, propylene carbonate, cyanoethyl sucrose, γ-butyrolactone, 2-methylglutaronitrile, N,N'-dimethylformamide, 3-methylsulfolane, glutaronitrile, 3,3'-oxydipropionitrile, methylethyl ketone, cyclopentanone, cyclohexanone, benzoyl acetone, 4-hydroxy-4-methyl-2-pentanone, acetophenone, 2-methoxyethyl ether, triethylene glycol dimethyl ether and any combination thereof. Particularly preferred solvents among that group are the combination of 3-ethoxypropionitrile with 2-acetylbutyrolactone in about 50:50, 75:25 and 80:20 ratios (v/v) and the combination of 3-ethoxypropionitrile with 2-acetylbutyrolactone and cyanoethyl sucrose in about a 55:15:30 ratio (v/v).

Additional particularly preferred solvents include, but are not limited to, solvents comprising a combination of propylene carbonate and glacial acetic acid, a combination of 3-hydroxypropionitrile and glacial acetic acid, a combination of glutaronitrile and glacial acetic acid, a combination of 3,3'-oxydipropionitrile and glacial acetic acid, a combination of 3-methylsulfolane and glacial acetic acid, a combination of propylene carbonate, cyanoethyl sucrose and glacial acetic acid and the like. Specifically, those solvents include the combination of 3-hydroxypropionitrile with glutaronitrile and glacial acetic acid in about 74:25:1 and about 49.5:49.5:1 ratios, the combination of 3-hydroxypropionitrile with 3,3'-oxydipropionitrile and glacial acetic acid in about a 69:30:1 ratio, the combination of propylene carbonate with glacial acetic acid in about a 99:1 ratio, the combination of propylene carbonate with cyanoethyl sucrose and glacial acetic acid in about a 64:35:1 ratio and the like. And, the glacial acetic acid or acidic solvent component may be added while the combination is being prepared as a percentage of the total volume of that solvent.

To that end, it is believed that such acidic solvents not only catalyze the initial pre-treatment reaction—i.e., the reaction between the redox agent and the anodic compound—but also assist to keep the pretreated anodic compound, in its altered valence state, from acting as a redox agent toward the cathodic compound when the two electrochemichromic compounds are combined in solution at the outset. In the event that a cathodic compound possesses a more negative redox potential than that of the anodic compound, these compounds may be employed in the absence of an acidic solvent.

Notwithstanding this event, in addition to glacial acetic acid, almost any acidic solvent component, such as hydrogen halide gases in solution, perchloric acid, 2-acetylbutyrolactone, 3-hydroxypropionitrile and any combination thereof, may suffice provided that it is substantially anhydrous and further provided that it is chemically and electrochemically inert toward the electrochemichromic compounds engaged in the present invention. Alternatively, acidic solvents such as weak organic acids, like citric acid solutions, may be added to otherwise non-acidic solvents to render those solvents acidic. Preferably, however, glacial acetic acid should be employed. For a further recitation of suitable acidic solvents, see, e.g. *Lange's Handbook of Chemistry*, table 5-8, J. A. Dean, ed., 13th ed., McGraw-Hill Co., N.Y. (1985). In general, the solvent may be selected with an eye toward having the anodic compound, bearing an altered valence state, possess a greater redox potential than that of the cathodic compound while each is in solution.

The acidic strength of the solvent should be sufficient to bring the redox potential of the anodic compound to a more positive value than that of the cathodic compound. Where at least a binary solvent is employed, the amount of the more acidic solvent component chosen should be in the range of about 0.01% (v/v) to about 75% (v/v). However, when glacial acetic acid is chosen as the acidic solvent component, about 1% (v/v) is preferred. It is worth noting, that a higher acidic strength of the solvent in the electrochemichromic solution may cause a different solution coloring spectrum or, for that matter, a different degree of intensity of the color so formed.

In addition to altering the valence state of the anodic compound by means of a redox agent, preferably in the presence of an acidic solvent, electrochemical means may also be employed to accomplish this objective. This electrochemical reaction may be performed, both with and without the presence of an acidic solvent component, employing a conventional multi-compartment electrochemical cell equipped with a working electrode, such as a platinum electrode or the like.

Other components may also be added to the subject electrochemichromic solutions including, but not limited to, an ultraviolet stabilizing agent, an electrolytic material and any combination thereof. Because many electrochemichromic compounds, particularly anodic compounds, show a substantial ultraviolet absorbance in the ultraviolet region from about 250 nm to about 350 nm, it is often desirable to shield the electrochemichromic compounds from ultraviolet radiation. Thus, by introducing an ultraviolet stabilizing agent to the subject solution, or a solvent which acts as an ultraviolet absorber, the lifetime of the electrochemichromic solution may be extended. Although any material known to absorb ultraviolet radiation, and thereby prevent or retard the ultraviolet degradation of the constituents presently in solution, may be employed to achieve the desired stabilizing result, provided that it is inert to those constituents and stable over the conditions of operation of the subject electrochemichromic solutions, an ultraviolet stabilizing agent, such as "UVINUL 400", "UVINUL D-49", "TINUVIN P", "TINUVIN 327", "TINUVIN 328", "Cyasorb 24", benzotriazole or conventional benzotriazole derivatives, benzophenone or conventional benzophenone derivatives, or many sterically hindered amine complexes known in the art and any combination thereof, is preferred. In fact, "UVINUL 400" is a most preferred ultraviolet stabilizing agent and it may be advantageously used in the range of about 0.1% (w/v) to about 10% (w/v), with about 5% (w/v) being preferred.

An electrolytic material may also be employed in the electrochemichromic solutions to assist or enhance the conductivity of the electrical current passing therethrough, and particularly when no electrochemichromic compound of the electrochemichromic solution or any other solution component exists in an ionic state. That material may be selected from a host of known materials inert to the constituents and stable over the conditions of operation of the subject solutions. Preferred electrolytic materials include tetraethylammonium perchlorate, tetrabutylammonium tetrafluoroborate, tetrabutylammonium hexafluorophosphate, tetrabutylammonium trifluoromethane sulfonate and any combination thereof, with tetrabutylammonium hexafluorophosphate and tetraethylammonium perchlorate being most preferred. Although impractical to specify absolute ranges for all possible electrolytic materials within the scope of this invention, if tetrabutylammonium hexafluorophosphate is chosen as the electrolytic material, a concentration of about equimolar to about five times the concentration of the electrochemichromic compounds is preferred.

Again, without intending to be bound by theory, an understanding of the triggering events which make this invention operational is instructive in the context of a preferred embodiment for preparing these electrochemichromic solutions and in a device manufactured with the same. In this connection, an anodic compound, such as MVTB, initially provided in its higher valence state as compared with the valence state that it will reach when contacted with a redox agent may be dissolved in any of the solvents identified herein, such as the combination of 3-ethoxypropionitrile with 2-acetylbutyrolactone in about an 80:20 ratio (v/v), so that a colored solution of that compound is formed.

The resulting solution may then be contacted with a redox agent, particularly a reducing agent, such as zinc, so that the anodic compound is reduced to a lower valence state and to a less colored form in solution. This reduction causes the anodic compound to gain at least one electron thereby causing the now reduced anodic compound-containing solution to lose substantially all of its color.

The preferred redox agent should be substantially insoluble in the preferred solvent used in the electrochemichromic solution of the present invention —i.e., being only soluble to the extent necessary to act upon the anodic compound—so that it may be easily removed by conventional separation means, such as filtering, decanting or the like. When the redox agent is substantially insoluble in the solvent employed therewith, it may alternatively be advantageous to solubilize the redox agent and the anodic compound in water and, once the redox reaction has occurred, thereafter extract the anodic compound (now bearing an altered valence state) from the aqueous solution with a substantially water-immiscible electrochemichromic solvent. Alternatively, the redox agent may indeed be soluble in that solvent, provided that it may be readily removed by other conventional separation means—such as, centrifuging, precipitating, extracting, fractionating, osmosis, vacuum or other separation means known to one of ordinary skill in the art. Although it is generally preferable to use a molar excess of an insoluble redox agent, when a soluble redox agent is employed, it may be advantageous to use only about a stoichiometric amount thereof so that no excess redox agent is permitted to remain and thus interfere with subsequent reactions that the electrochemichromic compounds present in solution may undergo.

While the redox agent to be used in the context of the present invention will typically be a reducing agent, it is within the scope of the present invention for the redox agent to be an oxidizing agent as well. In this connection, an electrochemichromic compound may be contacted with an oxidizing agent to alter its valence state—i.e., the compound assumes a higher valence state than its valence state prior to having been contacted with the oxidizing agent. For example, a viologen compound, such as $EVClO_4$ provided in its reduced colored form, may be employed. To a solution of this compound, an oxidizing agent, such as air or oxygen, may be introduced as a stream of bubbles to oxidize the reduced viologen compound to its substantially colorless form so that it serves as a cathodic compound. Excess oxidizing agent should thereafter be removed. Where a gaseous oxidizing agent is employed, the application of a vacuum—i.e., a reduced atmospheric pressure—or the introduction of a stream of bubbles of an inert gas should drive the excess gaseous oxidizing agent from the solution.

After removing that amount (if any) of redox agent that has remained unreacted, an anodic compound may be introduced to this solution. The anodic compound chosen should bear a redox potential in the solvent that is greater than the redox potential of the cathodic compound in that solvent. Once combined in solution, these two electrochemichromic compounds now act in concert like redox indicators.

The anodic compound and the cathodic compound (both typically present in solution initially in their respective substantially colorless or least colored forms), should reach a total electrochemichromic compound concentration in solution of about 0.005 M to about 0.5 M, with a level of about 0.04 M being preferred. The ratio of total anodic compound to total cathodic compound may be in the range of about 5:1 to about 1:5, with a ratio of about 1:1 being preferred. In addition, as discussed supra, it is contemplated by the present invention that this range be inclusive of the fact that the anodic compound may be comprised of different individual anodic compounds and that the cathodic compound may be comprised of different individual cathodic compounds in these electrochemichromic solutions or, for that matter, different individual anodic compounds and different individual cathodic compounds may be employed simultaneously within an electrochemichromic solution of the instant invention.

It is further contemplated that, alternatively, the cathodic compound may be contacted with a redox agent to alter its valence state. This compound (now bearing an altered valence state) may then be introduced to a solution containing the anodic compound, wherein the anodic compound is in its ground valence state or a lower valence state than the valence state that it will reach at steady state equilibrium. For instance, when the cathodic compound is $EVClO_4$, it may be placed in solution and thereafter contacted with a redox agent—

e.g., a reducing agent—to alter its valence state thereby producing a solution bearing intense color. A solution of an anodic compound, in this case, MVTB, may then be added dropwise to the solution containing the reduced cathodic compound so as to act as a redox agent itself—i.e., an oxidizing agent—and oxidize the reduced cathodic compound (in what amounts to a titration) to form, at its stoichiometric end-point, a substantially colorless solution. In this way, the electrochemichromic compounds also act in concert similar in behavior to redox indicators. The resulting solution may then be used as the electrochemichromic solutions described above to manufacture devices capable of coloring when an applied potential is introduced thereto.

Since, after contacting the anodic compound with a redox agent—e.g., a reducing agent, such as zinc—substantially none of that redox agent will remain in the solution (either in a soluble form or an insoluble form), the cathodic compound may become solubilized without itself becoming reduced (and subsequently changing color) while the anodic compound may remain in a reduced form, also substantially free of color. Thus, when no applied potential is introduced to this solution, the anodic compound is present in solution in a reduced, substantially colorless form and the cathodic compound is present in solution in an oxidized, substantially colorless form—i.e., as it was when initially introduced into the solution.

The electrochemichromic solutions of the present invention, and the constituents thereof, may be flushed with anhydrous nitrogen, or any other anhydrous inert gas, prior to; and during; use and storage in order to minimize the concentration of oxygen and, if the solvent is non-aqueous, water present therein. Conventional techniques may be employed to reduce and limit the concentrations of those above-noted materials that are deemed undesirable for the instant invention. For example, anhydrous nitrogen gas may be bubbled through an electrochemichromic solution to decrease the oxygen concentration therein. Solvents or liquid electrochemichromic constituents may alternatively, or additionally, be contacted with activated alumina or the like, in the preparation of the electrochemichromic solution. Solid electrochemichromic compounds, and other solid constituents of this electrochemichromic solutions, may be dried prior to use by elevating the temperature of their immediate environment to about 110° C., or to a temperature not to exceed its melting or decomposition temperature, with an Abderhalden drying apparatus using a suitable anhydrous solvent, such as toluene [commercially available from Aldrich Chemical Company, Inc., Milwaukee, Wis. (1986)]. Other than any of these aforementioned measures that might be employed in an attempt to reduce and limit the concentrations of oxygen and water in the solutions of the present invention, these solutions may be prepared in accordance with conventionally known methods, typically at room temperature, by simply placing the appropriate amounts of electrochemichromic compounds, or other constituents described in the instant teaching, in a disclosed solvent to achieve the desired concentrations.

Reference to FIGS. 1 and 2 will now be made in order to more faithfully describe the operation of the cell containing these electrochemichromic solutions. It can be seen that the cell 1 includes two substantially planar glass substrates 2,3 positioned substantially parallel to one another. It is preferable that these glass substrates 2,3 be positioned as close to parallel to one another as possible so as to avoid double imaging, which is particularly noticeable in mirrors, especially when in a colored state.

Inasmuch as a source of an applied potential need be introduced to the cell 1 so that solution coloring in a rapid, intense and uniform manner may be observed, that source may be connected by electrical leads 9 to conducting strips known in the art as "bus bars". The bus bars 8 may be constructed of copper, aluminum or silver and should be affixed to the conductive coatings 4. An exposed portion of the conductive coatings 4 may be provided for the bus bars 8 to adhere to due to the spaced-apart relationship and the displacement in directions relative to one another—i.e., opposite directions relative to one another—i.e., laterally from, but parallel to the cavity which is created in the cell by the glass substrates 2,3 and the sealing means 5—of the coated glass substrates 2,3.

As stated above, on each of the interior faces of these glass substrates 2,3 is coated a transparent conductive coating 4. While the conductive coatings 4 should be of substantially uniform thickness, they may each have the same uniform thickness or different uniform thicknesses relative to each other. The conductive coatings 4 are generally from about 300 521 to about 1600 Å in thickness, with a thickness of about 1200 Å being preferred. The conductive coatings 4 should also be highly and uniformly conductive in each direction to provide a substantially uniform response once an applied potential is introduced to the solution. And, the conductive coatings 4 should be inert to the constituents of the electrochemichromic solutions so that the constituents thereof do not anodically oxidize or cathodically reduce in preference to the electrochemichromic compounds present in the solution. To this end, the conductive coatings 4 may be constructed from the same material or different materials, including tin oxide, indium tin oxide ("ITO"), antimony-doped tin oxide, fluorine-doped tin oxide, antimony-doped zinc oxide, aluminum-doped zinc oxide, with ITO being preferred. However, where the ultraviolet stability of the device is a concern, tin oxides or zinc oxides are preferred.

The sheet resistance of these ITO-coated glass substrates 2,3 may be between about 1 to about 100 ohms per square, with about 6 to about 15 ohms per square being preferred [ITO-coated substrates may be obtained commercially, for instance, from Donnelly Corporation, Holland, Mich. or, alternatively, tin oxide-coated substrates may be obtained commercially as TEC-GLASS products from Libbey-Owens-Ford Co., LOF Glass Division, Toledo, Ohio].

As stated above, the spaced-apart ITO-coated glass substrates 2,3, have sealing means 5 positioned therebetween to define the cell cavity. The sealing means 5 may be constructed of any material inert to the constituents of the electrochemichromic solutions and any subsequently formed by-products thereof. To that end, the sealing means may be chosen from the following materials including, but not limited to, various thermosetting materials, such as epoxy resins and silicones, various thermoplastic materials, such as plasticized polyvinyl butyral, polyvinyl chloride, paraffin waxes, ionomer resins, various inorganic materials and the like. For a further recitation of suitable sealing materials, see U.S. Pat. No. 4,761,061 (Nishiyama).

The thickness of the sealing means 5 may vary from about 10 μm to about 1000 μm. Preferably, however, this thickness is about 50 μm to about 100 μm. The thickness of the sealing means 5 determines the thickness of the interpane space created between the glass substrates 2,3 by the sealing means 5—i.e., the cell gap. Thus, it is the sealing means 5 which spaces or separates the ITO-coated glass substrates 2,3 from one another. In addition, sealing means 5 may prevent escape of the electrochemichromic solution 6 from the cell cavity or, for that matter, penetration of environmental contaminants into the cell cavity.

In order to fill the cell 1, a small gap—e.g., about 2mm×1mm×150μm—may be allowed to remain in the sealing means 5 so that an electrochemichromic solution 6 may be placed into the cell cavity during a conventional vacuum backfilling process. In the vacuum backfilling process, the empty electrochemichromic device may be placed in a chamber having reduced atmospheric pressure therein—i.e., about 1 mm Hg or lower. A container—e.g., a dish or small cup—of the solution 6 should also be placed in this chamber so that it may fill the cell cavity through the fill hole.

The fill hole of the device may then be lowered just beneath the surface of the solution in the container. When the chamber is vented to atmospheric pressure, the solution 6 is thereby forced into the cell cavity and consequently fills it.

Alternatively, the cell cavity may be formed by positioning a thermoplastic sheet, constructed of an ionomer resin, a plasticized polyvinyl butyral or the like, onto the interior surface of one of the ITO-coated glass substrates 2. This sheet may be trimmed to size about the outer periphery of one of the ITO-coated glass substrates 2 after it is placed thereover. The interior portion of the thermoplastic sheet may thereafter be trimmed so that only a border of this sheet remains about the periphery of the ITO-coated glass substrate 2. Before curing the thermoplastic sheet so that it forms the sealing means 5, an electrochemichromic solution 6 according to the present invention may be dispensed onto the surface of one of the ITO-coated glass substrates 2. It is of no moment that a portion of the solution may escape under or over the sheet, because the other ITO-coated glass substrate 3 is thereafter placed in contact therewith so that the thermoplastic sheet is positioned between the ITO-coated glass substrates 2,3 and the cell cavity which is created as a result becomes filled with the solution 6.

This construction is then temporarily clamped together and thereafter baked in an oven at a temperature of about 25° C. to about 120° C. to cure the thermoplastic sheet into the sealing means 5 that will keep intact the integrity of the cell housed in the device.

Once assembled and filled, an applied potential may be introduced to the device by the bus bars 8 in order to induce solution coloring. The applied potential may be supplied from a variety of sources including, but not limited to, any source of alternating current (AC) or direct current (DC) known in the art, provided that, if an AC source is chosen, control elements, such as diodes, should be placed between the source and the conductive coatings 4 to ensure that the potential difference between the conductive coatings 4 does not change polarity with variations in polarity of the applied potential from the source. Suitable DC sources are storage batteries, solar thermal cells, photovoltaic cells or photoelectrochemical cells.

The applied potential generated from any of these sources may be introduced to this solution in the range of about 0.001 volts to about 5.0 volts. Typically, however, an applied potential of about 0.2 volts to about 2.0 volts is preferred to permit the current to flow across the solution 6 thereby oxidizing and reducing the electrochemichromic compounds to cause solution coloring—i.e., to change the amount of light transmitted therethrough.

A means for controlling the current created by the applied potential and delivered to the conductive coatings 4 is suggested so that the current, which thereafter disperses the potential uniformly throughout the solution 6, does not exceed the potential difference at which irreversible reactions occur—e.g., solvent electrolysis, redox reactions involving the inert electrolytic material, or reactions which degrade the electrochemichromic compound. The means for controlling the current delivered to the conductive coatings 4 may be manually or automatically operated.

The solutions of the present invention, once prepared, may be advantageously employed to manufacture devices using electrochemichromic cells, such as, mirrors—e.g., vehicular, architectural or specialty mirrors, such as those useful in periscopic or dental applications—, windows—e.g., architectural or automotive glazings like sun roofs, sun visors or shade bands—, information displays, optically attenuating contrast filters, privacy or security partitions, lenses and the like.

In the context of a mirror assembly, a reflective coating 7, having a thickness in the range of 250 Å to about 2000 Å, preferably about 1000 Å, should thereafter be applied to the exterior face of one of the ITO-coated glass substrates 3 in order to form a mirror. Suitable materials for this layer are aluminum, palladium, platinum, titanium, chromium, silver and stainless steel, with silver being preferred. As an alternative to such metal thin film reflectors, multi-coated thin film stacks of dielectric materials or a high index single dielectric thin film coating may be used as a reflector. The reflective coating 7 serves not only to assist in reflecting incident light but also in conducting an applied potential to the conductive coatings 4.

It is clear from the teaching herein that should a window, sun roof or the like be desirably constructed, the reflective coating 7 need only be omitted from the assembly so that the light which is transmitted through the transparent panel is not further assisted in reflecting back therethrough.

It is also clear, that only one of the substrates that comprise the device need be at least substantially transparent. That is, provided that a surface of a conductive coating 4 of the other substrate is in contact with the electrochemichromic solution 6, a functioning device in accordance with the teaching herein may be furnished. Specifically, in a mirror device, a polished metal plate or a metal-coated glass substrate may be used or, in a display device, a conductive ceramic material may be suitably employed inasmuch as these materials are physically, chemically and electrochemically compatible with the electrochemichromic solutions themselves.

Having stated the relationship between a mirror assembly and a window assembly in connection with the teaching of the present invention, it should also be readily understood by the art-skilled that the term "transmittance" refers to the amount of light that may pass through—i.e. transmitted through—an electrochemichromic solution that is contained, for example, within an electrochemichromic window assembly. On the other hand, the term "reflectance" refers to the amount of light that may pass through—i.e., transmitted through—an electrochemichromic solution and thereafter reflect off a reflective coating placed on the back of one of the glass substrates of, for example, an electrochemichromic mirror assembly and thereafter pass back through the solution in substantially the same direction from which it originated.

In addition, one of the ITO-coated glass substrates 2 should preferably be of a laminate assembly comprising at least two transparent panels affixed to one another by a substantially transparent adhesive material. This laminate assembly assists in reducing the scattering of glass shards from the glass substrate 2 should the mirror assembly break due to impact. While the term "glass" has been employed throughout the instant disclosure, it is intended by the teaching herein that that term also include optical plastics, such as polycarbonate, acrylic and polystyrene, as well as tempered glass and laminated glass.

Once constructed, the electrochemichromic device—e.g., a mirror or window assembly—may have a molded casing placed therearound. This molded casing may be pre-formed and then placed about the periphery of the assembly or, for that matter, injection molded therearound using conventional techniques, including injection molding of thermoplastic materials, such as polyvinyl chloride or polypropylene, or reaction injection molding of thermosetting materials, such as polyurethane or other thermosets. These techniques are well-known in the art [see, e.g. U.S. Pat. Nos. 4,139,234 (Morgan) and 4,561,625 (Weaver), respectively, for a discussion of those techniques in the context of modular window encapsulation].

Each of the documents cited in the present teaching is herein incorporated by reference to the same extent as if each document had individually been incorporated by reference.

The superior rapidity, intensity and uniformity of solution coloring and the redox pre-treatment of at least one of the electrochemichromic compounds distinguishes the present teaching from the electrochemichromic solutions known heretofore and sets the present invention separate and apart therefrom.

In view of the above description of the instant invention, it is evident that a wide range of practical opportunities is provided by the teaching herein. The following examples of electrochemichromic assemblies are provided to illustrate the utility of the present invention only and are not to be construed so as to limit in any way the teaching herein.

EXAMPLES

The constituents identified in the present invention may be obtained commercially from Aldrich Chemical Company, Inc., Milwaukee, Wis. or many other chemical suppliers, unless otherwise indicated.

EXAMPLE 1

To demonstrate the difference between an electrochemichromic solution of the present invention from those electrochemichromic solutions of the prior art with respect to uniform coloring and the concomitant Iris effect, two solutions were formulated and were used in interior rearview automotive mirrors constructed as depicted in FIGS. 1 and 2. These mirrors each have a cell gap of about 80 μm with ITO—coated glass substrates having about 8 ohms per square sheet resistance and the following approximate dimensions: 6 cm×25cm×2mm.

In the first mirror, we placed an electrochemichromic solution comprising about 0.02 M of $EVDIO_4$ (as the cathodic compound) and about 0.02 M of 5,10-dihydro5,10-dimethylphenazine ("DMPA") (as the anodic compound), both dissolved in the solvent propylene carbonate.

In the second mirror, we placed an electrochemichromic solution prepared according to the present invention comprising about 0.02 M of $EVCLO_4$ (as the cathodic compound) and about 0.02 M of MVTB (as the anodic compound), both dissolved in a solvent comprising about 99% propylene carbonate and about 1% glacial acetic acid (v/v).

In connection with the MVTB reduction, we first placed about 0.5 grams (0.002 moles) of MVTB into about 100 mls of a solvent comprising the combinatoin of about 99% propylene carbonate and about 1% acetic acid (v/v) under substantially inert conditions at about ambient temperature to about 50° C. to form a blue colored solution. We then added, with stirring, about 2 grams of zinc dust (325 mesh) thereto for a period of about 15 minutes to about 45 minutes after which period of time the solution became substantially colorless by reaching a pale yellow color. We performed this reaction under substantially the same conditions as those recited above. We removed that quantity of zinc dust which remained unreacted by filtration and thereafter contacted the substantially colorless MVTB solution (now in a reduced valence state) with the $EVCLO_4$ to reach a pale bluish green solution color.

We introduced an applied potential of about 1.0 volt to each of the filled mirrors, and thereafter observed that the second mirror, filled with an electrochemichromic solution of the present invention, colored rapidly and uniformly with a negligible Iris effect as compared with the first mirror, filled with an electrochemichromic solution of the prior art.

In addition, we observed that the high reflectance at the center portion of the second mirror decreased from about 66% to about 13% in a response time of about 1.5 seconds as compared with a decrease to only about 37% in the first mirror as determined by a reflectometer—set in reflectance mode—equipped with a light source (known in the art as Illuminate A) and a photopic detector attached to a strip chart recorder. What's more, we observed that the second mirror bleached from about 16% reflectance to about 60% reflectance in a response time of about 1.2 seconds. Since the first mirror colored to only about 37%, a fair comparison with the second mirror could not be made.

EXAMPLE 2

We used the electrochemichromic solutions described in Example 1, *supra*, to fill two interior rearview automotive mirrors each having about a 100 μm cell gap and constructed from ITO-coated glass substrates having about 12 ohms per square sheet resistance. Upon application of about 1.0 volt, we observed that the second mirror, filled with an electrochemichromic solution of the present invention, colored uniformly and rapidly whereas the first mirror, filled with an electrochemichromic solution of the prior art, did not color uniformly and the electrochemichromic response obtained was less rapid. And, the second mirror demonstrated an intense bluish purple color as compared with the largely dark green color with a slight purple tint demonstrated by the first mirror.

Specifically, we observed the second mirror to exhibit color formation of about 70% reflectance to about 20% reflectance in a response time of about 1.3 seconds as compared with the first mirror which registered substantially the same reflectance effect in about 4.3 seconds. We also observed that the second mirror and the first mirror demonstrated a comparable rate of bleaching—about 1.8 seconds as compared with about 1.6 seconds, respectively—from about 20% reflectance to about 60% reflectance. In addition, we noted that although the two mirrors exhibited no marked difference with respect to their high reflectance percentage in the bleached state—about 72.6% for the second mirror d about 74.4% for the first mirror—, the second mirror showed an improvement over the first mirror with respect to decreased reflectance—i.e., about 7.9% as compared with about 16.0%, respectively. We made and recorded these observations by the detection method described in Example 1, supra.

EXAMPLE 3

We also used the electrochemichromic solutions described in Example 1, supra, to fill two automotive mirrors each having about a 135 μm cell gap and constructed from ITO-coated glass substrates having about 12 ohms per square sheet resistance to illustrate the more intense color formation demonstrated by the electrchemichromic solutions of the present invention. We constructed a cell having a wider cell gap than in the previous examples to illustrate the enhanced uniform coloring of the solution of the instant invention when Iris effects are lessened or eliminated. When we introduced an applied potential of about 1.0 volt to each mirror, we observed that the second mirror yielded a low reflectance of about 6.9% whereas the first mirror yielded a reflectance of only about 10.8%. We made and recorded these observations using the detection method described in Example 1, supra.

EXAMPLE 4

We next used the electrchemichromic solutions as described in Example 1, supra, to demonstrate the ability of the electrchemichromic solutions of the present invention to be employed with high resistive glass—an inferior quality and accordingly less expensive glass—and afford similarly superior results over those electrochemichromic solutions of the prior art. To this end, we filled two mirrors each having about a 350 μm cell gap and constructed from ITO-coated glass substrates having about 80 ohms per square sheet resistance. Upon introducing an applied potential of about 1.0 volt to each of the mirrors, we observed that the second mirror yielded a low reflectance of about 5.7% whereas the first mirror yielded a reflectance of only about 34% and also exhibited an Iris effect even with the larger cell gap. We made and recorded these observations using the detection method described in Example 1, supra.

EXAMPLE 5

In this example, we used another preferred solvent, the combination of about 79% 3-ethoxypropionitrile, about 20% 2-acetylbutyrolactone and about 1% glacial acetic acid (v/v), to further demonstrate the enhanced characteristics with respect to uniform coloring and the concimitant Iris effect of the solutions of the present invention over those of the prior art.

In that regard, we constructed two interior rearview automotive mirrors each having a cell gap of about 50 μm with ITO-coated glass substrates having about 6 to about 8 ohms per square sheet resistance.

In the first mirror, we placed an electrochemichromic solution comprising about 0.02 M of $EVCLO_4$ and about 0.02 M of DMPA, both dissolved in a solvent comprising about 80% 3-ethoxypropionitrile and about 20% 2-acetylbutyrolactone (v/v). In addition, this solution contained about 5% of "UNINUL400" (w/v) as an ultraviolet stabilizing agent.

In the second mirror, we placed an electrochemichromic solution prepared according to the present invention comprising about 0.02 M of $EVCLO_4$ and about 0.02 M of reduced MVTB, both dissolved in a solvent comprisnig about 79% 3-ethoxypropionitrile, about 20% 2-acetylbutyrolactone and about 1% glacial acetic (v/v). In addition, this solution contained about 5% of "UVINUL 400" (w/v) as an ultraviolet stabilizing agent. As in Example 1, supra, prior to combining the anodic and cathodic compounds, we reacted MVTB with zinc and otherwise followed the protocol indicated.

After we prepared each mirror with the electrochemichromic solutions as described above, we introduced an applied potential of about 1.0 volt to each of the mirrors. The second mirror demonstrated an intense purple color as compared with the light green color demonstrated by the first mirror. In addition, in the bleached state, the second mirror displayed a clear yet silvery appearance while the first mirror displayed an almost clear appearance with a slightly yellow hue. Moreover, the second mirror demonstrated a fairly uniform coloring and a very small Iris effect in contrast to the non-uniform coloring and large Iris effect displayed by the first mirror.

We observed that the high reflectance was about 75.3% as compared with 79.2% for the first mirror. And, the reflectance at the center portion of the second mirror decreased from about 70% to about 20% in a response time of about 1.0 second, with an ultimate decrease to about 13.1% as compared with the first mirror which decreased from about 70% to only about 37% in about the same period of time, with an ultimate decrease to about 23.8% after about 2.9 seconds. With respect to bleaching, we observed that the second mirror and the first mirror demonstrated comparable response times in connection with their ability to bleach. That is, in the range from about 20% reflectance to about 70% reflectance, the second mirror bleached in about 0.9 seconds whereas the first mirror achieved the same results in about 1.0 second. We made and recorded these observations using the detection method described in Example 1, supra.

EXAMPLE 6

In the example, we used a combination of about 69% 3-ethoxypropionitrile, about 30% propylene carbonate and about 1% glacial acetic acid (v/v) as a solvent as yet another demonstration of the enhanced characteristics with respect to uniform coloring and the concomitant Iris effect of the solutions of the present invention over those of the prior art.

We constructed two interior rearview automotive mirrors as in Example 5, supra. In the first mirror, we placed an electrochemichromic solution comprising about 0.02 M of $EVClO_4$ and about 0.02 M of DMPA, both dissolved in a solvent comprising about 70% 3-ethoxypropionitrile and about 30% propylene carbonate.

In the second mirror, we placed an electrochemichromic solution prepared according to the present invention comprising about 0.02 M of EVClO and about 0.02 M of reduced MVTB dissolved in a solvent comprising about 9% 3-ethoxypropionitrile, about 30% propylene carbonate and about 1% glacial acetic (v/v). As in Example 1, supra prior to combining the anodic and cathodic compounds, we reacted the MVTB with zinc and otherwise followed the protocol indicated.

After we prepared each mirror with the electrochemichromic solutions as described above, we introduced an applied potential of about 1.0 volt to each of the mirrors. The second mirror demonstrated intense purple color as compared with the light green color demonstrated by the first mirror. In addition, in the bleached state, the second mirror displayed a clear yet silvery appearance while the first mirror displayed an almost clear appearance with a slight yellow hue. Moreover, the second mirror demonstrated a fairly uniform coloring and a very small Iris effect in contrast to the non-uniform coloring and large Iris effect displayed by the first mirror.

We further observed that the high reflectance at the center portion of the second mirror was about 76.5% as compared with about 78.7% for the first mirror. And, the reflectance decreased from about 70% to about 20% in a response time of about 1.0 second, with an ultimate decrease to about 13.1%, as compared with the first mirror which decreased from about 70% to only about 41% in about the same period of time, with an ultimate decrease to about 24.3% after about 2.2 seconds. We also observed that the second mirror and the first mirror demonstrated comparable response times in connection with their ability to bleach. We made and recorded these observations using the detection method described in Example 1, *supra*.

EXAMPLE 7

In order to demonstrate the enhanced intensity of the color formed by the electrochemichromic solutions of the present invention which thereby effectively decreases the reflectance percentage, we constructed two interior rearview automotive mirrors each having a cell gap of about 135 μm with ITO-coated glass substrates having about 12 to about 15 ohms per square sheet resistance.

In the first mirror, we placed an electrochemichromic solution comprising about 0.01 M of EVClO and about 0.01 M solution of DMPA, both dissolved in a solvent comprising about 80% 3-ethoxypropionitrile and about 20% 2-acetylbutyrolactone (v/v). In addition, this solution contained about 5% of "UVINUL 400" (w/v) as an ultraviolet stabilizing agent.

In the second mirror, we placed an electrochemichromic solution prepared according to the present invention comprising about 0.01 M of EVClO and about 0.01 M solution of reduced MVTB, both dissolved in a solvent comprising about 80% 3-ethoxypropionitrile and about 20% 2-acetylbutyrolactone (v/v). In addition, this solution contained about 5% of "UVINUL 400" (w/v) as an ultraviolet stabilizing agent. We dissolved the MVTB in a solvent comprising about 80% 3-ethoxypropionitrile and about 20% 2-acetylbutyrolactone (v/v), then reacted the solubilized MVTB with zinc dust and otherwise followed the protocol indicated in Example 1, supra.

After we prepared each mirror with the electrochemichromic solutions as described above, we introduced an applied potential of about 1.0 volt to each of the mirrors. The second mirror demonstrated an intense bluish purple color as compared with the light to dark green color demonstrated by the first mirror. In addition, in the bleached state, the second mirror displayed a clear yet silvery appearance while the first mirror displayed an almost clear, yet slightly yellow, non-silvery, appearance. Moreover, the second mirror demonstrated uniform coloring and no appreciable Iris effect in contrast to the non-uniform coloring with a lighter green color which formed in the center of the mirror and a small Iris effect displayed by the first mirror.

We further observed that the high reflectance at the center portion of the second mirror was about 73.5% as compared with about 80.2% for the first mirror. And, the reflectance decreased from about 70% to about 20% in a response time of about 1.4 seconds, with an ultimate decrease to about 10.2%, as compared with the first mirror which decreased from about 70% to only about 40% in about the same period of time, with an ultimate decrease to about 20.2%. We made and recorded these observations using the detection method described in Example 1, *supra*.

EXAMPLE 8

In Examples 8 and 9, we used combinations of 3-hydroxypropionitrile and glutaronitrile in the solvent to still further demonstrate the benefits of the solutions of the present invention.

We constructed two interior rearview automotive mirrors each having a cell gap of about 100 μm with ITO-coated glass substrates having about 12 to about 15 ohms per square sheet resistance.

In the first mirror, we placed an electrochemichromic solution comprising about 0.035 M of $EVClO_4$ and about 0.035 M of DMPA, both dissolved in a solvent comprising about 75% 3-hydroxypropionitrile combined with about 25% glutaronitrile (v/v). In addition, we placed about 5% of "UVINUL 400" (w/v) in this solution.

In the second mirror, we placed an electrochemichromic solution comprising about 0.0175 M of $EVClO_4$ and about 0.0175 M of reduced MVTB, both dissolved in a solvent comprising about 74% 3-hydroxypropionitrile, about 25% glutaronitrile and about 1% glacial acetic acid (v/v). In addition, we placed about 5% of "UVINUL 400" (w/v) in this solution. As in Example 1, supra prior to combining the anodic and cathodic compounds, we reacted MVTB with zinc and otherwise followed the protocol indicated.

We then introduced an applied potential of about 1.0 volt to each of the mirrors, and thereafter observed that the second mirror, filled with an electrochemichromic solution of the present invention, colored rapidly with excellent uniformity and without an appreciable Iris effect as compared with the first mirror. We observed an intense bluish purple color as compared with the largely dark green color demonstrated by the first mirror.

In addition, we observed that the high reflectance at the center portion of the second mirror was about 79.5% as compared with 74.7% in the first mirror. And, the reflectance decreased from about 70% to about 20% in a response time of about 1.7 seconds, with an ultimate decrease to about 8.6%, while the first mirror decreased from about 70% to only about 37% in about the same period of time, with an ultimate decrease to about 13.7% after about 5.3 seconds. We also observed that the second mirror bleached from about 20% reflectance to about 60% reflectance in a response time of about 1.9 seconds as compared with the first mirror which bleached to about the same degree in about 2.2 seconds. When in the bleached state, the second mirror displayed a clear and silvery appearance while the first mirror displayed a clear appearance with a slight yellow hue.

The numerical values obtained in connection with these observations were made using the detection method described in Example 1, supra.

EXAMPLE 9

In this example, we used a combination of about 49.5% 3-hydroxypropionitrile, about 49.5% glutaronitrile and about 1% glacial acetic acid (v/v) to construct an interior rearview automotive mirror having a cell gap of about 100 μm with ITO-coated glass substrates having about 12 to about 15 ohms per square sheet resistance.

We constructed this mirror with an electrochemichromic solution comprising about 0.02M of $EVClO_4$ and about 0.02M of reduced MVTB, both dissolved in a solvent comprising about 49.5% 3-hydroxypropionitrile, about 49.5% glutaronitrile and about 1% glacial acetic acid (v/v) placed between the substrates. In addition, we placed about 5% of "UVINUL 400" (w/v) to this solution. As in Example 1, supra, prior to combining the anodic and cathodic compounds, we reacted MVTB with zinc and otherwise followed the protocol indicated.

We then introduced an applied potential of about 1.0 volt to the mirror, and thereafter observed that the mirror colored rapidly with excellent uniformity and without an appreciable Iris effect. We thereafter observed the formation of an intense bluish purple color.

In addition, we observed that the high reflectance at the center portion of the mirror was about 74.3%. And, the reflectance decreased from about 70% to about 20% in a response time of about 1.5 seconds, with an ultimate decrease to about 7.7%. We also observed that the mirror bleached from about 10% reflectance to about 60% reflectance in a response time of about 4.7 seconds. When in the bleached state, the mirror displayed a clear appearance.

The numerical values obtained in connection with these observations were made using the detection method described in Example 1, supra.

EXAMPLE 10

In this example, we used the combination of about 69% 3-hydroxypropionitrile, about 30% 3,3'-oxydipropionitrile and about 1% glacial acetic acid (v/v) as a solvent in connection with the construction of an electrochemichromic interior rearview automotive mirror. This mirror was constructed from ITO-coated glass substrates having a cell gap of about 100 μm with about 12 to about 15 ohms per square sheet resistance.

We placed an electrochemichromic solution comprising about 0.02M of EVClO and about 0.02M of reduced MVTB, both dissolved in a solvent comprising about 69% 3-oxydipropionitrile about 30% 3,3'-ocydipropionitrile and about 1% glacial acetic acid (v/v). In addition, we placed about 5% of "UVINUL 400" (w/v) to this solution. As in Example 1, supra, prior to combining the anodic and cathodic compounds, we reacted MVTB with zinc and otherwise followed the protocol indicated.

We then introduced an applied potential of about 1.0 volt to the mirror, and thereafter observed that the mirror colored rapidly with excellent uniformity and without an appreciable Iris effect. We thereafter observed the formation of an intense bluish purple color.

In addition, we observed that the high reflectance at the center portion of the mirror was about 73.2%. And, the reflectance decreased from about 70% to about 20% in a response time of about 1.5 seconds, with an ultimate decrease to about 6.9%. What's more, we observed that the mirror bleached from about 10% reflectance to about 60% reflectance in a response time of about 4.7 seconds. When in the bleached state, the mirror displayed a clear and silvery appearance.

The numerical values obtained in connection with these observations were made using the detection method described in Example 1, supra.

EXAMPLE 11

In this example, we used the combination of about 69% 3-ethoxypropionitrile, about 30% 3-hydroxypropionitrile and about 1% glacial acetic acid (v/v) as a solvent in connection with the construction of an electrochemichromic interior rearview automotive mirror. This mirror was constructed from ITO-coated glass substrates having a cell gap of about 100 μm with about 12 to about 15 ohms per square sheet resistance.

We placed an electrochemichromic solution comprising about 0.02M of EVClO and about 0.02M of reduced MVTB, both dissolved in a solvent comprising about 69% ethoxypropionitrile, about 30% 3-hydroxypropionitrile and about 1% glacial acetic acid (v/v). In addition, we placed about 5% of "UVINUL 400" (w/v) to this solution. As in Example 1, supra, prior to combining the anodic and cathodic compounds, we reacted MVTB with zinc and otherwise followed the protocol indicated.

We then introduced an applied potential of about 1.0 volt to the mirror, and thereafter observed that the mirror colored rapidly with excellent uniformity and without an appreciable Iris effect. We thereafter observed the formation an intense bluish purple color.

In addition, we observed that the high reflectance at the center portion of the mirror was about 72.4%. And, the reflectance decreased from about 70% to about 20% in a response time of about 1.7 seconds, with an ultimate decrease to about 9.4%. Moreover, we observed that the mirror bleached from about 10% reflectance to about 60% reflectance in a response time of about 3.2 seconds. When in the bleached state, the mirror displayed a clear appearance.

The numerical values obtained in connection with these observations were made using the detection method described in Example 1, supra.

EXAMPLE 12

In this example, we used the combination of about 99% propylene carbonate and about 1% glacial acetic acid (v/v) as a solvent in connection with the construction of an electrochemichromic interior rearview automotive mirror. This mirror was constructed from ITO-coated glass substrates having a cell gap of about 50 μm with about 6 to about 8 ohms per square sheet resistance.

We placed an electrochemichromic solution comprising about 0.025M of $EVClO_4$ and about 0.025M of reduced MVTB, both dissolved in a solvent comprising about 99% propylene carbonate and about 1% glacial acetic acid (v/v). In addition, we placed about 5% of "UVINUL 400" (w/v) to this solution. As in Example 1, supra, prior to combining the anodic and cathodic compounds, we reacted MVTB with zinc and otherwise followed the protocol indicated.

We then introduced an applied potential of about 1.0 volt to the mirror, and thereafter observed that the mirror colored rapidly with excellent uniformity and without an appreciable Iris effect. We thereafter observed the formation of an intense bluish purple color.

In addition, we observed that the high reflectance at the center portion of the mirror was about 76.3%. And, the reflectance decreased from about 70% to about 20% in a response time of about 1.1 seconds, with an ultimate decrease to about 14.5%. What's more, we observed that the mirror bleached from low reflectance to about 60% reflectance in a response time of about 0.7 seconds. When in the bleached state, the mirror displayed a clear and silvery appearance.

The numerical values obtained in connection with these observations were made using the detection method described in Example 1, supra.

EXAMPLE 13

A window assembly or a sun roof assembly may also be constructed using the electrochemichromic solutions of the present invention. To that end, we constructed a sun roof assembly employing the subject solutions.

We constructed an automotive sun roof from tin oxidecoated glass having about 10 ohms per square sheet resistance [commercially available as TEC-Glass products from Libbey-Owens-Ford Co., LOF Glass Division, Toledo, Oh.]. The dimensions of the sun roof were approximately 38 cm×60 cm, with a cell gap of about 380 μm between the two tin oxide-coated glass substrates. The integrity of this cell gap was kept intact by a sealing means constructed of plasticized polyvinyl butyral which also ensured that the electrochemichromic solution remained therein.

We prepared an electrochemichromic solution according to the present invention whose constituents included about 0.01M of MVTB, that was previously reacted with zinc as in Example 1, supra, about 0.015M of $EVClO_4$, about 0.05M of tetraethylammonium perchlorate and about 5% of "UVINUL 400" (w/v). We prepared solutions of these constituents with a solvent comprising about 64% propylene carbonate, about 35% cyanoethyl sucrose and about 1% acetic acid (v/v).

After filling the cell in the sun roof with this solution, we introduced an applied potential of about 1.0 volt thereto and observed over a time period of about 2 minutes a change from about 74.5% to about 17% in the amount of light transmitted through the sun roof. When we applied zero potential, the electrochemichromic solution self-erased such that the amount of light transmitted therethrough was first observed at about 5% and then over a period of about 2 minutes the color lessened to the point that about 25% of the light was being transmitted through the solution. After a period of about 7 minutes, this solution completely self-erased. We made and recorded these observations using the detection method described in Example 1, supra, except that the reflectometer was set in transmission mode.

In general, we observed good cycle stability, heat stability and ultraviolet stability of the solutions of the present invention when contained within the devices described herein. Specifically, when MVTB is employed in conjunction with $EVClO_4$ in any of the solvents herein recited, a solution of even more ultraviolet stability is observed when compared with the combination of DMPA and $EVClO_4$ in that same solvent. We also observed greater rapidity of response times, especially when bleaching, with solutions having 3-ethoxypropionitrile as a solvent component.

While we have provided the above examples for illustrative purposes employing preferred electrochemichromic compounds and solvents, it is to be understood that each of the electrochemichromic compounds and solvents identified herein will provide suitable, if not comparable, results when viewed in connection with the results gleaned from these examples.

Although we have described the foregoing invention in some detail by way of illustration and example, it will be clear to one of ordinary skill in the art that changes and modifications may be practiced within the spirit of the claims which define the scope of the present invention. Thus, the art-skilled will recognize or readily ascertain using no more than routine experimentation, that equivalents exist to the embodiments of the invention described herein. And, it is intended that such equivalents be encompassed by the claims which follow hereinafter.

What we claim is:

1. An electrochemichromic solution capable of color change when an applied potential is introduced thereto, said electrochemichromic solution comprising:

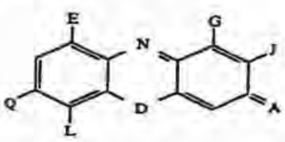
(a) at least one anodic compound, said anodic compound having been previously contacted with a redox agent such that said anodic compound exists in a different valence state than prior to having been contacted with said redox agent;

(b) at least one cathodic compound; and

(c) a solvent

wherein the redox potential of said anodic compound in said different valence state is greater than the redox potential of said cathodic compound while each is contacted with said solvent.

2. The electrochemichromic solution according to claim 1, wherein said anodic compound is represented by the formula below:



wherein

A is O, NRR_1;

wherein R and R may be the same or different and each may be selected from the group consisting of H or any straight-chain or branched alkyl constituent having from about one carbon atom to about six carbon atoms, provided that when A is NRR_1, Q is H or OH;

D is O, S;

E is R , COOH, $CONH_2$, phenyl, 2,4-dihydroxyphenyl;

G is H;

J is phenyl, 2,4-dihydroxyphenyl; or G and J, when taken together, represent an aromatic ring structure having six carbon ring atoms when viewed in conjunction with the ring carbon atoms to which they are attached;

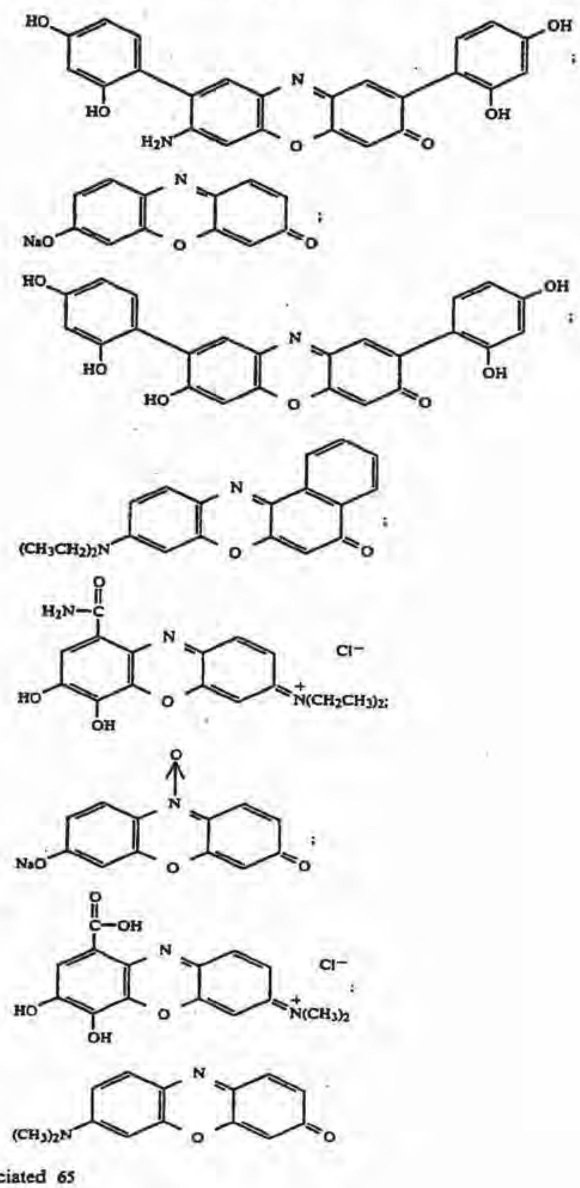
L is H, OH; and

Q is H, OH, NRR_1.

3. The electrochemichromic solution according to claim 2, wherein each A of said anodic compound is NRR_1, a salt selected from the group consisting of tetrafluoroborate, perchlorate, trifluoromethane sulfonate, hexafluorophosphate and any halogen is associated therewith.

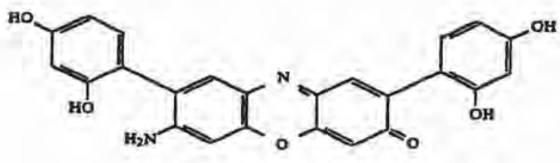
4. The electrochemical solution according to claim 2, wherein when Q of said anodic compound is OH, a salt selected from the group consisting of any alkali metal is associated therewith.

5. The electrochemichromic solution according to claim 2, wherein said anodic compound is a member selected from the class of chemical compounds consisting of the following formulae:

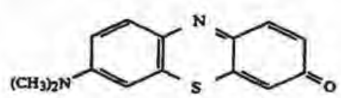


and any combination thereof.

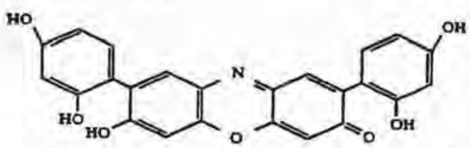
6. The electrochemichromic solution according to claim 2, wherein said anodic compound is represented by the formula below:



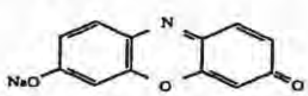
7. The electrochemichromic solution according to claim 2, wherein said anodic compound is represented by the formula below:



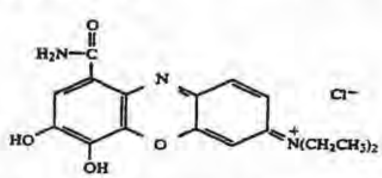
8. The electrochemichromic solution according to claim 2, wherein said anodic compound is represented by the formula below:



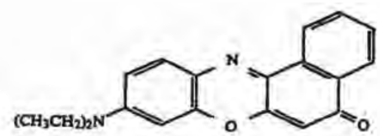
9. The electrochemichromic solution according to claim 2, wherein said anodic compound is represented by the formula below:



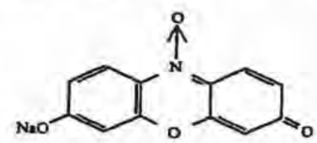
10. The electrochemichromic solution according to claim 2, wherein said anodic compound is represented by the formula below:



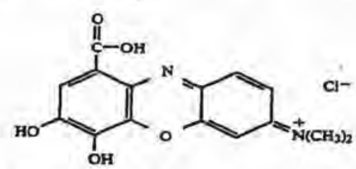
11. The electrochemichromic solution according to claim 2, wherein said anodic compound is represented by the formula below:



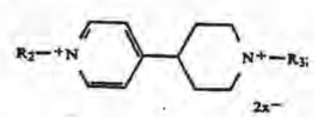
12. The electrochemichromic solution according to claim 2, wherein said anodic compound is represented by the formula below:

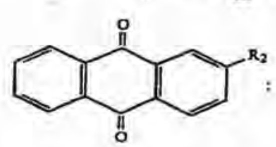


13. The electrochemichromic solution according to claim 2, wherein said anodic compound is represented by the formula below:



14. The electrochemichromic solution according to claim 1, wherein said cathodic compound is selected from the group of chemical compounds consisting of the following formulae:





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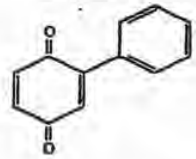


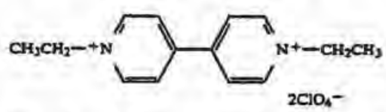
wherein

R_2 and R_3 may be the same or different and each may be selected from the group consisting of H or any straight-chain or branched alkyl constituent having from about one carbon atom to about six carbon atoms;

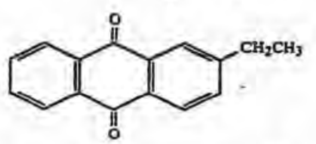
X is selected from the group consisting of tetrafluoroborate, perchlorate, trifluoromethane sulfonate, hexafluorophosphate, any halogen

and any combination thereof.

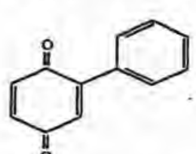
15. The electrochemichromic solution according to claim **14**, wherein said cathodic compound is



16. The electrochemichromic solution according to claim **14**, wherein said cathodic compound is



17. The electrochemichromic solution according to claim **14**, wherein said cathodic compound is



18. The electrochemichromic solution according to claim **1**, wherein said redox agent of (a) is in a solid form.

19. The electrochemichromic solution according to claim **18**, wherein said redox agent has a particle size of about 50 mesh to about 400 mesh.

20. The electrochemichromic solution according to claim **1**, wherein said redox agent of (a) is a reducing agent capable of causing an electrochemichromic compound to assume a decreased valence state upon contacting therewith as compared with that valence state possessed by said electrochemichromic compound prior to having been contacted with said reducing agent.

21. The electrochemichromic solution according to claim **20**, wherein said reducing agent is a member selected from the group consisting of zinc, ascorbic acid, sodium hydrosulfite, vanadium (III) chloride, chromium (II) acetate, sulfur dioxide and any combination thereof.

22. The electrochemichromic solution according to claim **21**, wherein said reducing agent is zinc.

23. The electrochemichromic solution according to claim **1**, wherein said redox agent of (a) is an oxidizing agent capable of causing an electrochemichromic compound to assume an increased valence state upon contacting therewith as compared with that valence state possessed by said electrochemichromic compound prior to having been contacted with said oxidizing agent.

24. The electrochemichromic solution according to claim **23**, wherein said oxidizing agent is a member selected from the group consisting of air, oxygen, sodium persulfate, methylene violet (Bernthsen) and any combination thereof.

25. The electrochemichromic solution according to claim **1**, wherein said solvent of (c) is a member selected from the group consisting of acetonitrile, 3-hydroxypropionitrile, methoxypropionitrile, 3-ethoxypropionitrile, propylene carbonate, 2-acetylbutyrolactone, cyanoethyl sucrose, 7-butyrolactone, 2-methylglutaronitrile, N,N'-dimethylformamide, 3,3'-ethylsulfolane, methylethyl ketone, cyclopentanone, cyclohexanone, benzoyl acetone, 4-hydroxy-4-methyl-2-pentanone, acetophenone, glutaronitrile, 3,3'-oxydipropionitrile, 2-methoxyethyl ether, triethylene glycol dimethyl ether and any combination thereof.

26. The electrochemichromic solution according to claim **1**, wherein said solvent of (c) is acidic.

27. The electrochemichromic solution according to claim **26**, wherein said solvent is rendered acidic by employing as a solvent component an acidic material selected from the group consisting of acetic acid, any hydrogen halide gas in solution, perchloric acid, 2-acetylbutyrolactone, 3-hydroxypropionitrile and any combination thereof.

28. The electrochemichromic solution according to claim **27**, wherein said solvent component is acetic acid.

29. The electrochemichromic solution according to claim **28**, wherein said solvent component is acetic acid employed in the range of about 0.01% (v/v) to about 75% (v/v).

30. The electrochemichromic solution according to claim **28**, wherein said solvent component is acetic acid employed at about 1% (v/v).

31. The electrochemichromic solution according to claim **26**, wherein said solvent is comprised of about 74% 3-hydroxypropionitrile, about 25% glutaronitrile and about 1% acetic acid (v/v).

32. The electrochemichromic solution according to claim **26**, wherein said solvent is comprised of about 49.5% 3-hydroxypropionitrile, about 49.5% glutaronitrile and about 1% acetic acid (v/v).

33. The electrochemichromic solution according to claim **26**, wherein said solvent is comprised of about 64% propylene carbonate, about 35% cyanoethyl sucrose and about 1% acetic acid (v/v).

34. The electrochemichromic solution according to claim **26**, wherein said solvent is comprised of about 69% 3-hydroxypropionitrite, 30% 3,3'-oxydipropionitrile and about 1% acetic acid (v/v).

35. The electrochemichromic solution according to claim **26**, wherein said solvent is comprised of about 99% propylene carbonate and about 1% acetic acid (v/v).

36. The electrochemichromic solution according to claim 1, further comprising (d) a constituent selected from the group consisting of an ultraviolet stabilizing agent, an electrolytic material and any combination thereof.

37. The electrochemichromic solution according to claim 36, wherein said ultraviolet stabilizing agent is a member selected from the group consisting of "UVINUL 400", "UVINUL D-49", TINUVIN P, "TINUVIN 327", "TINUVIN 328", "Cyasorb 24", benzotriazole, benzophenone and any combination thereof.

38. The electrochemichromic solution according to claim 37, wherein said ultraviolet stabilizing agent is "UVINUL 400".

39. The electrochemichromic solution according to claim 36, wherein said electrolytic material is a member selected from the group consisting of tetrabutylammonium hexafluorophosphate, tetraethylammonium perchlorate, tetrabutylammonium tetrafluoroborate, tetrabutylammonium trifluoromethane sulfonate, any halogen alkali metal salt and any combination thereof.

40. The electrochemichromic solution according to claim 39, wherein said electrolytic material is tetrabutylammonium hexafluorophosphate.

41. The electrochemichromic solution according to claim 1, wherein the total concentration of said first electrochemichromic compound and said second electrochemichromic compound in said electrochemichromic solution is in the range of about 0.001M to about 0.1M.

42. The electrochemichromic solution according to claim 41, wherein the total concentration of said first electrochemichromic compound and said second electrochemichromic compound in said electrochemichromic solution is about 0.04M.

43. The electrochemichromic solution according to claim 1, wherein said applied potential is introduced to said solution in the range of about 0.001 volts to about 5 volts.

44. The electrochemichromic solution according to claim 43, wherein said applied potential is introduced at about 1 volt.

45. A process for preparing an electrochemichromic solution, said process comprises:

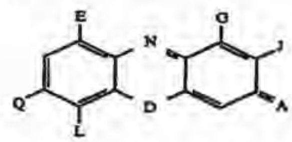
(a) solubilizing an electrochemichromic compound with a solvent;

(b) contacting said solubilized electrochemichromic compound with a redox agent to alter the valence state of said electrochemichromic compound such that an anodic compound is created in solution which has a different valence state than said solubilized electrochemichromic compound possessed prior to having been contacted with said redox agent;

(c) contacting a cathodic compound with said solubilized anodic compound of (b) to form said electrochemichromic solution; and

(d) introducing an applied potential to said electrochemichromic solution such that a current passes through said electrochemichromic solution thereby causing a color change thereof.

46. The process according to claim 45, wherein said anodic compound is represented by the formula below:



wherein

A is O, NRR_1;

wherein R and R_1 may be the same or different and each may be selected from the group consisting of H, any straight-chain or branched alkyl constituent having from about one carbon atom to about six carbon atoms, provided that when A is NRR_1, Q is H or OH;

D is O, S;

E is R_1, COOH, $CONH_2$, phenyl, 2,4-dihydroxyphenyl;

G is H;

J is phenyl, 2,4-dihydroxyphenyl; or G and J, when taken together, represent an aromatic ring structure having six carbon ring atoms when viewed in conjunction with the ring carbon atoms to which they are attached;

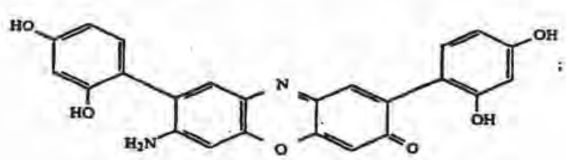
L is H, OH; and

Q is OH, NRR_1.

47. The process according to claim 46, wherein when A of said anodic compound is NRR_1, a salt selected from the group consisting of tetrafluoroborate, perchlorate, trifluoromethane sulfonate, hexafluorophosphate and any halogen is associated therewith.

48. The process according to claim 46, wherein when Q of said anodic compound is OH, a salt selected from the group consisting of any alkali metal is associated therewith.

49. The process according to claim 46, wherein said anodic compound is selected from the group consisting of the chemical compounds represented by the following formulae



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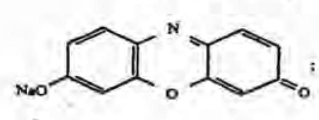

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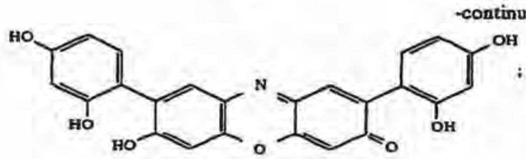
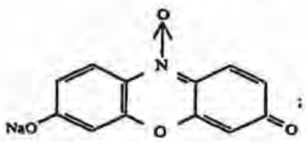
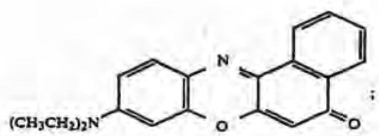
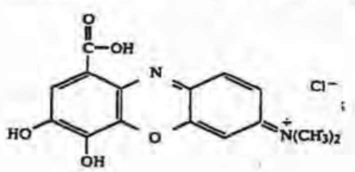
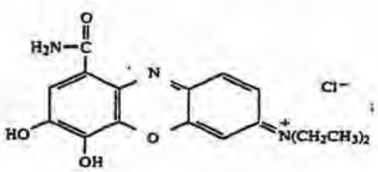
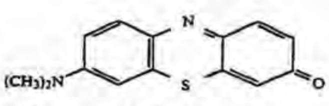






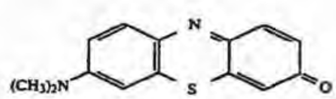




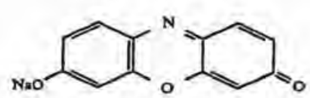


and any combination thereof.

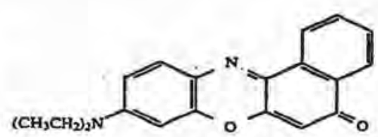
50. The process according to claim 46, wherein said anodic compound is represented by the formula below:



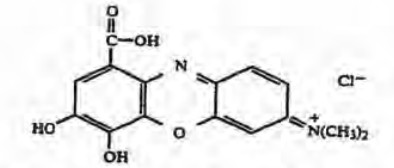
51. The process according to claim 46, wherein said anodic compound is represented by the formula below:



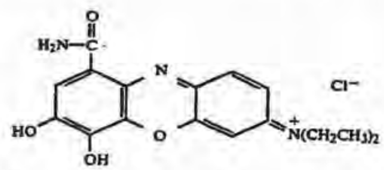
52. The process according to claim 46, wherein said anodic compound is represented by the formula below:



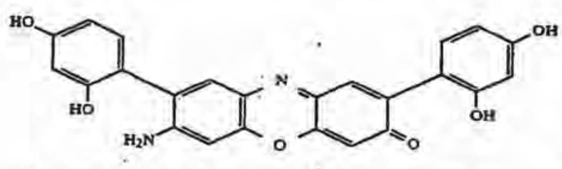
53. The process according to claim 46, wherein said anodic compound is represented by the formula below:



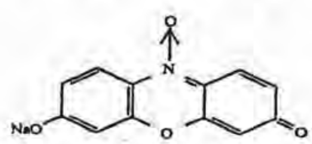
54. The process according to claim 46, wherein said anodic compound is represented by the formula below:



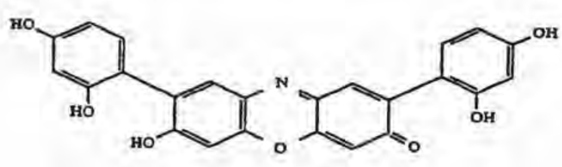
55. The process according to claim 46, wherein said anodic compound is represented by the formula below:



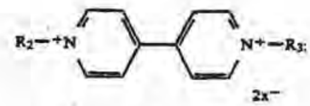
56. The process according to claim 46, wherein said anodic compound is represented by the formula below:

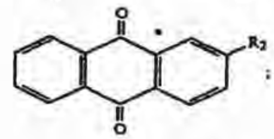


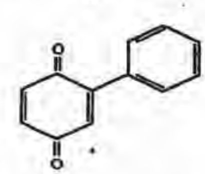
57. The process according to claim 46, wherein said anodic compound is represented by the formula below:



58. The process according to claim 45, wherein said cathodic compound is selected from the group consisting of the chemical compounds presented by the following formulae:







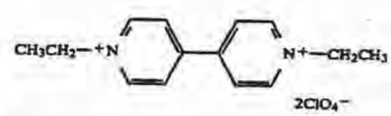
wherein

R_2 and R_3 may be the same or different and each may be selected from the group consisting of H or any straight-chain or branched alkyl constituent having from about one carbon atom to about six carbon atoms; and

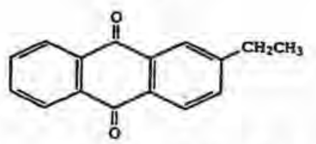
X is selected from the group consisting of tetrafluoroborate, perchlorate, trifluoromethane sulfonate, hexafluorophosphate, any halogen

and any combination thereof.

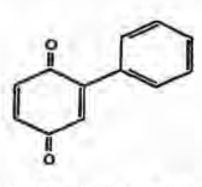
59. The process according to claim 58, wherein said cathodic compound is represented by the formula below:



60. The process according to claim 58, wherein said cathodic compound is represented by the formula below:



61. The process according to claim 58, wherein said cathodic compound is represented by the formula below:



62. The process according to claim 45, further comprising after (b) removing that quantity of said redox agent of (b) which has remained unreacted.

63. The process according to claim 62, wherein said redox agent is removed by a means selected from the group consisting of filtering, decanting, osmosis, fractionating, precipitating, extracting, centrifuging, vacuum and any combination thereof.

64. The process according to claim 45, wherein said redox agent of (b) is in a solid form.

65. The process according to claim 64, wherein said redox agent has a particle size of about 50 mesh to about 400 mesh.

66. The process according to claim 45, wherein said redox agent of (b) is a reducing agent capable of causing an electrochemichromic compound to assume a decreased valence state upon contacting therewith as compared with that valence state possessed by said electrochemichromic compound prior to having been contacted with said reducing agent.

67. The process according to claim 66, wherein said reducing agent is a member selected from the group consisting of zinc, ascorbic acid, sodium hydrosulfite, vanadium (III) chloride, chromium (II) acetate, sulfur dioxide and any combination thereof.

68. The process according to claim 67, wherein said reducing agent is zinc.

69. The process according to claim 45, wherein said redox agent of (b) is an oxidizing agent capable of causing an electrochemichromic compound to assume an increased valence state upon contacting therewith as compared with that valence state possessed by said electrochemichromic compound prior to having been contacted with said oxidizing agent.

70. The process according to claim 69, wherein said oxidizing agent is a member selected from the group consisting of air, oxygen, sodium persulfate, methylene violet (Bernthsen) and any combination thereof.

71. The process according to claim 45, wherein said electrochemichromic solution further comprises a constituent selected from the group consisting of an ultraviolet stabilizing agent, an electrolytic material and any combination thereof.

72. The process according to claim 71, wherein said constituent is an ultraviolet stabilizing agent.

73. The process according to claim 72, wherein said ultraviolet stabilizing agent is selected from the group consisting of "UVINUL 400"; "UVINUL D-49", "TINUVIN P", "TINUVIN 327", "TINUVIN 328", "Cyasorb 24", benzotriazole, benzophenone and any combination thereof.

74. The process according to claim 73, wherein said ultraviolet stabilizing agent is "UVINUL 400".

75. The process according to claim 71, wherein said constituent is an electrolytic material.

76. The process according to claim 75, wherein said electrolytic material is selected from the group consisting of tetrabutylammonium hexafluorophosphate, tetraethylammonium perchlorate, tetrabutylammonium tetrafluoroborate, tetrabutylammonium trifluoromethane sulfonate, any halogen alkali metal salt and any combination thereof.

77. The process according to claim 76, wherein said electrolytic material is tetrabutylammonium hexafluorophosphate.

78. The process according to claim 45, wherein said solvent of (a) is a member selected from the group consisting of acetonitrile, 3-hydroxypropionitrile, methoxypropionitrile, 3-ethoxypropionitrile, propylene carbonate, 2-acetylbutyrolactone, cyanoethyl sucrose, γ-butyrolactone, 2-methylglutaronitrile, N,N'-dimethylformamide, 3-methylsulfolane, methylethyl ketone, cyclopentanone, cyclohexanone, benzoyl acetone, 4-hydroxy-4-methyl-2-pentanone, acetophenone, glutaronitrile, 3,3'-oxydipropionitrile, 2-methoxyethyl ether, triethylene glycol dimethyl ether and any combination thereof.

79. The process according to claim 45, wherein said solvent of (a) is acidic.

80. The process according to claim 79, wherein said solvent is rendered acidic by employing as a solvent component an acidic material selected from the group consisting of acetic acid, any hydrogen halide gas in solution, perchloric acid, 2-acetylbutyrolactone, 3-hydroxypropionitrile and any combination thereof.

81. The process according to claim 80, wherein said solvent component is acetic acid.

82. The process according to claim 81, wherein said solvent component is acetic acid employed in the range of about 0.01% (v/v) to about 75% (v/v).

83. The process according to claim 82, wherein said solvent component is employed at about 1% (v/v).

84. The process according to claim 80, wherein said solvent is comprised of about 74% 3-hydroxypropionitrile, about 24% glutaronitrile and about 1% acetic acid (v/v).

85. The process according to claim 80, wherein said solvent is comprised of about 49.5% 3-hydroxypropionitrile, about 49.5% glutaronitrile and about 1% acetic acid (v/v).

86. The process according to claim 80, wherein said solvent is comprised of about 64% propylene carbonate, about 35% cyanoethyl sucrose (v/v) and about 1% acetic acid (v/v).

87. The process according to claim 80, wherein said solvent is comprised of about 69% 2-hydroxypropionitrile, about 30% 3,3'-oxydipropionitrile and about 1% acetic acid (v/v).

88. The process according to claim 80, wherein said solvent is comprised of about 99% propylene carbonate and about 1% acetic acid (v/v).

89. A process for using an electrochemichromic solution according to claim 1, said process comprises:

(a) inserting said electrochemichromic solution into a cell;

sealing said cell so that said electrochemichromic solution is prevented from escaping therefrom; and

(c) introducing an applied potential to said electrochemichromic solution contained in said cell such that a current passes therethrough to cause a color change thereof.

90. An electrochemichromic device comprising:

(a) a first substantially transparent substrate coated with a substantially transparent conductive coating on its interior face;

(b) a second substantially transparent substrate coated with a substantially transparent conductive coating on its interior face, said second substrate positioned in substantially parallel spaced-apart relationship with said first substrate and being laterally displaced therefrom;

(c) a sealing means positioned toward the peripheral edge of each of said first substrate and said second substrate and sealingly forming a cell cavity therebetween;

(d) the electrochemichromic solution according to claim 1 having been dispensed into and confined within said cell cavity; and

(e) a means for introducing an applied potential to said electrochemichromic solution to controllably cause a variation in the amount of light transmitted through said device.

91. The electrochemichromic device according to claim 90, wherein said transparent conductive coating may be constructed from a material selected from the group consisting of indium tin oxide, tin oxide, antimony-doped tin oxide, fluorine-doped tin oxide, antimony-doped zinc oxide and aluminum-doped zinc oxide.

92. The electrochemichromic device according to claim 90, wherein said device is a member selected from the group consisting of mirrors, glazings, partitions, filters, displays and lenses.

93. The electrochemichromic device according to claim 92, wherein said glazing is a window assembly.

94. The electrochemichromic device according to claim 92, wherein said glazing is a sun roof assembly.

95. The electrochemichromic device according to claim 92, wherein said device is a mirror assembly further comprising a reflective coating on a face of either one of said first substrate or said second substrate.

96. The electrochemichromic mirror assembly according to claim 95, wherein said reflective coating is constructed of a material selected from the group consisting of aluminum, silver, platinum, palladium, titanium, chromium and stainless steel.

97. The electrochemichromic device according to claim 90, wherein said first substrate of (a) is a laminate assembly comprising at least two substantially transparent panels affixed to one another by a substantially transparent adhesive layer.

98. The electrochemichromic device according to claim 90, further comprising (g) a molded casing formed about the periphery of said device.

99. The electrochemichromic device according to claim 98, wherein said molded casing is constructed of injection molded polyvinyl chloride.

100. The electrochemichromic device according to claim 98, wherein said molded casing is constructed of a moldable material that is reaction injected molded.

101. The electrochemichromic device according to claim 90, wherein said sealing means of (c) may be constructed from a member selected from the group consisting of thermosetting materials and thermoplastic materials.

102. The electrochemichromic device according to claim 101, wherein said sealing means is constructed from a thermosetting material.

103. The electrochemichromic device according to claim 101, wherein said sealing means is constructed of a thermoplastic material.

104. The electrochemichromic device according to claim 90, wherein said first substrate of (a) and said second substrate of (b) are constructed from a material selected from the group consisting of glass, optical plastics, laminated glass and tempered glass.

105. The electrochemichromic device according to claim 90, wherein said first substrate of (a) and said second substrate of (b) are each constructed of the same material.

106. The electrochemichromic device according to claim 90, wherein said first substrate of (a) and second substrate of (b) are each constructed of different materials.

107. An electrochemichromic device comprising:

(a) a first glass substrate coated with a conductive coating on its interior face;

(b) a second glass substrate coated with a conductive coating on its interior face, said second glass substrate positioned in substantially parallel spaced-apart relationship with said first glass substrate;

(c) a sealing means positioned toward, but inward from, the peripheral edge of each of said first substrate and said second substrate and sealingly forming a cell cavity therebetween;

(d) an electrochemichromic solution capable of color change when an applied potential is introduced thereto, said electrochemichromic solution comprising:

(1) methylene violet (Bernthsen), wherein said methylene violet (Bernthsen) has previously been reduced;

(2) an alkyl-substituted viologen salt, wherein said alkyl substituent is a member-selected from the group consisting of any straight-chain or branched alkyl group having from about one carbon atom to about six carbon atoms; and

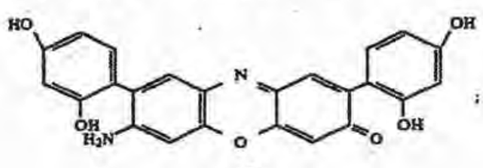
(3) a solvent, wherein said solvent is a member selected from the group consisting of the the combination of 3-hydroxypropionitrile, glutaronitrile and acetic acid, the combination of propylene carbonate and acetic acid, the combination of 3-ethoxypropionitrile and 2-acetylbutyrolactone, the combination of 3-ethoxypropionitrile, glutaronitrile and acetic acid, the combination of 3-hydroxypropionitrile, 3,3'-oxydipropionitrile and acetic acid, and the combination of propylene carbonate, cyanoethyl sucrose and acetic acid, wherein said solution has been dispensed into and confined within said cell cavity; and

(e) a means for introducing an applied potential to said electrochemichromic solution to controllably cause a variation in the amount of light transmitted through said solution.

108. The electrochemichromic device according to claim 107, wherein said device is selected from the group consisting of mirrors, glazings, partitions, filters, displays and lenses.

109. The electrochemichromic device according to claim 108, wherein said device is a mirror further comprising a reflective coating on a face of said second glass substrate.

110. The process for using an electrochemichromic solution according to claim 89, wherein said anodic compound of said electrochemichromic solution is a member selected from the group consisting of chemical compounds of the following formulae: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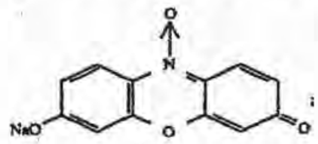
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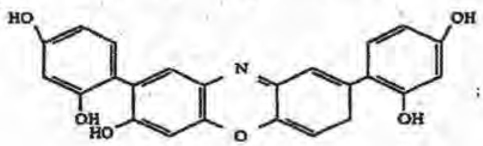
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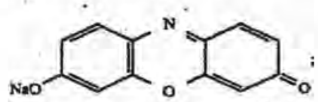
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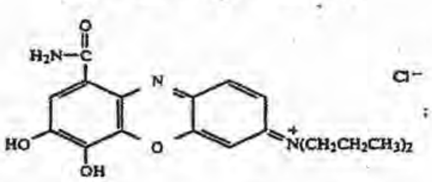
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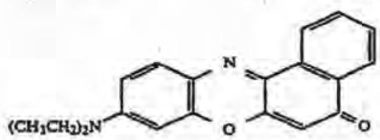
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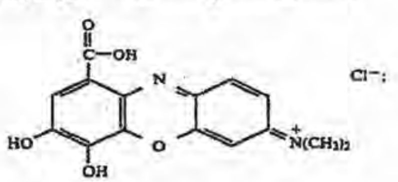
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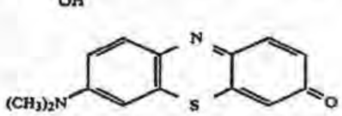
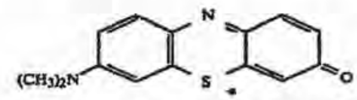
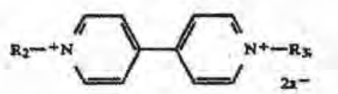


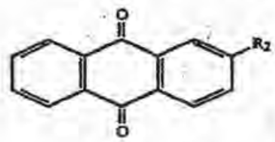
and any combination thereof.

111. The process for using an electrochemichromic solution according to claim 89, wherein said anodic compound of said electrochemichromic solution is



112. The process for using an electrochemichromic solution according to claim 89, wherein said cathodic compound of said electrochemichromic solution is a member selected from the group consisting of chemical compounds of the following formulae:

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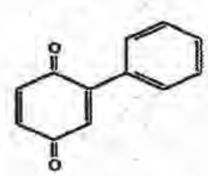


wherein

R_2 and R_3 may be the same or different and each may be selected from the group consisting of H or any straight-chain or branched alkyl constituent having from about one carbon atom to about six carbon atoms; and

X is selected from the group consisting of tetrafluoroborate, perchlorate, trifluoromethane sulfonate, hexafluorophosphate, any halogen

and any combination thereof.

113. The process for using an electrochemichromic solution according to claim 89, wherein said solvent of siad electrochemichromic solution is a member selected from the group consisting of acetonitrile, 3-hydroxypropionitrile, methoxypropionitrile, 3-ethoxypropionitrile, propylene carbonate, 2-acetylbutyrolactone, cyanoethyl sucrose, γ-butyrolactone, 2-methylglutaronitrile, N,N'-dimethylformamide, 3-methylsulfolane, methylethyl ketone, cyclopentanone, cyclohexanone, benzoyl acetone, 4-hydroxy-4-methyl-2-pentanone, acetophenone, glutaronitrile, 3,3'-oxydipropionitrile, 4-methoxyethyl ether, triethylene glycol dimethyl ether and any combination thereof.

114. The process for using an electrochemichromic solution according to claim 89, wherein said solvent of siad electrochemichromic solution is acidic.

115. The process according to claim 114, wherein said solvent is rendered acidic by employing as a solvent component an acidic material selected from the group consisting of acetic acid, any hydrogen halide gas

in solutio· ·chloric acid, 2-acetylbutyrolactone, 3-hydroxyp·opionitrile and any combination thereof.

116. The process for using an electrochemichromic solution according to claim 89, wherein the total concentration of said anodic compound and said cathodic compound in said electrochemichromic solution is in the range of about 0.005M to about 0.5M.

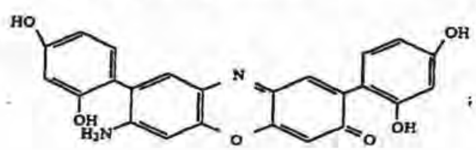
117. The process for using an electrochemichromic solution according to claim 89, wherein said redox agent which has previously contacted said anodic compound of said electrochemichromic solution is a reducing agent capable of causing an electrochemichromic compound to assume a decreased valence state upon contacting therewith as compared with that valence state possessed by said electrochemichromic compound prior to having been contacted with said reducing agent.

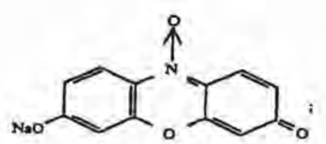
118. The process according to claim 117, wherein said reducing agent is zinc.

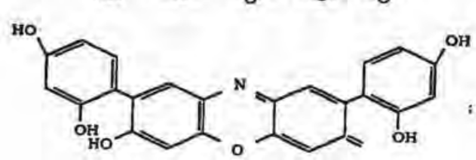
119. The process for using an electrochemichromic solution according to claim 89, wherein said electrochemichromic solution further comprises a constituent selected from the group consisting of ultraviolet stabilizing agents, electrolytic material and any combination thereof.

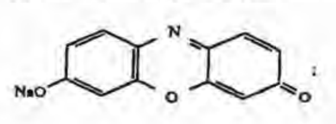
120. The process of using an electrochemichromic solution according to claim 89, wherein said applied potential is introduced to said electrochemichromic solution in the range of about 0.001 volts to about 5 volts.

121. The electrochemichromic device according to claim 90, wherein said anodic compound of said electrochemichromic solution of said device is a member selected from the group consisting of chemical compounds of the following formulae:









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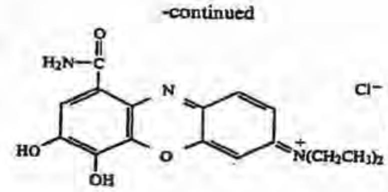
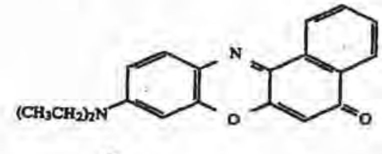
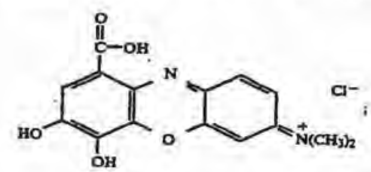
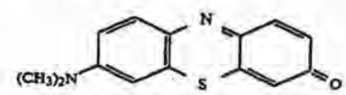


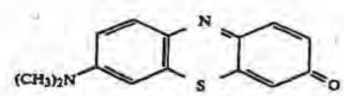




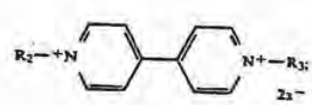


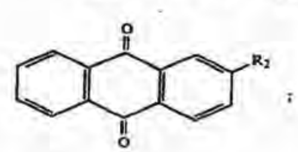
and any combination thereof.

122. The electrochemichromic device according to claim 90, wherein said anodic compound of said electrochemichromic solution of said device is



123. The electrochemichromic device according to claim 90, wherein said cathodic compound of said electrochemichromic solution of said device is a member selected from the group consisting of chemical compounds of the following formulae:





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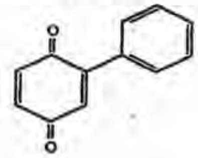


wherein

R$_2$ and R$_3$ may be the same or different and each may be selected from the group consisting of H or any straight-chain or branched alkyl constituent having from about one carbon atom to about six carbon atoms; and

X is selected from the group consisting of tetrafluoroborate, perchlorate, trifluoromethane sulfonate, hexafluorophosphate, any halogen

and any combination thereof.

124. The electrochemichromic device according to claim 90, wherein said solvent of said electrochemichromic solution of said device is member selected from the group consisting of acetonitrile, 3-hydroxypropionitrile, methoxypropionitrile, 3-ethoxypropionitrile, propylene carbonate, 2-acetylbutyrolactone, cyanoethyl sucrose, γ-butyrolactone, 2-methylglutaronitrile, N,N'-dimethylformamide, 3-methylsulfolane, methylethyl ketone, cyclopentanone, cyclohexanone, benzoyl acetone, 4-hydroxy-4-methyl-2-pentanone, acetophenone, glutaronitrile, 3,3'-oxydipropionitrile, 2-methoxyethyl ether, triehtylene glycol dimethyl ether and any combination thereof.

125. The electrochemichromic device according to claim 90, wherein said solvent of said electrochemichromic solution of said device is acidic.

126. The electrochemichromic device according to claim 125, wherein said solvent is rendered acidic by employing as a solvent component an acidic material selected from the group consisting of acetic acid, any hydrogen halide gas in solution, perchloric acid, 2-acetylbutyrolactone, 3-hydroxypropionitrile and any combination thereof.

127. The electrochemichromic device according to claim 90, wherein the total concentration of said anodic compound and said cathodic compound in said electrochemichromic solution of said device is in the range of about 0.005M to about 0.5M.

128. The electrochemichromic device according to claim 90, wherein said redox agent which has previously contacted said anodic compound of said electrochemichromic solution of said device is a reducing agent capable of causing an electrochemichromic compound to assume a decreased valence state upon contacting therewith as compared with that valence state possessed by said electrochemichromic compound prior to having been contacted with said reducing agent.

129. The electrochemichromic device according to claim 128, wherein said reducing agent is zinc.

130. The electrochemichromic device according to claim 90, wherein said electrochemichromic solution of said device further comprises a constituent selected from the group consisting of ultraviolet stabilizing agents, electrolytic materials and any combination thereof.

131. The electrochemichromic device according to claim 90, wherein said applied potential is introduced to said electrochemichromic solution of said device in the range of about 0.002 volts to about 5 volts.

132. The process for using an electrochemichromic solution according to claim 89, wherein that quantity of said redox agent which has remained unreacted after having previously contacted said anodic compound of said electrochemichromic solution has been removed therefrom.

133. The electrochemichromic device according to claim 90, wherein that quantity of said redox agent which has remained unreacted after having previously contacted said anodic compound of said device has been removed from said electrochemichromic solution.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 5,239,405 Page 1 of 8

DATED : August 24, 1993

INVENTOR(S) : DESARAJU V. VARAPRASAD ET AL.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

On the title page:

AT [56] REFERENCED CITED

Other Publications, under I.V. Shelepin et al. (first occurrence) "*Electrokhima*," should read --*Electrokhimya*,--.

AT [57] ABSTRACT

Line 11, "involve" should read --involves--.

COLUMN 1

Line 31, "*himva*," should read --*himya*,--.

COLUMN 2

Line 15, "involve" should read --involves--.

COLUMN 3

Line 51, "to a" should read --to refer to a--.

COLUMN 4

Line 1, "solution —and" should read --solution—and--.
Line 42, "Self-erasing" should read --¶ "Self-erasing"--.
Line 44, "hwen" should read --when--.
Line 53, "pr" should read --or--.

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 5,239,405

DATED : August 24, 1993

INVENTOR(S) : DESARAJU V. VARAPRASAD ET AL.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

COLUMN 5

Line 2, "formula" should read --formula:--.
Line 12, "wherein R and R" should read --¶ wherein R and R_1--.
Line 19, "OS;" should read --O, S;--.
Line 20, "R ," should read --R_1,--.

COLUMN 6

Line 8, "NRR ," should read --NRR_1,--.
Line 12, "(BF_4)," should read --(BF_4^-),--.
Line 13, "(ClO_4)," should read --(ClO_4^-),--.
Line 22, "formulae" should read --formulae:--.

COLUMN 7

Line 26, "formulae" should read --formulae:--.
Line 56, "BF_4, ClO_4," should read --BF_4^-, ClO_4^-,--.
Line 57, "CF_3SO_3, PF_6," should read --$CF_3SO_3^-$, PF_6^-,--.
Line 61, "ClO_4," should read --ClO_4^-,--.

COLUMN 9

Line 16, "nonexhaustive" should read --non-exhaustive--.
Line 65, "pretreated" should read --pre-treated--.

COLUMN 12

Line 67, "EVClO.," should read --$EVClO_4$,--.

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 5,239,405

DATED : August 24, 1993

INVENTOR(S) : DESARAJU V. VARAPRASAD ET AL.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

COLUMN 13

Line 32, "to;" should read --to,--.
Line 47, "solutions," should read --solution,--.

COLUMN 14

Line 13, "in direc-" should read --in opposite direc- --.
Line 14, "opposite directions" should be deleted.
Line 15, "relative to one another—i.e.," should be deleted.
Line 25, "300 521" should read --300 Å--.

COLUMN 15

Line 20, close up right margin.
Line 21, close up left margin.

COLUMN 16

Line 47, "clear," should read --clear--.
Line 64, "transmitted" should read --be transmitted--.
Line 68, "transmitted" should read --be transmitted--.

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 5,239,405
DATED : August 24, 1993
INVENTOR(S) : DESARAJU V. VARAPRASAD ET AL.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

<u>COLUMN 18</u>

Line 2, "$EVDlO_4$" should read --$EVClO_4$--.
Line 4, "dro5," should read--dro-5,--.
Line 9, "$EVCLO_4$" should read --$EVClO_4$--.
Line 16, "combination" should read --combination--.
Line 29, "$EVCLO_4$" should read --$EVClO_4$--.
Line 44, "Illuminate A)" should read --Illuminant A)--.
Line 55, "*supra,*" should read --supra,--.

<u>COLUMN 19</u>

Line 65, "concimitant" should read --concomitant--.

<u>COLUMN 20</u>

Line 4, "$EVCLO_4$" should read --$EVClO_4$--.
Line 8, "UNINUL400" should read --"UVINUL 400"--.
Line 12, "$EVCLO_4$" should read --$EVClO_4$--.
Line 14, "comprisnig" should read --comprising--.

<u>COLUMN 21</u>

Line 3, "EVClO" should read --$EVClO_4$--.
Line 5, "9%" should read --69%--.
Line 7, "supra" should read --supra,--.
Line 36, "*supra.*" should read --supra.--.
Line 48, "EVClO" should read --$EVClO_4$--.
Line 56, "EVClO" should read --$EVClO_4$--.

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 5,239,405

DATED : August 24, 1993

INVENTOR(S) : DESARAJU V. VARAPRASAD ET AL.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

COLUMN 22

Line 23, "*supra.*" should read supra.--.
Line 48, "supra" should read --supra,--.

COLUMN 23

Line 26, "to" should read --in--.
Line 60, "EVClO" should read --$EVClO_4$--.
Line 62, "69% 3-oxydipropionitrile" should read --69% 3-hydroxypropionitrile,-- and "3,3'-ocydipro-" should read --3,3'-oxydipro- --.

COLUMN 24

Line 29, "EVClO" should read --$EVClO_4$--.
Line 34, "to this" should read --in this--.

COLUMN 25

Line 2, "to" should read --in--.
Line 30, "oxidecoated" should read --oxide-coated--.

COLUMN 26

Line 35, "solvent" should read --solvent,--.
Line 54, "R and R" should read --R and R_1--.
Line 61, "R ," should read --R_1,--.

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 5,239,405

DATED : August 24, 1993

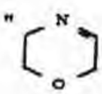
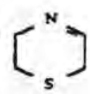
INVENTOR(S) : DESARAJU V. VARAPRASAD ET AL.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

COLUMN 27

Line 4, "each A" should read --when A--.
Line 67, "electrochemical" should read --electrochemichromic---.

COLUMN 28

Line 60, "  " should read --  --.

COLUMN 32

Line 23, "7-butyrolactone," should read --γ-butyrolactone,--.
Line 24, "3,3'-ethylsulfolane," should read --3-methylsulfolane,--.
Line 63, "3-hydroxypropionitrite," should read --3-hydroxypropionitrile,--.

COLUMN 33

Line 9, "TINUVIN P," should read --"TINUVIN P",--.
Line 44, "comprises:" should read --comprising:--.

COLUMN 34

Line 52, "formulae" should read --formulae:--.

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 5,239,405

DATED : August 24, 1993

INVENTOR(S) : DESARAJU V. VARAPRASAD ET AL.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

COLUMN 37

Line 67, "presented" should read --represented--.

COLUMN 40

Line 68, "comprises:" should read --comprising:--.

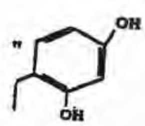
COLUMN 41

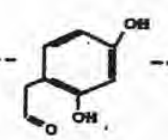
Line 3, "sealing" should read --(b) sealing--.

COLUMN 42

Line 20, "second" should read --said second--.
Line 42, "member-selected" should read --member selected--.
Line 47, "the the" should read --the--.

COLUMN 43

Line 26, " 

" should read -- 

--.

Line 43, "$\overset{+}{N}(CH_2CH_2CH_3)_2$" should read --$\overset{+}{N}(CH_2CH_3)_2$--.

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 5,239,405

DATED : August 24, 1993

INVENTOR(S) : DESARAJU V. VARAPRASAD ET AL.

Page 8 of 8

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

COLUMN 45

Line 26, "material" should read --materials--.
Line 29, "of" should read --for--.

COLUMN 47

Line 32, "triehtylene" should read --triethylene--.

COLUMN 48

Line 28, "0.002 volts" should read --0.001 volts--.

Signed and Sealed this

Ninth Day of August, 1994

Attest:

BRUCE LEHMAN

Attesting Officer

Commissioner of Patents and Trademarks

United States Patent [19]

McCord

[11] **4,449,786**

[45] **May 22, 1984**

[54] **REARVIEW MIRROR**

[76] Inventor: **Robert C. McCord**, 6220 Burton, Romulus, Mich. 48174

[21] Appl. No.: **257,490**

[22] Filed: **Apr. 24, 1981**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 916,598, Jun. 19, 1978, Pat. No. 4,264,144.

[51] **Int. Cl.**[3] **G02B 5/10**

[52] **U.S. Cl.** **350/293**

[58] **Field of Search** 350/303, 293; D12/187; D28/65

[56] **References Cited**

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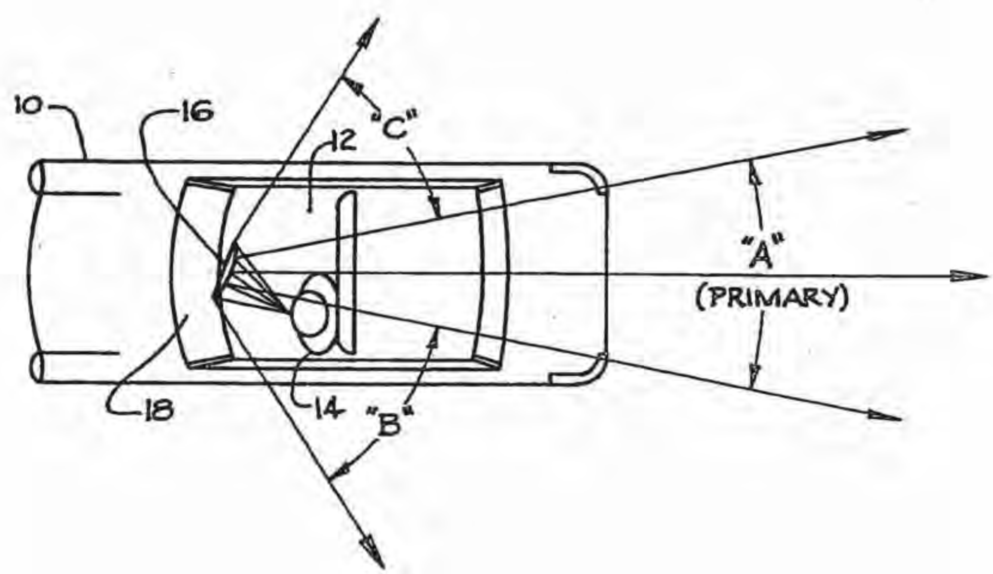
Primary Examiner—Jon W. Henry

[57] **ABSTRACT**

Rearview mirrors are disclosed having a convex curvature defined by mathematical and geometrical relationships between the position of the observer, the viewed objects, and the mirror. The mathematical relationships are designed to minimize bi-ocular distortions while producing the desired field of view.

33 Claims, 15 Drawing Figures



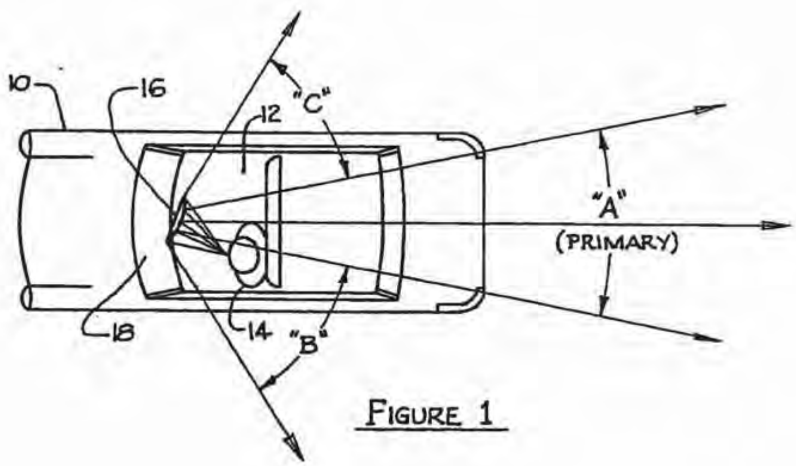


FIGURE 1

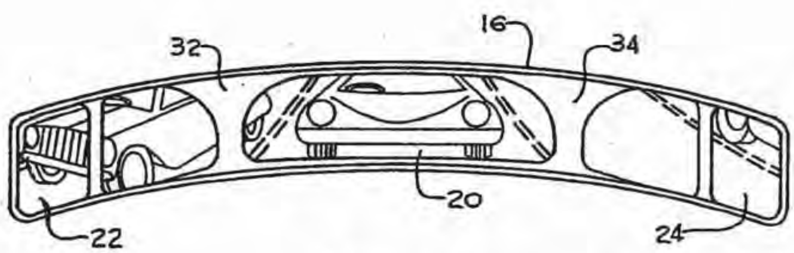


FIGURE 2

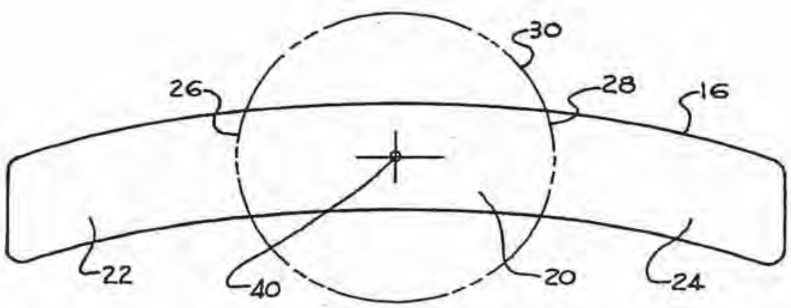


FIGURE 3

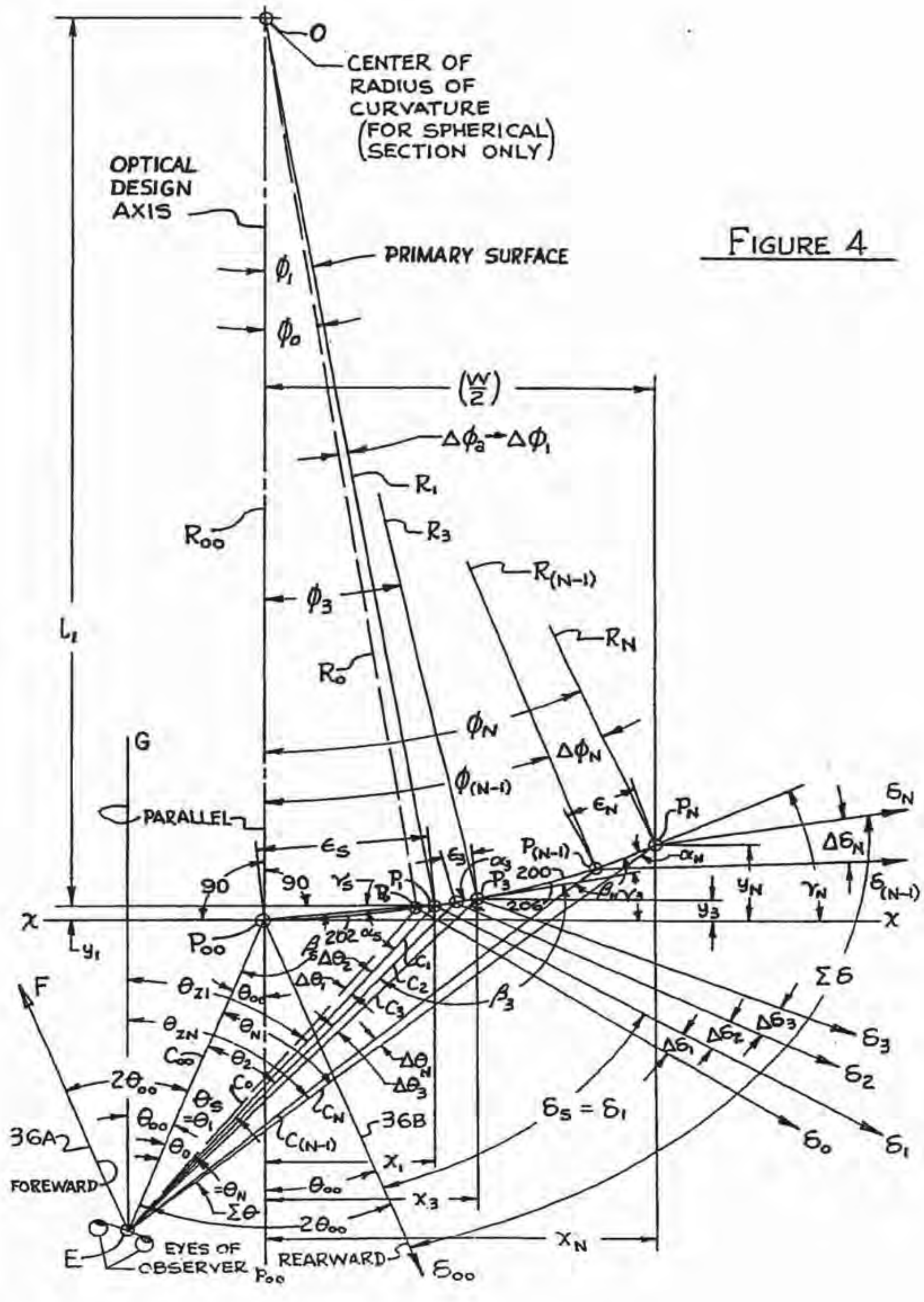
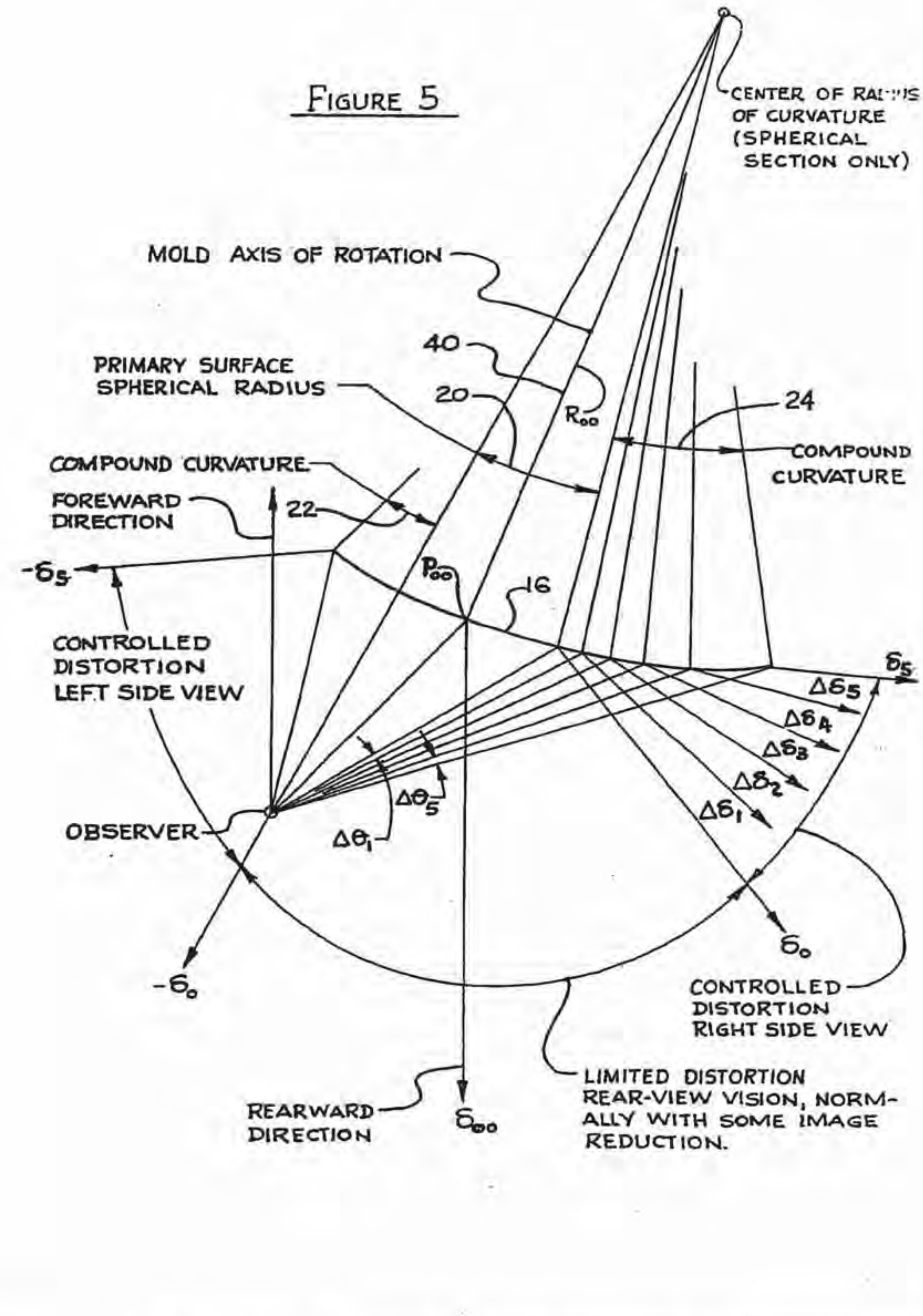
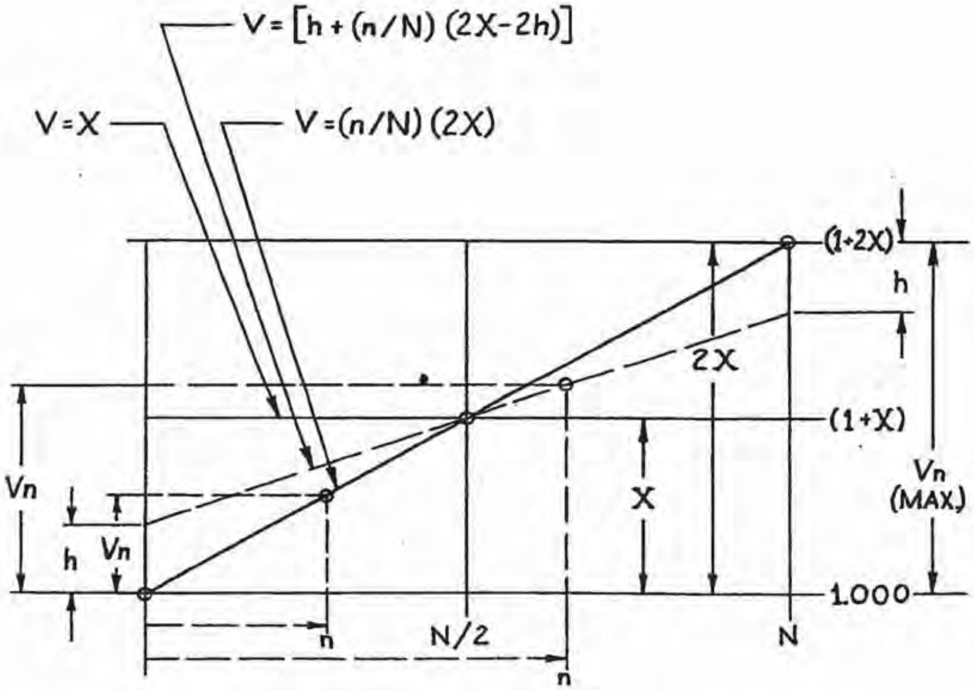

O
CENTER OF RADIUS OF CURVATURE (FOR SPHERICAL SECTION ONLY)
OPTICAL DESIGN AXIS
PRIMARY SURFACE
FIGURE 4
PARALLEL
G
F
36A
36B
FOREWARD
REARWARD
EYES OF OBSERVER
E
200
202
206

FIGURE 5


CENTER OF RADIUS
OF CURVATURE
(SPHERICAL
SECTION ONLY)
MOLD AXIS OF ROTATION
40
PRIMARY SURFACE
SPHERICAL RADIUS
20
R_{oo}
24
COMPOUND
CURVATURE
COMPOUND CURVATURE
FOREWARD
DIRECTION
22
$-\delta_5$
P_{oo}
16
CONTROLLED
DISTORTION
LEFT SIDE VIEW
δ_5
$\Delta\delta_5$
$\Delta\delta_4$
$\Delta\delta_3$
$\Delta\delta_2$
$\Delta\delta_1$
$\Delta\theta_5$
$\Delta\theta_1$
OBSERVER
δ_o
$-\delta_o$
CONTROLLED
DISTORTION
RIGHT SIDE VIEW
LIMITED DISTORTION
REAR-VIEW VISION, NORM-
ALLY WITH SOME IMAGE
REDUCTION.
REARWARD
DIRECTION
δ_{oo}



FACTOR FOR CONSTANT DISTORTION RATE Y=(1+V)

FIGURE 6

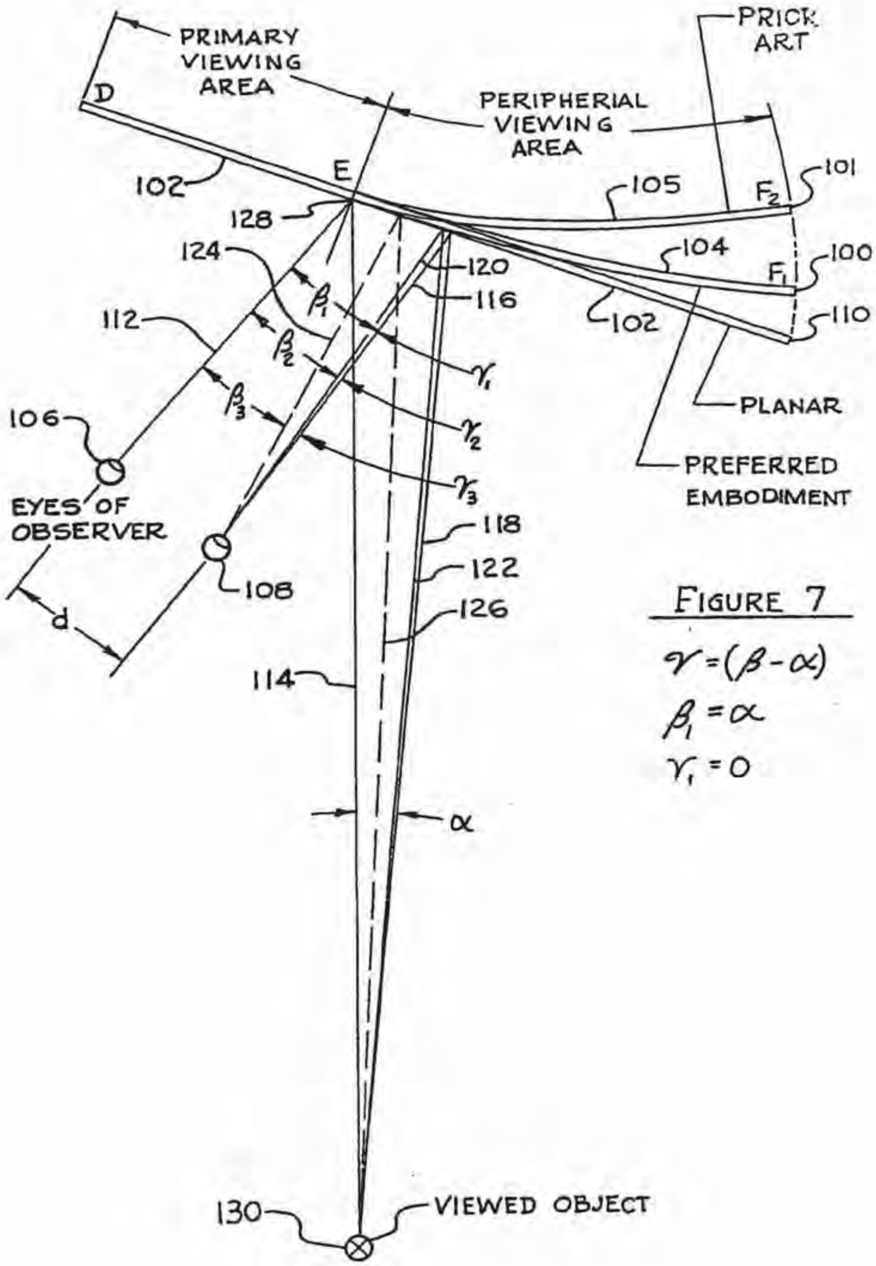


FIGURE 7

$\gamma = (\beta - \alpha)$

$\beta_1 = \alpha$

$\gamma_1 = 0$

FIGURE 8

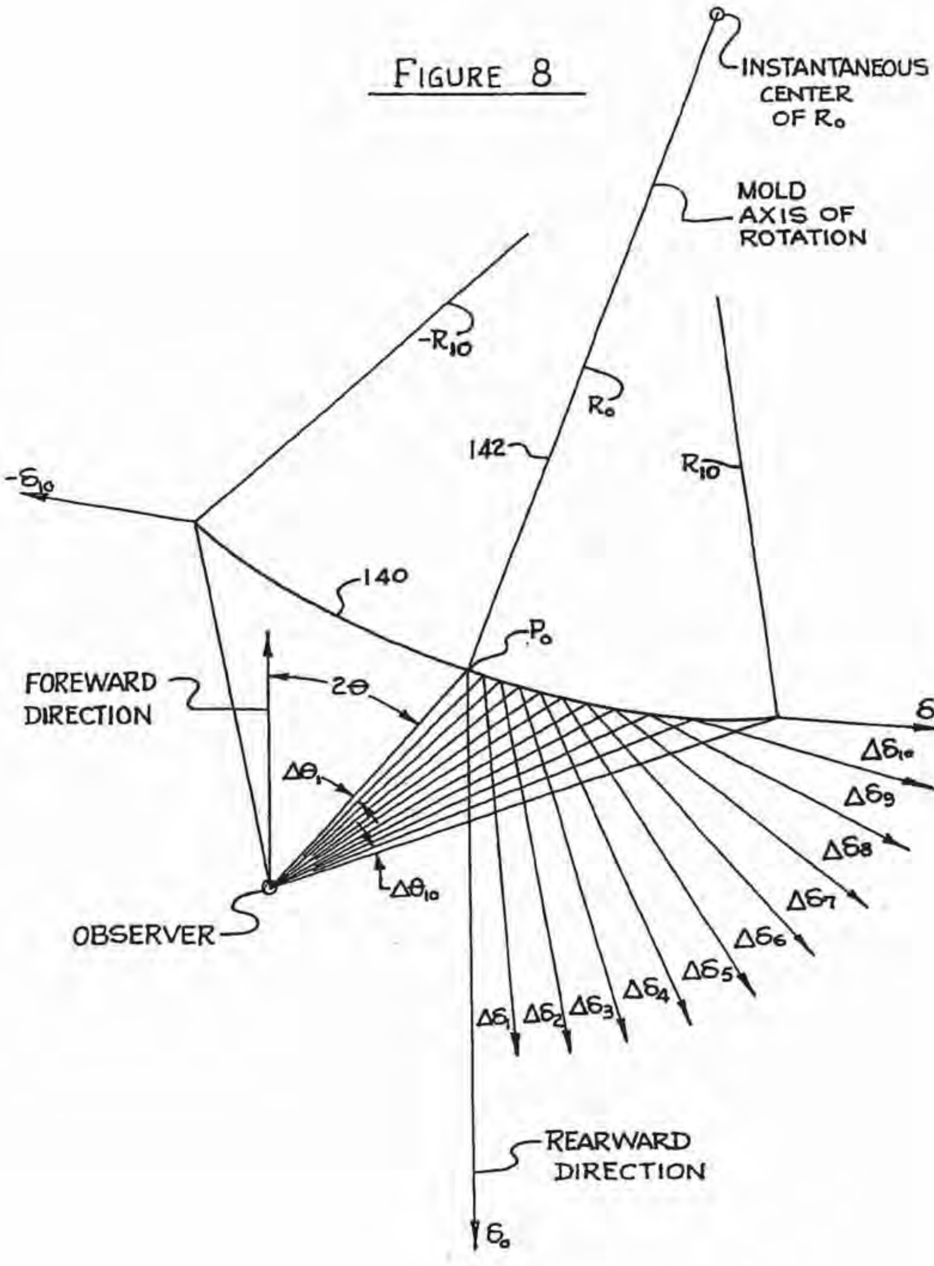

INSTANTANEOUS CENTER OF R_o
MOLD AXIS OF ROTATION
$-R_{10}$
R_o
142
R_{10}
$-\delta_{10}$
140
P_o
FOREWARD DIRECTION
2θ
δ_{10}
$\Delta\delta_{10}$
$\Delta\delta_9$
$\Delta\delta_8$
$\Delta\delta_7$
$\Delta\delta_6$
$\Delta\delta_5$
$\Delta\delta_4$
$\Delta\delta_3$
$\Delta\delta_2$
$\Delta\delta_1$
$\Delta\theta_1$
$\Delta\theta_{10}$
OBSERVER
REARWARD DIRECTION
δ_o

FIGURE 9

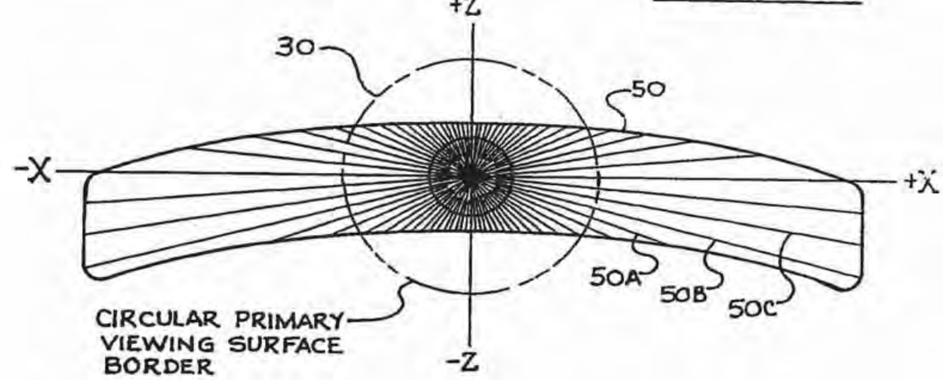
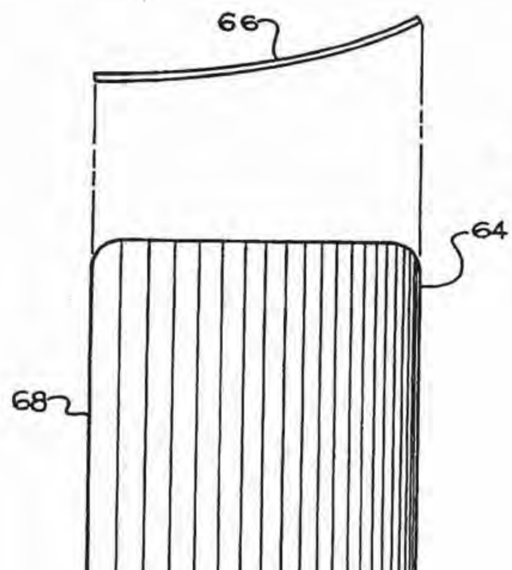


FIGURE 10



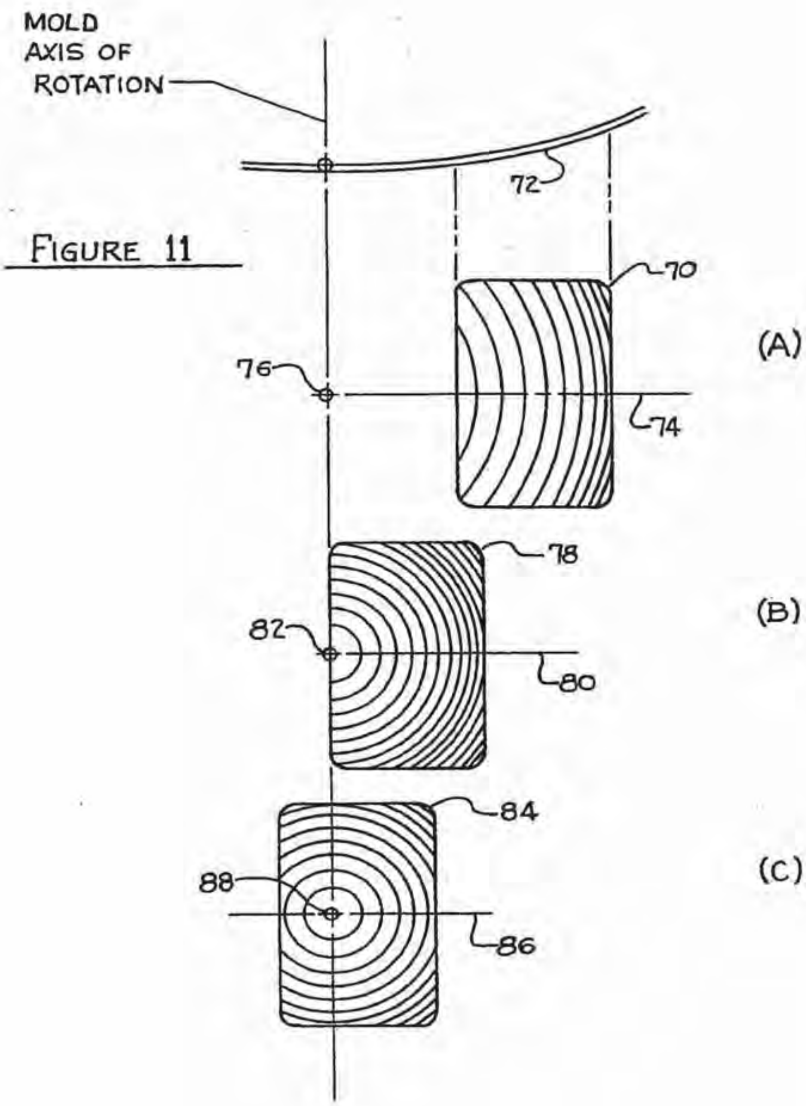
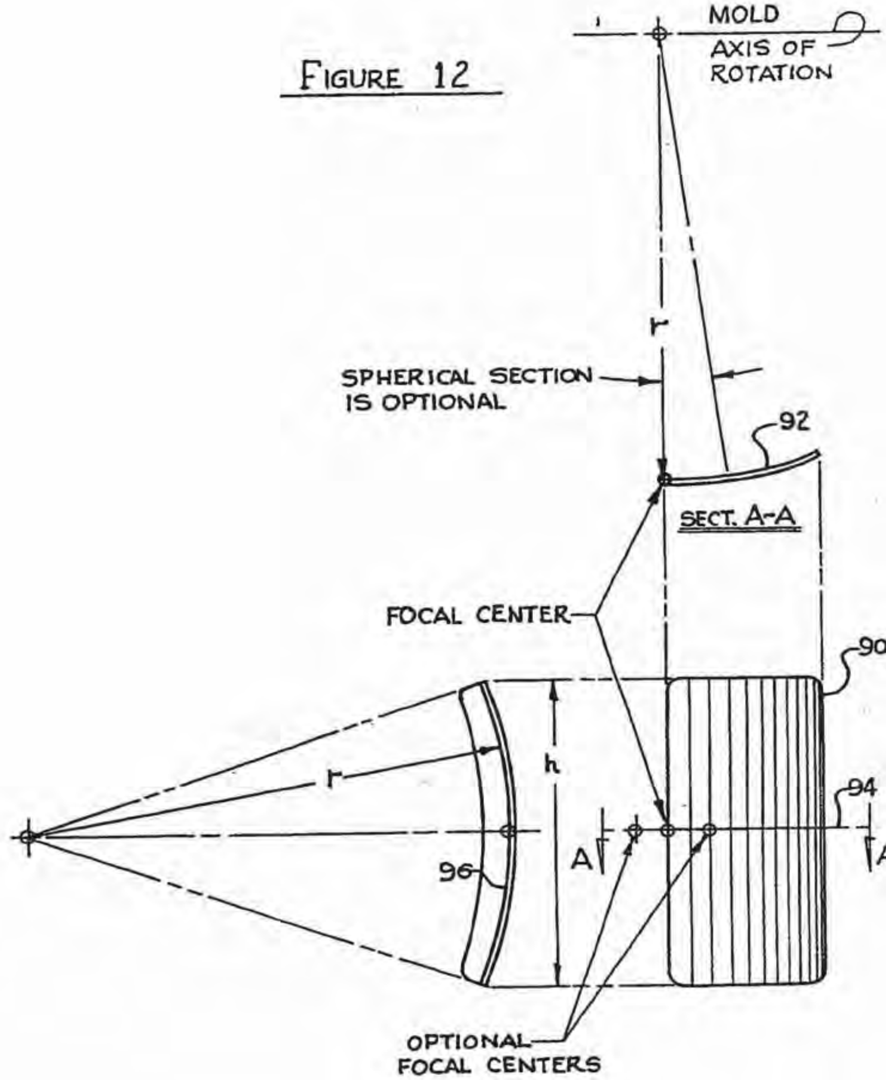


FIGURE 11

FIGURE 12



SEGMENT OF NON-CIRCULAR TORUS SECTION

FIGURE 13

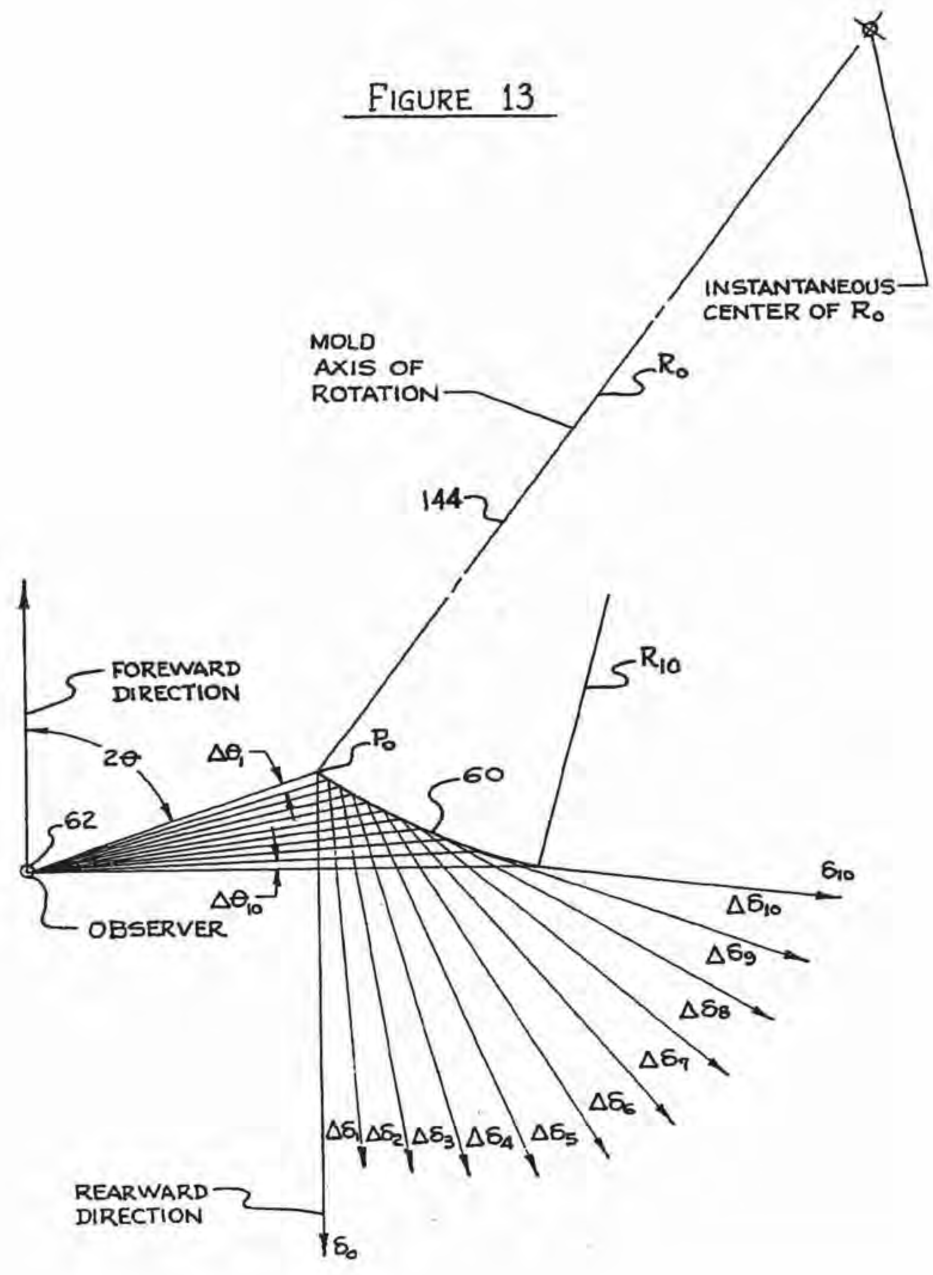

INSTANTANEOUS CENTER OF R_o
MOLD AXIS OF ROTATION
R_o
144
R_{10}
FOREWARD DIRECTION
2θ
$\Delta\theta_1$
P_o
60
62
δ_{10}
$\Delta\theta_{10}$
OBSERVER
$\Delta\delta_{10}$
$\Delta\delta_9$
$\Delta\delta_8$
$\Delta\delta_7$
$\Delta\delta_6$
$\Delta\delta_1$ $\Delta\delta_2$ $\Delta\delta_3$ $\Delta\delta_4$ $\Delta\delta_5$
REARWARD DIRECTION
δ_o

FIGURE 14

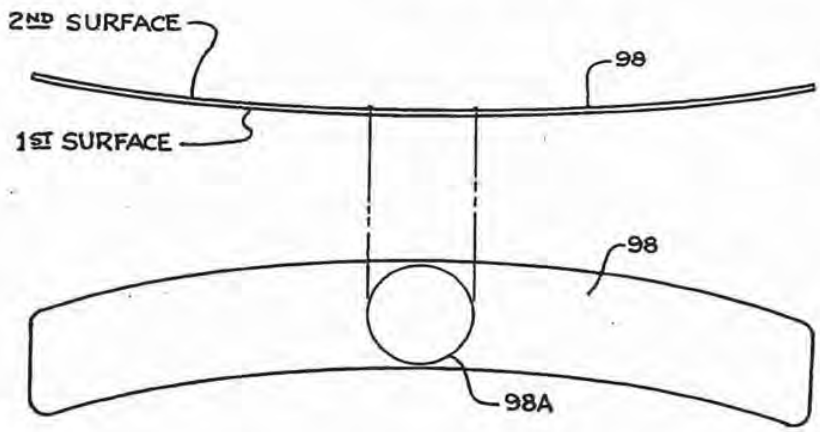
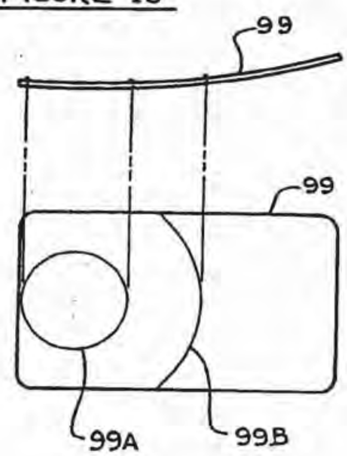


FIGURE 15



REARVIEW MIRROR

CROSS REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of my application Ser. No. 916,598 filed June 19, 1978 now U.S. Pat. No. 4,264,144.

BACKGROUND OF THE INVENTION

This invention relates to rearview mirrors of the type employed by automotive vehicles, and more specifically to a family of mirrors formed in accordance with certain structural, geometrical and mathematical relationships to provide a wide field of view of objects in the rear and along side of the vehicle by providing a controlled distortion of the viewed objects, and minimizing the effects of bi-ocular vision of the image of an object in a mirror having a compound curve of variable radius.

Many rearview mirrors in automotive vehicles, as well as the side mirrors, provide a compromise between several conflicting factors. To obtain a relatively large and accurate image of other vehicles moving in the rear, as well as along both sides of the observer's vehicle obviously calls for a relatively large mirror, the larger the mirror, the better the field of view. However, large mirrors interfere with the observer's forward vision through the windshield, as well as oblique vision beyond side view mirrors.

Another problem is that a flat mirror provides only a limited view of vehicles along side the observer's vehicle. One answer is to provide a compound convex mirror having a relatively flat primary viewing surface for viewing objects to the rear of the vehicle, and increasingly curved mirror ends for extending the observer's view of side objects. This approach, however, presents several problems. Since the mirror ends are convex, there usually is considerable image distortion depending upon the curvature of the mirror, and other geometric considerations. Some of the distortion has been reduced in the prior art, but by sacrificing image size, for example U.S. Pat. No. 4,012,125 issued to Philip J. Hart. Other approaches have utilized various conic sections curves and other empirically derived curves in attempts to make an acceptable transition between the primary and edge viewing surfaces. Without exception, results are mirrors having optical distortions because of the observer's bi-ocular vision. In most cases, extremely severe bi-ocular distortions are instantaneously generated at the transition line between different geometric curvatures of the mirror. These basic problems occur in some mirrors having a compound curvature when one eye of the observer is viewing an object through one curvature, and his other eye is viewing the same object through a portion of the mirror having a different curvature. This bi-ocular problem becomes aggravated when the observer is viewing a moving object having an image progressively passing through several curvatures.

My co-pending application, Ser. No. 916,598, utilizing a continuous function modified cycloidal geometry, provides a solution for this type of mirror in which the mirror has a relatively flat primary central viewing surface for viewing objects to the rear of the observer, and a peripheral curved end portion having a curvature continuously decreasing from the primary mirror portion surface. Such a mirror, with properly selected and proportioned geometric curvature sections, provides a useful balance between a unit image or zero distortion image and a wide field of vision.

SUMMARY OF THE INVENTION

The broad purpose of the present invention is to provide an improved mirror having a controlled image distortion and a wide field of view while minimizing the distortions caused by the bi-ocular vision of the observer in accordance with defined structural, geometrical and mathematical relationships between the position of the observer, the position of the mirror, the position of the viewed objects, and the field of view. The preferred embodiment of the invention employs a mirror that may or may not have a continuously decreasing radius of curvature from the central or primary viewing portion of the mirror toward the mirror ends. Preferably the primary viewing surface is relatively flat, being either a large spherical radius or a truly non-distorting geometry. On full rearview mirrors, the opposite ends of the mirror are curved downward to provide additional surface area for viewing objects along either side of the vehicle. Side mounted mirrors employ primary and peripheral viewing surfaces, the primary surface being nearest the observer.

The preferred mirror has a transition between the primary viewing surface and the end curved peripheral surface in which the instantaneous radius of curvature of the primary surface is tangent to the curvature of the peripheral area. In addition, the instantaneous radius of curvature of the two areas at the transition point may be made substantially equal to one another to minimize any distortions caused by the observer's bi-ocular vision, and to generate a smooth image size change through said transition point.

Still other objects and advantages of the invention will become readily apparent to those skilled in the art to which the invention pertains upon reference to the following detailed description.

DESCRIPTION OF THE DRAWINGS

The description refers to the accompanying drawings in which like reference characters refer to like parts throughout the several views, and in which:

FIG. 1 is a schematic plan view of an observer in an automotive vehicle illustrating the field of view of a rearview mirror representing the preferred embodiment of the invention;

FIG. 2 is a view illustrating typical images observed in the preferred mirror;

FIG. 3 is an illustration of the reflective surfaces of the preferred mirror;

FIG. 4 is a diagram illustrating the basic geometric relationships between the observer, the mirror, the direction of observation and reflection, and the field of view developed by the mirror relative to the observer;

FIG. 5 is a diagram illustrating the geometric relationships defining the curvature of the mirror;

FIG. 6 is a chart which illustrates typical modifying factors. Embodiment 1 exclusively employs $V=X$ and $Y=(1+V)$. Embodiment 2 exclusively employs $V=(n/N)(2X)$ and $Y=(1+V)$. Embodiment 3 employs $V=[h+(n/N)(2X-2h)]$ and $Y=(1+V)$;

FIG. 7 compares the curvature of the preferred mirror to a flat plane mirror and to a prior art geometry;

FIG. 8 is another diagram illustrating the geometric relationship of the curvature of another embodiment of the invention;

FIG. 9 illustrates another embodiment of the invention;

FIGS. 10–13 show various outside mirrors and geometries illustrating curvatures derived from the preferred formulae;

FIG. 14 shows a mirror having a bull's eye ring to aid viewing adjustments; and

FIG. 15 shows an outside mirror having an additional concentric arc to aid distance perception and to locate observed objects.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the drawings, FIG. 1 illustrates a vehicle 10 having a passenger compartment 12 and an observer 14 disposed in the driver's seat. A rearview mirror 16 is mounted in the conventional position adjacent windshield 18 of the vehicle.

Referring to FIGS. 2 and 3, mirror 16 has a primary central viewing surface 20, a left peripheral area 22, and a right peripheral area 24. The left peripheral area is connected by a transition line 26 to the primary viewing surface. The right periphery area is connected by a transition line 28 to the primary viewing surface. Lines 26 and 28 are circular arcs of an imaginary circle 30.

Mirror 16 is elongated with a somewhat bananna shape with the two peripheral areas extending lower than the primary viewing surface. The advantage of such a shape is illustrated in FIGS. 1 and 2 which show that the objects viewed directly to the rear, in the sector illustrated in FIG. 1 at "A", are somewhat higher than those objects in the adjacent lanes, viewed in opposite ends of the mirror. Further, transition lines 26 and 28, coincide approximately with rear posts 32 and 34 of the vehicle. The observer observes the image of the objects viewed through the left side windows of the vehicle in the sector of the mirror illustrated at "B", and the image of those objects viewed through the right side windows in sector "C". Sector "B" gives the field of view through the left peripheral area of the mirror, and sector "C" gives a field of view for the right peripheral area of the mirror.

The bottom of the mirror, as viewed in FIGS. 2 and 3, is curved to reduce interference with the observer's forward vision, while eliminating a portion of the mirror that would only view backseat structure. The vertical height of the mirror's primary viewing surface is chosen to accomodate the vertical height of the image of the rearview window, any further height being unnecessary for viewing objects rearward of the vehicle.

The basic geometry necessary to develop any of the mirrors herein described is shown in FIG. 4. A definition of symbols and structure is now put forth, being followed by a typical design example.

The convex curve (P_{00}, P_N) is an approximation of the right half of the surface of mirror 200. P_{00}, P_0, P_1, P_2, P_3, P_n, $P_{(N-1)}$, and P_N are points on the mirror's surface. Line R_{00}=(0, P_{00}) is the instantaneous radius of curvature at point P_{00}, and is a measure of the spherical radius of the primary viewing surface 202 of the mirror, which extends from point P_{00} to point P_1. The transition between the primary viewing surface and the peripheral viewing surface 206 occurs at point P_1. The focal center, design center, and manufacturing center of the mirror, is P_{00}. R_{00} is the axis of rotation of the mirror geometry.

The mirror surface is defined by a set of planar coordinates (x_n, y_n). The line (x—X) is the "x" axis, and is perpendicular to R_{00} at P_{00}. The "y" axis is coincident with R_{00}. (W/2) is the right half width of the mirror.

(P_{00}, p_{00}) is an extension of R_{00}, from which "x" values are measured to the right. "y" values are measured from the "x" axis toward point "0" and parallel to R_{00}.

R_1 is the instantaneous radius of curvature at point P_1, and is equal to R_{00} since said spherical radius is inclusive of these two points.

Point E is midway between the eyes of an observer, and is the design point of observation. Line 36A=(E, F), and is the line of direct forward sight. Line 36B=(P_{00}, δ_{00}) is the reflected line of direct rearward sight, toward an object (not shown), as viewed by the observer from point E and reflected from the mirror's surface at point P_{00}. Lines 36A and 36B are parallel to each other. Point P_{00} is hereby constructed as the focal center of the mirror.

For reflected light, the angle of incidence (δ_{00}, P_{00}, p_{00}) is equal to the angle of reflection (p_{00}, P_{00}, E), as measured from line (P_{00}, p_{00}I which by construction is perpendicular to the instantaneous radius of curvature of the mirror at point P_{00}. Said angles are designated as θ_{00}. Therefore, angle (δ_{00}, P_{00}, E)=$2\theta_{00}$, by addition. By further geometric principles, angle (P_{00}, E, F)=$2\theta_{00}$, as well. Line (E, G) is now drawn parallel to line (p_{00}, P_{00}, 0) and, for identical geometric reasons, angle (G, E, P_{00})=angle (E, P_{00}, p_{00})=θ_{00}. The foregoing facts establish the geometric relationships between the vehicle's attitude and the design geometry of the mirror.

Angle (P_{00}, E, P_1)=$(\theta_{z1}-\theta_{00})=\theta_s=\theta_1$, is the vision angle across the spherical primary viewing surface of the mirror. A series of equal $\Delta\theta$ increments are generated for the purpose of establishing uniform vision angle elements. Therefore, by definition, $\Delta\theta_1=\Delta\theta_2=\Delta\theta_3=\Delta\theta_n=\Delta\theta_N$ are all equal vision angle differential increments. These equal $\Delta\theta$ vision angle increments subtend arc/chords (P_0, P_1), (P_1, P_2), (P_2, P_3), ($P_{(n-1)}$, P_n), and ($P_{(N-1)}$, P_N), respectively, along the mirrors convex curve (P_{00}, P_N), which are normally not equal. Angle $\Sigma\theta-\theta_1$ is the total vision angle across the right half of the mirror, and is: $\Sigma\theta=(\theta_{zN}-\theta_{00})=\theta_n$.

Subscripts symbols are defined as follows: All numeral values are specific points of interest. The letter (N) defines the final point at the right peripheral edge of the mirror. The letter (n) defines any random point of interest along the mirror's curvature.

β_n and α_n are internal obtuse and acute angles, respectively, of respective oblique triangles of interest. ϵ_n values are the short side of said respective triangles, and are chordal segments along the mirror's curvature. All symbols with "s" subscripts in FIG. 4 refer to spherical sections of the mirror. Typically, $\beta_{\Sigma1}$,$\alpha_{\Sigma1}$, and $\epsilon_{\Sigma1}$ are elements of triangles (P_{00}, E, P_1). Similarly, β_1, α_1, and ϵ_1 are elements of triangles (P_0, E, P_1); and β_n, α_n, and ϵ_n are elements of triangle ($P_{(n-1)}$, E, P_n); and β_N, α_N, and ϵ_N are elements of triangle ($P_{(N-1)}$, E, P_N). C_{00}, C_0, C_1, C_2, C_3, C_n, $C_{(N-1)}$, and C_N are typical vision ray lengths from the observer at point E to their respective points on the mirror's surface. Typically, C_2=(E, P_2)

R_n values are radii of curvature at respective points P_n. For the spherical primary surface only, the origin of all R_n value is at point "0". At all other random points of interest P_n, the origin of the respective R_n values does not lie at point "0" nor at any other point of defined interest. The origins of said instantaneous radii of curvature are of no interest, only the ϕ_n angles and their $\Delta\phi_n$ increments are of interest. By definition, ϕ_n is constructed perpendicular to a tangent line drawn to the instantaneous radius of curvature of the mirror at point P_n. ϕ_n is the angular displacement of R_n from the axis of rotation of the mirror R_{00}. Also, because perpendicular lines form equal angles with respective elements of other perpendicular lines, ϕ_n is also a measure of the slope angle of instantaneous tangents to the mirror's curvature through point P_n, with respect to the (x—x) axis, which slope controls the angle of reflection of light rays incident thereupon; those reaching the observer at point E being of principle interest in this invention. $\Delta\phi_n$ is the differential increment between $\phi_{(n-1)}$ *and* ϕ_n.

γ_n, not to be confused with ϕ_n, is a measure of the instantaneous slope angle of the chord $\epsilon_n=(P_{(n-1)}, P_n)$, with respect to the (x—x) axis.

Finally, all δ and $\Delta\delta$ values are representations and/or measurements of field angle components, which this invention compares to respective constant $\Delta\theta$ values according to well defined mathematical relationships of said invention. The $\Delta\theta$ increments are always taken equal to each other, while the $\Delta\delta$ increments are usually continuously increasing in value based upon said formula(s). The basic relationships between θ and δ are:

$\Delta\delta_n=(\Delta\theta+2\Delta\phi_n)$, is the incremental angular relationship;

$\delta_N=(\theta_N+2\phi_N)=[\theta_N+2\gamma_N+(\Delta\gamma_N/2)]$, is the field angle relationship.

$\delta_N=(\delta_0+\Delta\delta_1+\Delta\delta_2+\Delta\delta_3+\ldots+\Delta\delta_N)$, is another field angle relationship.

The composition of the preferred embodiment is shown in FIG. 5, and is applicable to both full-rearview and side-view types. For full-rearview types, three distinct viewing areas are distinguished: primary viewing area 20, left peripheral viewing area 22, and right peripheral viewing area 24. For side view types, either the left viewing area 22 or the right viewing area 24 is eliminated for right-side or left-side mirrors, respectively.

The primary viewing area consists of a relatively large spherical radius producing little image size reduction. The intent is to limit image reduction. The peripheral areas and curvature interfaces conform to certain mathematical and geometric relationships herein disclosed.

The geometry of the preferred embodiment is defined by the following mathematical relationships which apply to the curvature of the right and left peripheral viewing areas for generating a constant rate of optical distortion from the primary viewing area to the end of the mirror.

The basic principal of all of the following formulas, (1) through (6), is that the ever changing field angle differentials ($\Delta\delta_n$) are always derived in relationship to constant vision angle differentials ($\Delta\theta_1=\Delta\theta_2=\Delta\theta_n\ldots=\Delta\theta_N$).

$$\Delta\delta_n=\{\Delta\delta_{(n-1)}\}\{1+X\} \qquad \text{FORMULA (1)}$$

when $(1+X)=(Y)$ then:

$$\Delta\delta_n=\{\Delta\delta_{(n-1)}\}(Y) \qquad \text{FORMULA (2)}$$

Formula (2) is the general formula for a "constant rate" of optical distortion for these mirror applications.

This expression states that "Y" is the constant multiplying factor which develops a constant rate of change for the $\Delta\delta_n$ value with respect to each respective field angle increment $(\Delta\delta_{(n-1)})$ for the field of view (δ), relative to a constantly and uniformly changing field of vision θ.

"X" is a constant value and is chosen by trial and error until all physical conditions for a particular application, including total field angle $(\Sigma\delta)=S_n$ are satisfied. In FIG. 6, the horizontal line $Y=(1+X)$ illustrates this constant multiplying factor.

A second preferred mathematical relationship for defining the curvature of the periphery areas generates a constantly changing rate of optical distortion and is illustrated in the following formula:

$$\Delta\delta_n=\{\Delta\delta_{(n-1)}\}\{(1+X)-X+(n/N)(2X)\} \qquad \text{FORMULA (3)}$$

combining:

$$\Delta\delta_n=\{\Delta\delta_{(n-1)}\}\{1+(n/N)(2X)\} \qquad \text{FORMULA (4)}$$

when $(n/N)\,(2X)=(V)$ then:

$$\Delta\delta_n=\{\Delta\delta_{(n-1)}\}\{1+V\} \qquad \text{FORMULA (5)}$$

The "X" value of this expression is defined the same as that in Formulae 1 and 2 and is derived in the same manner. In this formula, the (n/N) (2X) factor defines and produces a constantly changing rate of change for the $\Delta\delta_n$ value with respect to each respective field angle increment $(\Delta\delta_{(n-1)})$, thus controlling the optical distortion factor, and is illustrated in FIG. 6 as the diagonal straight line function $V=\{(n/N)\cdot(2X)\}$.

Referring again to FIG. 6, a multiplying factor may be generated to vary between those used in formula (1) and in formula (4), as follows:

$$\Delta\delta_n=(\Delta\delta_{(n-1)})\{1+[h+(n/N)(2X-2h)]\} \qquad \text{FORMULA (6)}$$

Because the formula are based upon the relationship of the observer's eyes to the mirror, the right and left peripheral viewing areas are not symmetrical.

With further reference to FIG. 5, the basic curvature of the left and right hand viewing areas is revolved about an axis 40 passing through the geometric center of the mirror. The result is a compound curvature having a relatively flat midsection, and left and right peripheral viewing areas each having a unique compound convex curvature, usually with a decreasing radius of curvature, from the primary viewing area to the ends of the mirror.

FIG. 13 illustrates a mirror 50 having the same peripheral border as mirror 16, but in which the surface of the peripheral ends are developed independently along a plurality of radial lines 50A, 50B, 50C, etc., which extend completely around the axis of the mirror in equal-spaced angular relationship, being generated per either Formula (1), (2) or (6). The surface of the mirror is smoothly generated from each radial line to its neighboring radial lines. This differs from mirror 16 in which a single curvature is developed for one end of the mirror which is then revolved around the focal axis to generate the surface of that mirror end and a second curvature is developed for the opposite end, which is then also revolved around the focal axis to develop the opposite peripheral viewing surface.

FIG. 8 illustrates another mirror 140 embodying the invention in which there is no primary or central viewing area, the left and right periphery areas being joined along the center of the mirror 140. The mirror is symmetrical about the line of joinder. The curvature of the right peripheral viewing area is defined according to Formula (1), the curvature of the left peripheral viewing area is also defined according to Formula (1), and then the values of corresponding points on opposite sides of the central axis are averaged to define a final curve that is revolved about the axis of rotation. This type of mirror having an averaged peripheral area can also be made with a central viewing area.

FIG. 13 illustrates a peripheral curvature developed in which none of the $\Delta\delta$ components are equal. This mirror is an outside mirror having a curvature 60. The eye of the observer is located at 62.

FIG. 10 shows a mirror 64 in which the generated curve is not revolved about a central axis, but has a curvature 66 extended along a linear border 68.

It is to be understood that the inventive mirror may be molded from a prismatic glass blank, thus giving the vehicle observer the option of a silvered second surface providing maximum light reflection for normal daylight driving conditions, or a plain first surface providing minimum light reflection for a night driving condition. See FIG. 14.

In addition, anti-glare type glass or glass treatments may be applied to any of the mirrors disclosed herein, such as a tinted mirror.

Mirrors developed in accordance with the preferred formula are illustrated in FIGS. 11A, 11B, and 11C. FIG. 11A shows a mirror 70 generated with a curvature 72 along line 74 that is revolved about an axis 76 to develop the reflective surface. Axis 76 is displaced from the edge of the mirror.

FIG. 11B illustrates a mirror 78 developed by generating a curvature along line 80 which is then revolved about an axis 82 that extends through the edge of the mirror.

FIG. 11C illustrates a mirror 84 developed by generating a curvature along line 86 which is then revolved about an axis 88 which extends through the surface of the mirror.

FIG. 12 shows a method for developing a mirror 90 having a curvature 92 developed along line 94. Curvature 92 shows the cross section of the mirror as seen along section line A—A. This mirror has a second curvature along its Y axis, as illustrated at 96. In this case, the reflective surface of the mirror has a decreasing radius of curvature and forms a segment of a non-circular torus section. Radius r is determined by the height "h" of the mirror and by the required total vertical field-of-view of the mirror. This geometric concept is particularly applicable to an eighteen-wheeler commercial trailer and some commercial bus type vehicles, where the mirror is mounted very high above the road surface, which demands a substantially increased vertical field of view. The horizontal curvature selected is rotated about a different horizontal axis, which is displaced from the primary curvature by the dimension of radius "r".

Optional locations of the focal center with respect to the horizontal curvature shown in FIG. 12, agree with the concept shown in FIGS. 11A, 11B, and 11C. A plane, which is tangent to the horizontal curvature at its focal center, is parallel to the axis of rotation and is normal to a radius line therefrom.

FIG. 14 shows a preferred rearview mirror 98 having a thin bull's eye ring 98A affixed preferably to the rear surface of the mirror prior to silvering. Ring 98A aids the user in adjusting the mirror.

FIG. 15 illustrates a side view mirror 99 having the preferred curvature with a pair of concentric rings 99A and 99B. The larger ring aids the user in judging distance and the relative position of trailing or passing vehicles.

FIG. 7 illustrates the problem of bi-ocular vision with respect to compound mirrors 100 and 101, having a primary viewing surface 102 which extends from point "D" to point "E" and then curved peripheral viewing areas 104 or 105 that extend from point "E" to point "F_1" and "F_2", respectively. The bi-ocular vision of the observer is the result of the user having two eyes 106 and 108 spaced a distance "d". The γ angles illustrated are a measure of bi-ocular astigmatism. The relationship is: $\gamma=(\beta-\alpha)$. Note: These α,β and γ symbols do not relate to FIG. 4. The greatest γ value represents the greatest astigmatic problem, since it is the result of a proportionately smaller instantaneous radius of curvature which in turn produces a more reduced image size that cannot be comfortably compared to the larger image size observed by the left eye at the point "E". Assuming the cross sections of mirrors 100 and 101 are superimposed on the cross section of a planar mirror 110, if the user views an object through the planar mirror, the ling-of-sight 112 of his left eye will be reflected off the reflective surface of the mirror to a continuation of his line-of-sight 114. Since the compound mirrors 100 and 101 are constructed tangent to the planar mirror 110 at point 128, and all three have coincident surfaces between points "D" and "E", the viewer's line-of-sight 112 and 114 for his left eye 106 are identical. Three conditions are then illustrated for the lines-of-sight of the observer's right eye 108, as follows:

For the planar mirror 110 his line-of-sight 116 is reflected to a continuation of his line-of-sight 118 toward the viewed object 130. For the peripheral surface 104 of mirror 100 having a radius of curvature at the point of tangency 128 substantially equal to that of the primary viewing surface 102 and gradually reducing as the curvature proceeds from the point of tangency 128, his line-of-sight 120 is reflected to a continuation of his line-of-sight 122 converging upon viewed object 130. For the peripheral surface 105 of mirror 101, having a radius of curvature at the point of tangency 128 significantly smaller than that of the primary viewing surface 102, his line-of-sight 124 is reflected to a continuation of his line-of-sight 126 toward the object 130.

γ_1, γ_2, and γ_3, respectively, represent the three foregoing astigmatic factors for the three conditions just described for right eye 108. For planar mirror 110, no astigmatism exists since γ_1 equals zero. For mirror 101, γ_3 is very large and unacceptable, causing great eye discomfort and blurred images. For mirror 100, which agrees with the preferred embodiments and concept of this invention, γ_2 is small and controlled within acceptable limits of distortion. This condition is affected by two principal factors of this invention, namely causing the instantaneous radius of curvature of the primary and peripheral viewing surfaces to be substantially equal at their point of tangency 128 and by controlling the reducing radius of curvature of the peripheral viewing surface according to the mathematical relationships of Formulae (1) through (6).

Summarizing, if the viewer is looking at a compound mirror so that his left eye is looking at the primary viewing surface of the compound mirror, but the right eye is looking at the image through the peripheral viewing area, having a significantly reduced radius of curvature, the sudden change in the curvature of the peripheral viewing area from the primary area produces a reflected line-of-sight that produces an unacceptable astigmatic factor with a great difference in image size observed by the two eyes. On the other hand, by using the preferred mathematical relationships, the astigmatic factor (which is the angle γ_2 illustrated in FIG. 7) is relatively small.

The result is a gradual change in the image size observed by the observer's two eyes so that he can comfortably observe an image crossing the transition between the two curvatures of the mirror, and crossing the peripheral section itself.

In summary, it is to be understood that I have described a rearview mirror having a controlled image distortion as the observer views an object moving across the mirror such that his eyes can comfortably adjust as the image travels through the transition between the peripheral portion and the primary viewing surface of the mirror, and across the peripheral areas as well.

It is to be further understood that I have described a mirror having a relatively common height, but in which the mirror ends are formed so as to be lower than the midsection of the mirror in order to optimize the viewing area through the rearview window of a conventional vehicle, as well as to provide a line-of-sight through the side windows and thereby provide an effective and wide field of view about the sides and rear of the vehicle.

Having described my invention, I claim:

1. A mirror having a viewing surface with a curvature substantially in accordance with the following mathematical relationship, expressed in incremental field angular relationships:

$$\Delta\delta_n = \Delta\delta_{(n-1)}[1+X]$$

in which (n) defines the point of interest along a substantially horizontal line of the mirror's surface, beginning at the optical design axis at which point the line of sight of an observer located substantially in the normal operator's position with respect to the mirror is reflected straight rearward with respect to the vehicle's forward direction; or beginning at the interface with a primary viewing surface, wherein: (n−1) defines the point of interest immediately preceding (n); δ_n defines the accumulated field angle from the optical design axis of the mirror, or from the interface with a primary viewing surface, to the point of interest (n); $\Delta\delta_n$ defines the incremental field angle between (n) and (n−1); X is the constant factor generating a constant rate of horizontal optical distortion with respect to $\Delta\delta_{(n-1)}$, which is chosen to produce a desired total field of view across the variable-radius surface, all other factors remaining unchanged; and $\Delta\theta$ is the constant vision angle increment to which all $\Delta\delta_n$ values are related.

2. A mirror having a viewing surface, whose cross-section is generated according to the structural, geometrical and mathematical relationships as defined in claim 1, and which cross-section is revolved about an axis which is located (r) distance from a point on the mirror's surface, which point lies on a plane passing through the center of rotation, said plane being at right angles to any other plane which is tangent to the mirror's surface at its focal point.

3. A mirror having a viewing surface with a curvature substantially in accordance with the following mathematical relationship, expressed in incremental field angular relationships:

$$\Delta\delta_n = \Delta\delta_{(n-1)}[1+(n/N)(2X)]$$

in which (n) defines the point of interest along a substantially horizontal line of the mirror's surface, beginning at the optical design axis at which point the line of sight of an observer located substantially in the normal operator's position with respect to the mirror is reflected straight rearward with respect to the vehicle's forward direction; or, beginning at the interface with a primary viewing surface, wherein: (n−1) defines the point of interest immediately preceding (n); δ_n defines the accumulated field angle from the optical design axis of the mirror, or from the interface with a primary viewing surface, to the point of interest (n); $\Delta\delta_n$ defines the incremental field angle between (n) and (n−1); N represents total iterations across the variable-radius surface; X is the constant factor controlling horizontal optical distortion, which is chosen to produce a desired total field of view across the variable-radius surface, all other factors remaining unchanged; and the (n/N) ratio generates a constantly changing rate of change of $\Delta\delta_n$ with respect to $\Delta\delta_{(n-1)}$; and $\Delta\theta$ is the constant vision angle increment to which all $\Delta\delta_n$ values are related.

4. A mirror having a viewing surface with a curvature substantially in accordance with the following mathematical relationship, expressed in incremental field angular relationships:

$$\Delta\delta_n = \Delta\delta_{(n-1)}[1+h+(n/N)(2X-2h)]$$

in which (n) defines the point of interest along a substantially horizontal line of the mirror's surface, beginning at the optical design axis at which point the line of sight of an observer located substantially in the normal operator's position with respect to the mirror is reflected straight rearward with respect to the vehicle's forward direction; or, beginning at the interface with a primary viewing surface, wherein: (n−1) defines the point of interest immediately preceding (n); δ_n defines the accumulated field angle from the optical design axis of the mirror, or from the interface with a primary viewing surface, to the point of interest (n); $\Delta\delta_n$ defines the incremental field angle between (n) and (n−1); (N) represents total iterations across the variable-radius surface; (X) is the constant factor controlling horizontal optical distortion, which is chosen to produce a desired total field of view across the variable-radius surface, all other factors remaining unchanged; (h) is a value chosen between zero and (X) and becomes the initial value for the multiplying factor at the beginning of the variable-radius curve where (n=1) and is subtracted-from (2X) at the final iteration point where (n=N), thus altering the rate of change characteristics of the constantly changing multiplying factor across the variable-radius surface as well as changing its magnitude at both the beginning and ending points of said variable-radius curve; the (n/N) ratio generates a constantly changing rate of change of $\Delta\delta_n$ with respect to $\Delta\delta_{(n-1)}$; and $\Delta\theta$ is the constant vision angle increment to which all $\Delta\delta_n$ values are related.

5. A mirror having a viewing surface with a final curvature revolved about a central axis of curvature to form a right mirror half and a left mirror half, said final curvature being developed by generating a first curve for the right mirror half and a second curve for the left mirror half and then generating said final curvature as an average of the first and second mirror halves, said first and second curvatures being generated in accordance with the structural, geometrical and mathematical relationships as defined in claim 1, wherein the averaging process is carried out by independently generating the right half and left half (x_n, y_n) curvature coordinate pairs, wherein the right and left (x_n) values are equal to each other, and then for each pair adding the respective (y_n) off-set components and dividing them by (2) to produce new (y_n) values for each respective (x_n) pair, thus completing the averaging process.

6. A mirror having a spherical primary viewing surface with a circular border, the diameter of which is considerably larger than the height of the mirror's central structure, and having right and left edge viewing surfaces with a curvature revolved about a central axis thus forming a right mirror segment and a left mirror segment, said curvature being developed by generating a first curve for the right mirror segment and a second curve for the left mirror segment, each segment of curvature being rotated 180 degrees about the common central axis and tangentially joining the spherical primary surface, said curvature being generated in accordance with the structural, geometrical and mathematical relationships as defined in claims 1.

7. A mirror having a viewing surface with a curvature developed about a central axis having a predetermined angle with respect to a predetermined line of sight of an observer and generated along a plurality of radial lines radiating from the intersection of said lines with said central axis and extending 360 degrees about said axis, the curve developed along each of said radial lines being in accordance with the structural, geometrical and mathematical relationships defined in claim 1.

8. A mirror as defined in claims 1, 3, 4, 5, 6 or 7, in which the mirror has a primary viewing surface, said primary viewing surface having a border merging substantially tangentially into said first-mentioned viewing surface.

9. A mirror as defined in claim 8, in which the primary viewing surface is flat.

10. A mirror as defined in claim 8, in which the primary viewing surface is curved.

11. A mirror as defined in claim 8, in which the primary viewing surface is spherical.

12. A mirror as defined in claim 8, in which the primary viewing surface is generated by a non-distorting geometry.

13. A mirror as defined in claim 8, in which the primary viewing surface has an instantaneous radius of curvature at said border, and said first-mentioned viewing surface has an instantaneous radius of curvature at said border substantially equal to the instantaneous radius of curvature of the primary viewing surface at their points of tangency; so that the instantaneous slope angles of said surfaces, with respect to common reference axis (x—x), are equal to each other at said point of tangency.

14. A mirror as defined in claim 8, in which the viewing surface of the mirror forms a segment of a surface of revolution developed by revolving said curvature about an axis.

15. A mirror as defined in claim 8, in which the viewing surface of the mirror forms an elongated structure.

16. An inside mounted rearview mirror for an automotive vehicle, as defined in claim 8, said mirror having a reflective surface being elongated and having opposite end sections curved downward in a common direction parallel to a plane which is normal to the focal axis of the mirror.

17. A mirror as defined in claim 8, in which the first-mentioned viewing surface forms a segment of a surface of revolution developed by revolving said curvature about an axis normal to said primary viewing surface and extending through the center thereof.

18. A mirror as defined in claim 8, in which the mirror is formed by extending the curvature along a linear axis such that the curvature defines the cross section of said mirror.

19. A mirror as defined in claim 14, in which the axis of revolution is spaced from the mirror.

20. A mirror as defined in claim 14, in which the axis of revolution extends through the edge of the viewing surface.

21. A mirror as defined in claim 14, in which the axis extends through the mirror.

22. A mirror as defined in claim 8, in which the mirror is formed of an anti-glare glass means.

23. A mirror as defined in claim 8, in which the mirror has the shape of a prismatic wedge producing maximum light reflection from a silvered second surface and minimum light reflection from an untreated first surface.

24. A mirror as defined in claim 14, and having a silvered surface, upon which a narrow but visible bull's eye ring is permanently affixed to the silvered surface of the mirror, being located such as to essentially define the boundary between the primary viewing surface and edge viewing surface; and to which one or more additional concentric ring(s) may also be affixed, being concentric with said first mentioned ring.

25. A mirror as defined in claim 8, constructed of a transparent plastic material.

26. A mirror having a viewing surface with a final curvature revolved about a central axis of curvature to form a right mirror half and a left mirror half, said final curvature being developed by generating a first curve for the right mirror half and a second curve for the left mirror half and then generating said final curvature as an average of the first and second mirror halves, said first and second curvatures being generated in accordance with the structural, geometrical and mathematical relationships as defined in claim 3, wherein the averaging process is carried out by independently generating the right half and left half (x_n, y_n) curvature coordinate pairs, wherein the right and left (x_n) values are equal to each other, and then for each pair adding the respective right and left (y_n) off-set components and dividing them by (2) to produce new (y_n) values for each respective (x_n) pair, thus completing the averaging process.

27. A mirror having a viewing surface with a final curvature revolved about a central axis of curvature to form a right mirror half and left mirror half, said final curvature being developed by generating a first curve for the right mirror half and a second curve for the left mirror half and then generating said final curvature as an average of the first and second mirror halves, said first and second curvatures being generated in accordance with the structural, geometrical and mathematical relationships as defined in claim 4, wherein the averaging process is carried out by independently generating the right half and left half (x_n, y_n) curvature coordinate pairs, wherein the right and left (x_n) values are equal to each other, and then for each pair adding the respective right and left (y_n) off-set components and dividing them by (2) to produce new (y_n) values for each respective (x_n) pair, thus completing the averaging process.

28. A mirror having a spherical primary viewing surface with a circular border, the diameter of which is considerably larger than the height of the mirror's central structure, and having right and left edge viewing surfaces with a curvature revolved about a central axis thus forming a right mirror segment and a left mirror segment, said curvature being developed by generating a first curve for the right mirror segment and a second curve for the left mirror segment, each segment of curvature being rotated 180 degrees about the common central axis and tangentially joining the spherical primary surface, said curvature being generated in accordance with the structural, geometrical and mathematical relationships as defined in claim 3.

29. A mirror having a spherical primary viewing surface with a circular border, the diameter of which is considerably larger than the height of the mirror's central structure, and having right and left edge viewing surfaces with a curvature revolved about a central axis thus forming a right mirror segment and a left mirror segment, said curvature being developed by generating a first curve for the right mirror segment and a second curve for the left mirror segment, each segment of curvature being rotated 180 degrees about the common central axis and tangentially joining the spherical primary surface, said curvature being generated in accordance with the structural, geometrical and mathematical relationships as defined in claim 4.

30. A mirror having a viewing surface with a curvature developed about a central axis having a predetermined angle with respect to a predetermined line of sight of an observer and generated along a plurality of radial lines radiating from the intersection of said lines with said central axis and extending 360° about said axis, the curve developed along each of said radial lines being in accordance with the structural, geometrical and mathematical relationships defined in claim 3.

31. A mirror having a viewing surface with a curvature developed about a central axis having a predetermined angle with respect to a predetermined line of sight of an observer and generated along a plurality of radial lines radiating from the intersection of said lines with said central axis and extending 360° about said axis, the curve developed along each of said radial lines being in accordance with the structural, geometrical and mathematical relationships defined in claim 4.

32. A mirror having a viewing surface, whose cross-section is generated according to the structural, geometrical and mathematical relationships as defined in claim 3, and which cross-section is revolved about an axis which is located (r) distance from a point on the mirror's surface, which point lies on a plane passing through the center of rotation, said plane being at right angles to any other plane which is tangent to the mirror's surface at its focal point.

33. A mirror having a viewing surface, whose cross-section is generated according to the structural, geometrical and mathematical relationships as defined in claim 4, and which cross-section is revolved about an axis which is located (r) distance from a point on the mirror's surface, which point lies on a plane passing through the center of rotation, said plane being at right angles to any other plane which is tangent to the mirror's surface at its focal point.

* * * * *

9442872

PATENT
DON01 P-793

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant	:	Niall R. Lynam
Serial No.	:	09/478,315
Filed	:	January 6, 2000
Group	:	2872
For	:	EXTERIOR MIRROR PLANO-AUXILIARY REFLECTIVE ELEMENT ASSEMBLY

Assistant Commissioner for Patents
Washington, D.C. 20231

Dear Sir:

CERTIFICATE OF MAIL

I certify that the attached return postcard, Information Disclosure Statement, Form PTO-1449, and copies of references cited herein are being deposited with the United States Postal Service as first class mail an envelope addressed to:

Assistant Commissioner for Patents
Washington, D.C. 20231

on July 5, 2000.

Lynette M. S. Clark

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P.O. Box 888695
Grand Rapids, MI 49588-8695
(616) 975-5500

CSC:lmsc
Enclosures

UNITED STA...S DEPARTMENT OF COMMERCE
Patent and Trademark Office
Address: COMMISSIONER OF PATENTS AND TRADEMARKS
Washington, D.C. 20231

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.
09/478,315	01/06/00	LYNAM N	DON01-P-793

MMC2/0919
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EXAMINER	
SHAFER, R	
ART UNIT	PAPER NUMBER
2872	5

DATE MAILED: 09/19/00

Please find below and/or attached an Office communication concerning this application or proceeding.

Commissioner of Patents and Trademarks

PTO-90C (Rev. 2/95) U.S. G.P.O. 1999 460-693 1- File Copy

Office Action Summary	Application No. 09/478,315	Applicant(s) LYNAM
	Examiner R.D. SHAFER	Group Art Unit 2872

—The MAILING DATE of this communication appears on the cover sheet beneath the correspondence address—

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 1 MONTH MONTH(S) FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If the period for reply specified above is less than thirty (30) days, a reply within the statutory minimum of thirty (30) days will be considered timely.
- If NO period for reply is specified above, such period shall, by default, expire SIX (6) MONTHS from the mailing date of this communication .
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133).

Status

☒ Responsive to communication(s) filed on 1/6/00.

☐ This action is **FINAL.**

☐ Since this application is in condition for allowance except for formal matters, **prosecution as to the merits is closed** in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 1 1; 453 O.G. 213.

Disposition of Claims

☒ Claim(s) 1-83 is/are pending in the application.

Of the above claim(s) ______ is/are withdrawn from consideration.

☐ Claim(s) ______ is/are allowed.

☐ Claim(s) ______ is/are rejected.

☐ Claim(s) ______ is/are objected to.

☒ Claim(s) 1-83 are subject to restriction or election requirement.

Application Papers

☐ See the attached Notice of Draftsperson's Patent Drawing Review, PTO-948.

☐ The proposed drawing correction, filed on ______ is ☐ approved ☐ disapproved.

☐ The drawing(s) filed on ______ is/are objected to by the Examiner.

☐ The specification is objected to by the Examiner.

☐ The oath or declaration is objected to by the Examiner.

Priority under 35 U.S.C. § 119 (a)-(d)

☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 11 9(a)-(d).

☐ All ☐ Some* ☐ None of the CERTIFIED copies of the priority documents have been

☐ received.

☐ received in Application No. (Series Code/Serial Number) ______.

☐ received in this national stage application from the International Bureau (PCT Rule 1 7.2(a)).

*Certified copies not received: ______.

Attachment(s)

☐ Information Disclosure Statement(s), PTO-1449, Paper No(s). ______

☐ Notice of Reference(s) Cited, PTO-892

☐ Notice of Draftsperson's Patent Drawing Review, PTO-948

☐ Interview Summary, PTO-413

☐ Notice of Informal Patent Application, PTO-152

☐ Other ______

Office Action Summary

U. S. Patent and Trademark Office
PTO-326 (Rev. 9-97)

Part of Paper No. 3

*U.S. GPO: 1998-454-457/97505

1. This application contains claims directed to the following patentably distinct species of the claimed invention:

A). The mirror species depicted by Fig. 5A;

B). The mirror species depicted by Fig. 5B;

C). The mirror species depicted by Fig. 5C;

D). The mirror species depicted by Fig. 5D;

E). The mirror species depicted by Fig. 5E;

F). The mirror species depicted by Fig. 5F;

G). The mirror species depicted by Fig. 5G; and

H). The mirror species depicted by Fig. 5H.

Applicant is required under 35 U.S.C. 121 to elect a single disclosed species for prosecution on the merits to which the claims shall be restricted if no generic claim is finally held to be allowable. Currently, claims 1 and 44 are generic.

In addition to the above, Applicant is further required to elect one of the following patentably distinct sub-species of the claimed invention:

1). The mirror assembly being a fixedly attached exterior side view mirror assembly;

2). The mirror assembly being a break-away exterior side view mirror assembly; and

3). The mirror assembly being a power-folded exterior side view mirror assembly.

Applicant is required under 35 U.S.C. 121 to elect a single disclosed sub-species consistent with the elected mirror species for prosecution on the merits to which the claims shall be restricted if no generic claim is finally held to be allowable.

Applicant is advised that a reply to this requirement must include an identification of the species that is elected consonant with this requirement, and a listing of all claims readable thereon, including any claims subsequently added. An argument that a claim is allowable or that all claims are generic is considered nonresponsive unless accompanied by an election.

Upon the allowance of a generic claim, applicant will be entitled to consideration of claims to additional species which are written in dependent form or otherwise include all the limitations of an allowed generic claim as provided by 37 CFR 1.141. If claims are added after the election, applicant must indicate which are readable upon the elected species. MPEP § 809.02(a).

Should applicant traverse on the ground that the species are not patentably distinct, applicant should submit evidence or identify such evidence now of record showing the species to be obvious variants or clearly admit on the record that this is the case. In either instance, if the examiner finds one of the inventions unpatentable over the prior art, the evidence or admission may be used in a rejection under 35 U.S.C. 103(a) of the other invention.

2. Applicant is advised that the reply to this requirement to be complete must include an election of the invention to be examined even though the requirement be traversed (37 CFR 1.143).

3. Any inquiry concerning this communication or earlier communications from the examiner should be directed to R.D. Shafer whose telephone number is (703) 308-4813.

RDS

September 18, 2000

RICKY D. SHAFER
PATENT EXAMINER
ART UNIT 2872

PATENT
DON01 P-793

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Examiner	:	R. Shafer
Applicant	:	Niall R. Lynam
Serial No.	:	09/478,315
Filed	:	January 6, 2000
Group	:	2872
For	:	EXTERIOR MIRROR PLANO-AUXILIARY REFLECTIVE ELEMENT ASSEMBLY

#e1 Election J.mcmiller 10/18/01

Box Non-Fee Amendment
Assistant Commissioner for Patents
Washington, D.C. 20231

Dear Sir:

ELECTION

In response to the Office Action mailed September 19, 2000, the Applicant wishes to elect the following species. Applicant elects the mirror species depicted in FIG. 5B, and the sub-species of the mirror assembly incorporating the break-away exterior sideview mirror assembly. The claims readable thereon include: Claims 1-31, 33, 35-73, 75, and 77-83.

REMARKS

The Examiner requires an election between the species illustrated in: FIG. 5A, FIG. 5B, FIG. 5C, FIG. 5D, FIG. 5E, FIG. F, FIG. 5G, and FIG. 5H. In addition, the Examiner requires election between sub-species identified as: 1) a fixedly attached exterior rearview mirror assembly; 2) a break-away exterior sideview mirror assembly; and 3) a power-fold exterior sideview mirror assembly.

As noted above, Applicant identifies Claims 1-31, 33, 35-73, 75, and 77-83 as being readable on the elected species, namely FIG. 5B and the sub-species of the break-away exterior sideview mirror assembly. The Examiner states Claims 1 and 44 are generic. It is respectfully submitted that Claims 2-17, 19-31, 35-59, 61-74, and 78-83 are generic with respect to these species as well.

An early and favorable action on the merits is respectfully requested.

Respectfully submitted,

NIALL R. LYNAM

By: Van Dyke, Gardner, Linn & Burkhart, LLP

Date: October 11, 2000.

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GP 2872

PATENT
DON01 P-793

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Examiner	:	R. Shafer
Applicant	:	Niall R. Lynam
Serial No.	:	09/478,315
Filed	:	January 6, 2000
Group	:	2872
For	:	EXTERIOR MIRROR PLANO-AUXILIARY REFLECTIVE ELEMENT ASSEMBLY

Box Non-Fee Amendment
Assistant Commissioner for Patents
Washington, D.C. 20231

Dear Sir:

CERTIFICATE OF MAIL

I certify that the attached return postcard and Election are being deposited with the United States Postal Service as first class mail an envelope addressed to:

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Washington, D.C. 20231

on October 11, 2000.

Lynette M. S. Clark

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Enclosures

UNITED STATES DEPARTMENT OF COMMERCE
Patent and Trademark Office
Address: COMMISSIONER OF PATENTS AND TRADEMARKS
Washington, D.C. 20231

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.
09/478,315	01/06/00	LYNAM N	DON01-P-793

MMC2/0103
VAN DYKE GARDNER LINN & BURKHART LLP
2851 CHARLEVOIX DRIVE SE
SUITE 207
GRAND RAPIDS MI 49546

EXAMINER	
SHAFER, R	
ART UNIT	PAPER NUMBER
2872	5

DATE MAILED:
01/03/01

Please find below and/or attached an Office communication concerning this application or proceeding.

Commissioner of Patents and Trademarks

PTO-90C (Rev. 2/95)
*U.S. GPO: 2000-473-000/44602

1- File Copy

Office Action Summary	Application No. 09/478,315	Applicant(s) MR. LYNAM
	Examiner R.D. SHAFER	Group Art Unit 2872

—The MAILING DATE of this communication appears on the cover sheet beneath the correspondence address—

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 1 MONTH MONTH(S) FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If the period for reply specified above is less than thirty (30) days, a reply within the statutory minimum of thirty (30) days will be considered timely.
- If NO period for reply is specified above, such period shall, by default, expire SIX (6) MONTHS from the mailing date of this communication .
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133).

Status

☒ Responsive to communication(s) filed on 10/16/00.

☐ This action is **FINAL.**

☐ Since this application is in condition for allowance except for formal matters, **prosecution as to the merits is closed** in accordance with the practice under *Ex parte Quayle,* 1935 C.D. 1 1; 453 O.G. 213.

Disposition of Claims

☒ Claim(s) 1-83 is/are pending in the application.

Of the above claim(s) ________ is/are withdrawn from consideration.

☐ Claim(s) ________ is/are allowed.

☐ Claim(s) ________ is/are rejected.

☐ Claim(s) ________ is/are objected to.

☒ Claim(s) 1-83 are subject to restriction or election requirement.

Application Papers

☐ See the attached Notice of Draftsperson's Patent Drawing Review, PTO-948.

☐ The proposed drawing correction, filed on ________ is ☐ approved ☐ disapproved.

☐ The drawing(s) filed on ________ is/are objected to by the Examiner.

☐ The specification is objected to by the Examiner.

☐ The oath or declaration is objected to by the Examiner.

Priority under 35 U.S.C. § 119 (a)-(d)

☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 11 9(a)-(d).

☐ All ☐ Some* ☐ None of the CERTIFIED copies of the priority documents have been

☐ received.

☐ received in Application No. (Series Code/Serial Number) ________.

☐ received in this national stage application from the International Bureau (PCT Rule 1 7.2(a)).

*Certified copies not received: ________.

Attachment(s)

☐ Information Disclosure Statement(s), PTO-1449, Paper No(s). ________

☐ Notice of Reference(s) Cited, PTO-892

☐ Notice of Draftsperson's Patent Drawing Review, PTO-948

☐ Interview Summary, PTO-413

☐ Notice of Informal Patent Application, PTO-152

☐ Other ________

Office Action Summary

U. S. Patent and Trademark Office
PTO-326 (Rev. 9-97)

Part of Paper No. 5

*U.S. GPO: 1998-454-457/97505

1. The restriction requirement set forth in Paper No. 3 is withdrawn. Accordingly, a new restriction requirement follows. The examiner apologizes for any inconvenience.

2. Restriction to one of the following inventions is required under 35 U.S.C. 121:

I. Claims 2-15, drawn to an exterior side view mirror system comprising an exterior side view mirror assembly including a reflective element having a plano reflective element and a multiradius reflective element, an actuator and a demarcation element with particular demarcation details, classified in class 359, subclass 864.

II. Claims 16-36, drawn to an exterior side view mirror system comprising an exterior side view mirror assembly including a reflective element having a plano reflective element and a multiradius reflective element and an actuator with particular attachment, arrangement and size details, classified in class 359, subclass 864.

III. Claims 37-43, drawn to an exterior side view mirror system comprising an exterior side view mirror assembly including a reflective element having a plano reflective element and a multiradius reflective element and an actuator, wherein at least one of the reflective elements comprises an electro-optic reflective element, classified in class 359, subclass 265.

IV. Claims 45-57, drawn to an exterior side view mirror system comprising an exterior side view mirror assembly including a reflective element having a plano reflective element and an auxiliary reflective element, an actuator and a demarcation element with particular demarcation details, classified in class 359, subclass 866.

V. Claims 58-77, drawn to an exterior side view mirror system comprising an exterior side view mirror assembly including a reflective element having a plano reflective element and an auxiliary reflective element, an actuator and a demarcation element with particular attachment, arrangement and size details, classified in class 359, subclass 866.

VI. Claims 78-83, drawn to an exterior side view mirror system comprising an exterior side view mirror assembly including a reflective element having a plano reflective element and an auxiliary reflective element, an actuator and a demarcation element, wherein at least one of the reflective elements comprises an electro-optic reflective element, classified in class 359, subclass 265.

3. Claim 1 link(s) inventions I, II and III. The restriction requirement between the linked inventions is subject to the nonallowance of the linking claim(s), claim 1. Upon the allowance of the linking claim(s), the restriction requirement as to the linked inventions shall be withdrawn and any claim(s) depending from or otherwise including all the limitations of the allowable linking claim(s) will be entitled to examination in the instant application. Applicant(s) are advised that if any such claim(s) depending from or including all the limitations of the allowable linking claim(s) is/are presented in a continuation or divisional application, the claims of the continuation or divisional application may be subject to provisional statutory and/or nonstatutory double patenting rejections over the claims of the instant application. Where a restriction requirement is

withdrawn, the provisions of 35 U.S.C. 121 are no longer applicable. See *In re Ziegler*, 44 F.2d 1211, 1215, 170 USPQ 129, 131-32 (CCPA 1971). See also MPEP § 804.01.

Claim 44 link(s) inventions IV, V and VI. The restriction requirement between the linked inventions is subject to the nonallowance of the linking claim(s), claim 44. Upon the allowance of the linking claim(s), the restriction requirement as to the linked inventions shall be withdrawn and any claim(s) depending from or otherwise including all the limitations of the allowable linking claim(s) will be entitled to examination in the instant application. Applicant(s) are advised that if any such claim(s) depending from or including all the limitations of the allowable linking claim(s) is/are presented in a continuation or divisional application, the claims of the continuation or divisional application may be subject to provisional statutory and/or nonstatutory double patenting rejections over the claims of the instant application. Where a restriction requirement is withdrawn, the provisions of 35 U.S.C. 121 are no longer applicable. See *In re Ziegler*, 44 F.2d 1211, 1215, 170 USPQ 129, 131-32 (CCPA 1971). See also MPEP § 804.01.

4. The inventions are distinct, each from the other because of the following reasons:

Inventions I, II and III are related as subcombinations disclosed as usable together in a single combination. The subcombinations are distinct from each other if they are shown to be separately usable. In the instant case, each of the inventions I, II and III has separate utility such as an exterior side view mirror system with the separate details of the other invention. For example, the exterior side view mirror system of invention I has separate utility as an exterior side view mirror system without the particular attachment, arrangement and size details of invention II or the particular reflective element(s) comprises an electro-optic reflective element of invention III; the exterior side view mirror system II has separate utility as an exterior side view mirror system without a demarcation element with particular demarcation details of invention I or the particular reflective element(s) comprises an electro-optic reflective element of invention III; and ...etc.. See MPEP § 806.05(d).

Inventions IV, V and VI are related as subcombinations disclosed as usable together in a single combination. The subcombinations are distinct from each other if they are shown to be separately usable. In the instant case, each of the inventions IV, V and VI has separate utility such as an exterior side view mirror system with the separate details of the other invention. For example, the exterior side view mirror system of invention IV has separate utility as an exterior side view mirror system without the particular attachment, arrangement and size details of invention V or the particular reflective element(s) comprises an electro-optic reflective element of invention VI; the exterior side view mirror system V has separate utility as an exterior side view mirror system without the particular demarcation details of invention IV or the particular reflective element(s) comprises an electro-optic reflective element of invention VI; and ...etc.. See MPEP § 806.05(d).

Inventions I and IV are related as combination and subcombination. Inventions in this relationship are distinct if it can be shown that (1) the combination as claimed does not require the particulars of the subcombination as claimed for patentability, and (2) that the subcombination has utility by itself or in other combinations (MPEP § 806.05(c)). In the instant case, the combination as claimed does not require the particulars of the subcombination as claimed because of the omission of the details that the auxiliary reflective element is a multiradius reflective element having a multiradius curvature, as evidenced by claim 1. The subcombination has separate utility such as an exterior side view mirror system without the auxiliary reflective element being a multiradius reflective element having a multiradius curvature.

Inventions V,VI and II,III are related as combination and subcombination. Inventions in this relationship are distinct if it can be shown that (1) the combination as claimed does not require the particulars of the subcombination as claimed for patentability, and (2) that the subcombination has utility by itself or in other combinations (MPEP § 806.05(c)). In the instant case, the combination as claimed does not require the particulars of the subcombination as claimed because of the omission of the details that the auxiliary reflective element is a multiradius reflective element having a multiradius curvature. The subcombination has separate utility such as an exterior side view mirror system without a demarcation element.

5. Because these inventions are distinct for the reasons given above and have acquired a separate status in the art because of their recognized divergent subject matter or have acquired a separate status in the art as shown by their different classifications and/or the search required for one of the Inventions I-VI is not coextensive with the search for any of the remaining Inventions I-VI as stated below. Therefore, restriction for examination purposes as indicated is proper.

Invention II would further require a search in class 359, subclass 872 which would not be required for inventions I, III, IV and VI.

Invention III would further require a search in class 359, subclass 864 which would not be required for inventions IV-VI.

Invention V would further require a search in class 359, subclass 872 which would not be required for inventions IV and VI.

Invention VI would further require a search in class 359, subclass 866 which would not be required for inventions I-III.

6. This application contains claims directed to the following patentably distinct species of the claimed invention:

A). The mirror species depicted by Fig. 5A;

B). The mirror species depicted by Fig. 5B;

C). The mirror species depicted by Fig. 5C;

D). The mirror species depicted by Fig. 5D;

E). The mirror species depicted by Fig. 5E;

F). The mirror species depicted by Fig. 5F;

G). The mirror species depicted by Fig. 5G; and

H). The mirror species depicted by Fig. 5H.

Applicant is required under 35 U.S.C. 121 to elect a single disclosed species for prosecution on the merits to which the claims shall be restricted if no generic claim is finally held to be allowable. Currently, claims 1 and 44 are generic.

In addition to the above, Applicant is further required to elect one of the following patentably distinct sub-species of the claimed invention:

1). The mirror assembly being a fixedly attached exterior side view mirror assembly;

2). The mirror assembly being a break-away exterior side view mirror assembly; and

3). The mirror assembly being a power-folded exterior side view mirror assembly.

Applicant is required under 35 U.S.C. 121 to elect a single disclosed sub-species consistent with the elected invention for prosecution on the merits to which the claims shall be restricted if no generic claim is finally held to be allowable.

Applicant is advised that a reply to this requirement must include an identification of the species that is elected consonant with this requirement, and a listing of all claims readable thereon, including any claims subsequently added. An argument that a claim is allowable or that all claims are generic is considered nonresponsive unless accompanied by an election.

Upon the allowance of a generic claim, applicant will be entitled to consideration of claims to additional species which are written in dependent form or otherwise include all the limitations of an allowed generic claim as provided by 37 CFR 1.141. If claims are added after the election, applicant must indicate which are readable upon the elected species. MPEP § 809.02(a).

Should applicant traverse on the ground that the species are not patentably distinct, applicant should submit evidence or identify such evidence now of record showing the species to be obvious variants or clearly admit on the record that this is the case. In either instance, if the examiner finds one of the inventions unpatentable over the prior art, the evidence or admission may be used in a rejection under 35 U.S.C. 103(a) of the other invention.

7. Applicant is advised that the reply to this requirement to be complete must include an election of the invention to be examined even though the requirement be traversed (37 CFR 1.143).

8. Any inquiry concerning this communication or earlier communications from the examiner should be directed to R.D. Shafer whose telephone number is (703) 308-4813.

RDS

January 1, 2001

2872

OIPE JC133
JAN 16 2001
PATENT & TRADEMARK OFFICE

#6
23 Jan 01
R. Talbot

PATENT
DON01 P-793

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

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Examiner	:	R. Shafer
Applicant	:	Niall R. Lynam
Serial No.	:	09/478,315
Filing Date	:	January 6, 2000
Group Art	:	2872
For	:	EXTERIOR MIRROR PLANO-AUXILIARY REFLECTIVE ELEMENT ASSEMBLY

Assistant Commissioner for Patents
Washington, D.C. 20231

Dear Sir:

SUPPLEMENTAL INFORMATION DISCLOSURE STATEMENT

In accordance with 37 CFR 1.51, 1.56, 1.97 and 1.98, Applicant submits herewith patents, publications or other information listed on attached Form PTO-1449 for consideration by the Examiner in connection with examination of the present application.

This Supplemental Information Disclosure Statement is being filed: (a) within three months of the filing date of the national application; (b) within three months of the date of entry of the national stage as set forth in 37 CFR § 1.491 in the corresponding international application; or (c) before the Applicant is aware of any mailing date of a first Office Action on the merits, whichever occurs last.

This Supplemental Information Disclosure Statement is not intended to constitute an admission that any patent, publication or other information referred to herein is "prior art" for this invention unless specifically designated as such.

Under 37 CFR 1.97(h), the filing of this Supplemental Information Disclosure Statement shall not be construed to mean that a search has been made or that no other material information as defined in 37 CFR 1.56(a) exists.

An early and favorable action on the merits is respectfully requested.

Respectfully submitted,

NIALL R. LYNAM

By: Van Dyke, Gardner, Linn & Burkhart, LLP

January 9, 2001
Date

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Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: 0 310 261 A1

EUROPEAN PATENT APPLICATION

(21) Application number: 88308482.4

(51) Int. Cl.⁴ B60R 1/08

(22) Date of filing: 14.09.88

(30) Priority: 30.09.87 GB 8723010

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(84) Designated Contracting States: DE ES FR GB

(71) Applicant: BRITAX WINGARD LIMITED
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(74) Representative: Hollinghurst, Antony
Britax Limited Patent Department
Chichester West Sussex PO19 2AQ(GB)

(54) Exterior rear-view mirror assembly for a vehicle.

(57) An exterior rear-view mirror assembly for a vehicle has a housing (10) arranged to be mounted at a predetermined orientation on a vehicle body and a mirror (30) mounted in the housing (10) on means (28) permitting its orientation to be adjusted relative to the housing (10). A second mirror (36), which is convex and of smaller radius of curvature than the first mirror (30), is mounted in the housing (10) either above or below the first mirror (30) so that no part thereof is further from the vehicle than the outboard edge of the first mirror (30).

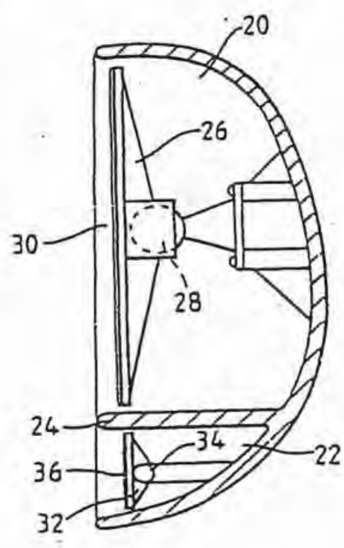
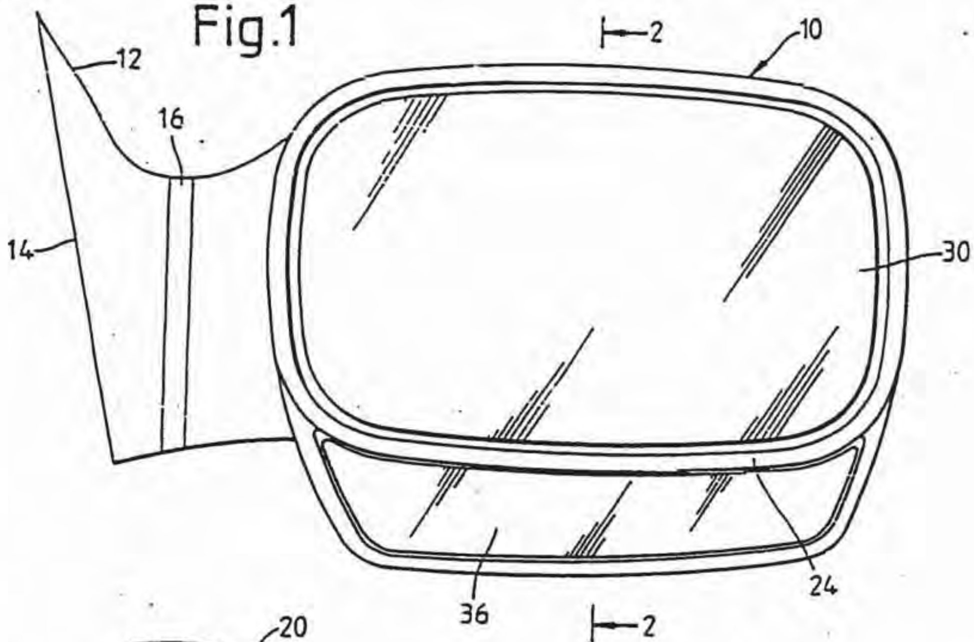


Fig.2

EP 0 310 261 A1

Fig.1



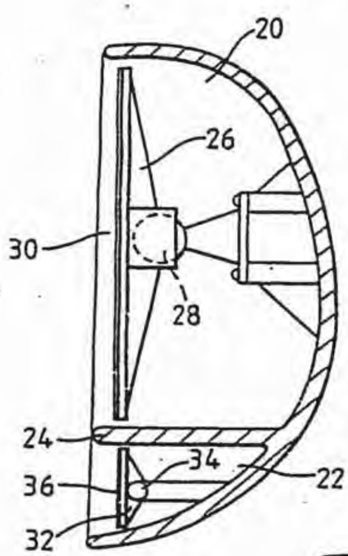
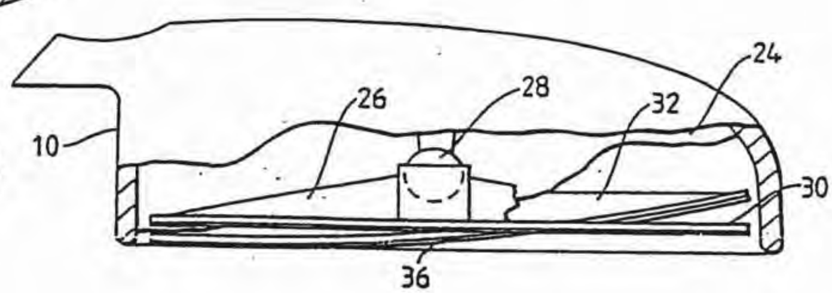


Fig.2

Fig.3



EXTERIOR REAR-VIEW MIRROR ASSEMBLY FOR A VEHICLE

This invention relates to an exterior rear-view mirror assembly for a vehicle of the type in which a housing is arranged to be mounted at a predetermined orientation on a vehicle body and a mirror is mounted in the housing on means permitting its orientation to be adjusted relative to the housing.

The mirrors of such mirror assemblies are commonly either plane mirrors or convex mirrors having a relatively large radius of curvature. Consequently, although a driver using such a mirror is able to form a relatively accurate impression of the distance between his vehicle and a following vehicle, it is probable that such a mirror will leave a so-called "blind spot" in which another vehicle passing the vehicle to which the mirror is fitted moves out of the driver's field of view in the mirror before it enters the periphery of the driver's field of view by direct vision. The present invention aims to provide a mirror assembly which is not subject to this disadvantage.

According to the invention, a mirror assembly of the foregoing type has a second convex mirror of smaller radius of curvature than the first mirror mounted in the housing either above or below the first mirror so that no part thereof is further from the vehicle than the outboard edge of the first mirror.

An embodiment of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is an elevational view of a rear view mirror in accordance with the invention from the side from which the mirror is viewed:

Figure 2 is a cross-sectional view taken on the line 2-2 in Figure 1:

Figure 3 is a partially broken away plan view of the mirror shown inFigure 2.

Referring to Figure 1, a rear view mirror assembly comprises a housing 10 mounted at one side on a base member 12, the surface 14 of which is adapted to abut against and be secured to the body of a motor vehicle (not shown). The connection between the housing 10 and the base member 12 comprises mechanism allowing the housing 10 to be displaced forwardly or rearwardly in the event that the housing is subjected to impact. This mechanism which, in Figure 1 is covered by a sleeve 16 of flexible material, is of known type and will therefore not be described in detail.

As can be seen from Figures 1 and 2, the housing 10 comprises an upper chamber 20 and a lower chamber 22 which are separated by a partitition wall 24. A first mirror carrier 26 is mounted on a ball-and-socket joint 28 which is secured to the interior of the chamber 20. A plane mirror 30 is mounted on the mirror carrier 26.

Similarly, a mirror carrier 32 is mounted on a ball-and-socket joint 34 which is secured to the interior of the lower chamber 22. The mirror carrier 32 carries a convex mirror 36. The relative curvatures of the mirrors 30 and 36 can best be seen from Figure 3.

As is well known, it will be necessary for different drivers to adjust the orientation of the plane mirror 30 to suit their requirements. If desired, mechanism of known type may be provided for making this adjustment remotely from the interior of the vehicle. It will usually be unnecessary for the orientation of the convex mirror 36 to be altered, only two settings being necessary depending on whether the vehicle with which it is to be used has left hand drive or right hand drive. Consequently, the ball-and-socket joint 34 may be replaced by a mounting which can be set to either of two predetermined positions at the time when the mirror is fitted to a vehicle.

Claims

1. An exterior rear-view mirror assembly for a vehicle having a housing (10) arranged to be mounted at a predetermined orientation on a vehicle body and a mirror (30) mounted in the housing (10) on means (28) permitting its orientation to be adjusted relative to the housing (10), characterised by a second mirror (36) which is convex and of smaller radius of curvature than the first mirror (30) mounted in the housing (10) either above or below the first mirror (30) so that no part thereof is further from the vehicle than the outboard edge of the first mirror (30).

2. An exterior rear-view mirror assembly according to claim 1, wherein the second mirror (36) is mounted on means (34) permitting its orientation to be adjusted relative to the housing (10).

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	APPLICANT Niall R. Lynam	
	FILING DATE January 6, 2000	GROUP 2872

U.S. PATENT DOCUMENTS

EXAMINER INITIAL		DOCUMENT NUMBER	DATE	NAME	CLASS	SUB-CLASS	FILING DATE IF APPROPRIATE

FOREIGN PATENT DOCUMENTS

EXAMINER INITIAL		DOCUMENT NUMBER							DATE	COUNTRY	CLASS	SUB-CLASS	TRANSLATION Y	TRANSLATION N
RDS	EP	0	3	1	0	2	6	1 A1	04/05/89	EPC	—	—		

OTHER DOCUMENTS (Including Author, Title, Date, Pertinent Pages, Etc.)

EXAMINER INITIAL		

EXAMINER R.D. Shafer	DATE CONSIDERED 4/02/01

EXAMINER: Initial if citation considered, whether or not citation is in conformance with MPEP 609; Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

(Form PTO-1449 [6-4])

GAU 2872

OIPE JC138
JAN 1 6 2001
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PATENT
DON01 P-793

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Examiner	:	R. Shafer
Applicant	:	Niall R. Lynam
Serial No.	:	09/478,315
Filed	:	January 6, 2000
Group	:	2872
For	:	EXTERIOR MIRROR PLANO-AUXILIARY REFLECTIVE ELEMENT ASSEMBLY

Assistant Commissioner for Patents
Washington, D.C. 20231

Dear Sir:

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I certify that the attached return postcard, Information Disclosure Statement, Form PTO-1449, and copies of information referenced herein are being deposited with the United States Postal Service as first class mail an envelope addressed to:

Assistant Commissioner for Patents
Washington, D.C. 20231

on January 9, 2001.

Lynette M. S. Clark

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PATENT
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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Examiner	:	R. Shafer
Applicant	:	Niall R. Lynam
Serial No.	:	09/478,315
Filing Date	:	January 6, 2000
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Assistant Commissioner for Patents
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FORM PTO-1449 U.S. DEPARTMENT OF COMMERCE (Rev. 2-32) PATENT AND TRADEMARK OFFICE INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Use several sheets if necessary)	ATTY. DOCKET NO. DON01 P-793	SERIAL NO. 09/478,315
	APPLICANT Niall R. Lynam	
	FILING DATE January 6, 2000	GROUP 2872

OIPE JC134 JAN 2 5 2001 PATENT & TRADEMARK OFFICE

U.S. PATENT DOCUMENTS

EXAMINER INITIAL		DOCUMENT NUMBER							DATE	NAME	CLASS	SUB-CLASS	FILING DATE IF APPRO-PRIATE
RDS		4	2	6	8	1	2	0	05/19/1981	Jitsumori	350	302	
RDS		3	3	7	5	0	5	3	05/26/1968	W.W. Ward	350	293	

FOREIGN PATENT DOCUMENTS

EXAMINER INITIAL		DOCUMENT NUMBER							DATE	COUNTRY	CLASS	SUB-CLASS	TRANSLATION Y	TRANSLATION N
[redacted]	~~EP~~	~~0~~	~~3~~	~~1~~	~~0~~	~~2~~	~~6~~	~~1 A1~~	~~04/05/89~~	~~EPC~~				
RDS	FR	2	6	2	8	0	4	2	09/1929	France			X	
RDS	DT	2	4	0	9	7	4	8	09/04/1975	Germany			X	
RDS		1	1	8	6	4	4	3	07/25/1989	Japan			X	

OTHER DOCUMENTS (Including Author, Title, Date, Pertinent Pages, Etc.)

EXAMINER INITIAL		

EXAMINER RD Shafer DATE CONSIDERED 4/02/01

EXAMINER: Initial if citation considered, whether or not citation is in conformance with MPEP 609; Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

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JAN 2 5 2001
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PATENT
DON01 P-793

#7
2 Feb 01
R. Talbot

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Examiner	:	R. Shafer
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Dear Sir:

CERTIFICATE OF MAIL

I certify that the attached return postcard, Supplemental Information Disclosure Statement, and copies of information referenced herein are being deposited with the United States Postal Service as first class mail an envelope addressed to:

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Assistant Commissioner for Patents
Washington, D.C. 20231

on January 17, 2001.

Lynette M.S. Clark

Lynette M. S. Clark
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CSC:lmsc
Enclosures

#8/Election
2/7/01
C. McKinney

PATENT
DON01 P-793

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Examiner	:	R. Shafer
Applicant	:	Niall R. Lynam
Serial No.	:	09/478,315
Filed	:	January 6, 2000
Group	:	2872
For	:	EXTERIOR MIRROR PLANO-AUXILIARY REFLECTIVE ELEMENT ASSEMBLY

Box Non-Fee Amendment
Assistant Commissioner for Patents
Washington, D.C. 20231

Dear Sir:

ELECTION

In response to the Office Action mailed January 3, 2001, having a one month period of response ending February 3, 2001, the Applicant wishes to elect the following invention. Applicant elects Group II, namely Claims 16-36 and linking Claim 1. Furthermore, in response to the election of species, Applicant elects the mirror species depicted in FIG. 5B, and the sub-species of the break-away exterior sideview mirror assembly. The claims readable thereon in the elected invention include: Claims 1, 16-31, 33, and 35.

REMARKS

The Examiner requires restriction between six groups of claims, namely Group I represented by Claims 2-15; Group II represented by Claims 16-36; Group III represented by Claims 37-43; Group IV represented by Claims 45-57; Group V represented by Claims 58-77; and Group VI represented by Claims 78-83. The Examiner identifies Claim 1 as a linking claim between Groups I, II, and III. The Examiner identifies Claim 44 as a linking claims for Groups IV, V, and VI. As indicated in the Office Action, upon the allowance of a linking claim, the restriction requirement as to the linked inventions shall be withdrawn and any claims depending from or otherwise including all the limitations of the allowable linking claims will be entitled to examination in this application.

The Examiner also requires election between the species depicted in FIGS. 5A, 5B, 5C, 5D, 5E, 5F, 5G, and 5H. The Examiner indicates that Claims 1 and 44 are currently generic. Furthermore, the Examiner requires election between the following sub-species, namely: a fixedly attached exterior sideview mirror assembly; a break-away exterior sideview mirror assembly; and a powerfolded exterior sideview mirror assembly.

As noted above, Applicant provisionally elects Group II, which includes Claims 16-36 and, further, Claim 1, as the linking claim and, further elects the species illustrated in FIG. 5B and sub-species of the break-away exterior sideview mirror assembly, with Claims 1, 16-31, 33, and 35 being readable thereon.

An early and favorable action on the merits is respectfully requested.

Respectfully submitted,

NIALL R. LYNAM

By: Van Dyke, Gardner, Linn & Burkhart, LLP

Date: January 11, 2001.

Catherine S. Collins
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2872

OIPE JC127 JAN 16 2001 PATENT & TRADEMARK OFFICE

PATENT
DON01 P-793

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Examiner	:	R. Shafer
Applicant	:	Niall R. Lynam
Serial No.	:	09/478,315
Filed	:	January 6, 2000
Group	:	2872
For	:	EXTERIOR MIRROR PLANO-AUXILIARY REFLECTIVE ELEMENT ASSEMBLY

Box Non-Fee Amendment
Assistant Commissioner for Patents
Washington, D.C. 20231

Dear Sir:

CERTIFICATE OF MAIL

I certify that the attached return postcard and Election are being deposited with the United States Postal Service as first class mail an envelope addressed to:

Box Non-Fee Amendment
Assistant Commissioner for Patents
Washington, D.C. 20231

on January 11, 2001.

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UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER OF PATENTS AND TRADEMARKS
Washington, D.C. 20231

RD
TS

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.
09/478,315	01/06/00	LYNAM	N DON01-P-793

MM92/0424

VAN DYKE GARDNER LINN & BURKHART LLP
2851 CHARLEVOIX DRIVE SE
SUITE 207
GRAND RAPIDS MI 49546

EXAMINER	
SHAFER,R	
ART UNIT	**PAPER NUMBER**
2872	9

DATE MAILED: 04/24/01

Please find below and/or attached an Office communication concerning this application or proceeding.

Commissioner of Patents and Trademarks

PTO-90C (Rev.11/00)

1- File Copy

Office Action Summary	Application No. 09/478,315	Applicant(s) MR. LYNAM
	Examiner RD SHAFER	Group Art Unit 2872

—The MAILING DATE of this communication appears on the cover sheet beneath the correspondence address—

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTHS MONTH(S) FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If the period for reply specified above is less than thirty (30) days, a reply within the statutory minimum of thirty (30) days will be considered timely.
- If NO period for reply is specified above, such period shall, by default, expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133).
- Any reply received by the Office later than three months after the mailing date of this communication, even if timely, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

☒ Responsive to communication(s) filed on 1/16/01.

☐ This action is **FINAL.**

☐ Since this application is in condition for allowance except for formal matters, **prosecution as to the merits is closed** in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 1 1; 453 O.G. 213.

Disposition of Claims

☒ Claim(s) 1-83 is/are pending in the application.

Of the above claim(s) 2-15, 32, 34 AND 36-83 is/are withdrawn from consideration.

☐ Claim(s) ___ is/are allowed.

☒ Claim(s) 1, 16-31, 33 AND 35 is/are rejected.

☐ Claim(s) ___ is/are objected to.

☐ Claim(s) ___ are subject to restriction or election requirement

Application Papers

☐ The proposed drawing correction, filed on ___ is ☐ approved ☐ disapproved.

☒ The drawing(s) filed on 1/6/00 is/are objected to by the Examiner

☐ The specification is objected to by the Examiner.

☐ The oath or declaration is objected to by the Examiner.

Priority under 35 U.S.C. § 119 (a)-(d)

☐ Acknowledgement is made of a claim for foreign priority under 35 U.S.C. § 119 (a)-(d).

☐ All ☐ Some* ☐ None of the:

☐ Certified copies of the priority documents have been received.

☐ Certified copies of the priority documents have been received in Application No. ___.

☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a))

*Certified copies not received: ___.

Attachment(s)

☒ Information Disclosure Statement(s), PTO-1449, Paper No(s). 2, 6 & 7

☒ Notice of Reference(s) Cited, PTO-892

☒ Notice of Draftsperson's Patent Drawing Review, PTO-948

☐ Interview Summary, PTO-413

☐ Notice of Informal Patent Application, PTO-152

☐ Other ___

Office Action Summary

1. Applicant's election of Invention II (claims 16-36), species "B", depicted by fig. 5B and subspecies "2", the mirror assembly being a break-away exterior side view mirror assembly, in Paper No. 8 is acknowledged. Because applicant did not distinctly and specifically point out the supposed errors in the restriction requirement, the election has been treated as an election without traverse (MPEP § 818.03(a)).

2. Claims 2-15, 32, 34 and 36-83 withdrawn from further consideration by the examiner, 37 CFR 1.142(b) as being drawn to a non-elected invention and/or species. Election was made **without** traverse in Paper No. 8.

3. Claims 1, 16-31, 33 and 35 are rejected under 35 U.S.C. 112, second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which applicant regards as the invention.

In claim 1, line 1, the use of the language "in an automobile" is vague, indefinite and/or confusing. It is unclear to the examiner how the exterior side view mirror system is suitable for use in an automobile.

4. The following is a quotation of the appropriate paragraphs of 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

> A person shall be entitled to a patent unless --
>
> (b) the invention was patented or described in a printed publication in this or a foreign country or in public use or on sale in this country, more than one year prior to the date of application for patent in the United States.

Claims 1, 16-18, 20, 21 and 23 are rejected under 35 U.S.C. 102(b) as being anticipated by Van Nostrand ('294).

Van Nostrand discloses an exterior side view mirror system comprising an exterior side view mirror assembly (1) including a plano reflective element (3 or 4), a multiradius reflective element (9), an actuator (24, 31), a control (20A) and a backing plate (21), note figures 1-6C, wherein said reflective elements are attached to said backing plate by mechanical attachments (12, 13, 15, 16).

5. The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

Claims 24-31 are rejected under 35 U.S.C. 102(b) as anticipated by or, in the alternative, under 35 U.S.C. 103(a) as obvious over Van Nostrand ('294).

Van Nostrand discloses all of the subject matter claimed, note the above explanation, except for explicitly stating the angle in which the multiradius reflective element is orientated such that a particular rearward field of view of interest is obtained.

However, the examiner is of the opinion due to the fact that the multiradius reflective element of Van Nostrand is adjustable via elements (15, 16 and 31), the assembly of Van Nostrand is inherently capable of obtaining the selected range (s) recited by applicant.

However, it this is not the case, it would have been obvious and/or within the level of one of ordinary skill in the art at the time the invention was made to adjust the multiradius reflective element of Van Nostrand to the selected range(s) recited by applicant in order to view of particular rearward field of view of interest, since it has been held that where the general conditions of a claim are disclosed in the prior art or discovering an optimum or workable ranges involves only routine skill in the art. Note In re Aller, 105 USPQ 233 and In re Boesch, , 617 F.2d 272, 205 USPQ 215 (CCPA 1980).

6. Claims 19, 22, 24-32, 33 and 35 are rejected under 35 U.S.C. 103(a) as being unpatentable over Van Nostrand ('294) as applied to claims 1, 16-18, 20, 21 and 23 above, and further in view of Jonsson ('802).

Van Nostrand ('294) discloses all of the subject matter claimed, note the above explanation, except for explicitly stating the radii of curvature and the downward angle of the multiradius reflective element.

Jonsson teaches it is well known to use an auxiliary (multiradius) reflective element having the radii of curvature and downward angle range recited by applicant in order to optimize the identification of objects.

Therefore, it would have been obvious and/or within the level of one of ordinary skill in the art at the time the invention was made to modify the auxiliary multiradius reflective element of Van Nostrand to include the auxiliary multiradius reflective element of Jonsson in order to optimize the identification of objects.

As to the limitations of claim 22, it would have been obvious and/or within the level of one of ordinary skill in the art at the time the invention was made to modify the size of the multiradius and/or plano reflective elements of Van Nostrand in order to obtain a desirable ratio of interest.

Since such a modification would have involved a mere change in the size of a component. A change in size is generally recognized as being within the level of one of ordinary skill in the art. Note in re Rose, 105 USPQ 237 (CCPA 1955).

As to the limitations of claims 33 and 35, it is well known to use electrically operable actuators in the same field of endeavor for the purpose of adjusting and/or folding the position and/or orientation of a mirror. Therefore, it would have been obvious and/or within the level of one ordinary skill in the art at the time the invention was made to modify the bracket and/or actuator(s) of Van Nostrand to include electrically operable actuator(s) as is well known and commonly used and/or employed in the mirror art in order to adjust and/or fold the position and/or orientation of the reflective element(s).

Moreover, it has been held that providing automatic means to replace manual activity which accomplishes the same result involves only routine skill in the art.

Note In Re Venner, 120 USPQ 192.

7. The drawings are objected to under 37 CFR 1.83(a). The drawings must show every feature of the invention specified in the claims. Therefore, the break-away exterior side view mirror assembly must be shown or the feature(s) canceled from the claim(s). No new matter should be entered.

8. The prior art made of record and not relied upon is considered pertinent to applicant's disclosure. King teaches it is known to employ a multiradius reflective element having applicant's recited radii of curvature in order to optimize the identification of objects.

9. Any inquiry concerning this communication should be directed to R. D. Shafer at telephone number (703) 308-4813.

Shafer/ds RDS

04/12/01

RICKY D. SHAFER
PATENT EXAMINER
ART UNIT 2872

Form PTO 948 (Rev. 8-98) U.S. DEPARTMENT OF COMMERCE - Patent and Trademark Office Application No. 9/478315

NOTICE OF DRAFTSPERSON'S PATENT DRAWING REVIEW

The drawing(s) filed (insert date) 1/6/00 are:
A. ☐ approved by the Draftsperson under 37 CFR 1.84 or 1.152.
B. ☑ objected to by the Draftsperson under 37 CFR 1.84 or 1.152 for the reasons indicated below. The Examiner will require submission of new, corrected drawings when necessary. Corrected drawing must be sumitted according to the instructions on the back of this notice.

1. DRAWINGS. 37 CFR 1.84(a): Acceptable categories of drawings:
Black ink. Color.
___ Color drawings are not acceptable until petiton is granted.
Fig(s) ________
___ Pencil and non black ink not permitted. Fig(s) ________
2. PHOTOGRAPHS. 37 CFR 1.84 (b)
___ 1 full-tone set is required. Fig(s) ________
___ Photographs not properly mounted (must use brystol board or photographic double-weight paper). Fig(s) ________
___ Poor quality (half-tone). Fig(s) ________
3. TYPE OF PAPER. 37 CFR 1.84(e)
___ Paper not flexible, strong, white, and durable.
Fig(s) ________
___ Erasures, alterations, overwritings, interlineations, folds, copy machine marks not accepted. Fig(s) ________
___ Mylar, velum paper is not acceptable (too thin).
Fig(s) ________
4. SIZE OF PAPER. 37 CFR 1.84(f): Acceptable sizes:
___ 21.0 cm by 29.7 cm (DIN size A4)
___ 21.6 cm by 27.9 cm (8 1/2 x 11 inches)
___ All drawing sheets not the same size.
Sheet(s) ________
___ Drawings sheets not an acceptable size. Fig(s) ________
5. MARGINS. 37 CFR 1.84(g): Acceptable margins:

Top 2.5 cm Left 2.5cm Right 1.5 cm Bottom 1.0 cm
SIZE: A4 Size
Top 2.5 cm Left 2.5 cm Right 1.5 cm Bottom 1.0 cm
SIZE: 8 1/2 x 11
Margins not acceptable. Fig(s) 5A, 5E, 6, 1
________ Top (T) ✓ ________ Left (L)
________ Right (R) ________ Bottom (B)
6. VIEWS. 37 CFR 1.84(h)
REMINDER: Specification may require revision to correspond to drawing changes.
Partial views. 37 CFR 1.84(h)(2)
___ Brackets needed to show figure as one entity.
Fig(s) ________
___ Views not labeled separately or properly.
Fig(s) ________
___ Enlarged view not labeled separetely or properly.
Fig(s) ________
7. SECTIONAL VIEWS. 37 CFR 1.84 (h)(3)
___ Hatching not indicated for sectional portions of an object.
Fig(s) ________
___ Sectional designation should be noted with Arabic or Roman numbers. Fig(s) ________

8. ARRANGEMENT OF VIEWS. 37 CFR 1.84(i)
___ Words do not appear on a horizontal, left-to-right fashion when page is either upright or turned so that the top becomes the right side, except for graphs. Fig(s) ________
9. SCALE. 37 CFR 1.84(k)
___ Scale not large enough to show mechanism without crowding when drawing is reduced in size to two-thirds in reproduction.
Fig(s) ________
10. CHARACTER OF LINES, NUMBERS, & LETTERS.
37 CFR 1.84(l)
✓ Lines, numbers & letters not uniformly thick and well defined, clean, durable, and black (poor line quality).
Fig(s) 1-19
11. SHADING. 37 CFR 1.84(m)
___ Solid black areas pale. Fig(s) ________
___ Solid black shading not permitted. Fig(s) ________
___ Shade lines, pale, rough and blurred. Fig(s) ________
12. NUMBERS, LETTERS, & REFERENCE CHARACTERS.
37 CFR 1.84(p)
✓ Numbers and reference characters not plain and legible.
Fig(s) 1-19
✓ Figure legends are poor. Fig(s) 1-17
___ Numbers and reference characters not oriented in the same direction as the view. 37 CFR 1.84(p)(1)
Fig(s) ________
___ English alphabet not used. 37 CFR 1.84(p)(2)
Figs ________
✓ Numbers, letters and reference characters must be at least .32 cm (1/8 inch) in height. 37 CFR 1.84(p)(3)
Fig(s) 1-19
13. LEAD LINES. 37 CFR 1.84(q)
___ Lead lines cross each other. Fig(s) ________
___ Lead lines missing. Fig(s) ________
14. NUMBERING OF SHEETS OF DRAWINGS. 37 CFR 1.84(t)
___ Sheets not numbered consecutively, and in Arabic numerals beginning with number 1. Sheet(s) ________
15. NUMBERING OF VIEWS. 37 CFR 1.84(u)
___ Views not numbered consecutively, and in Arabic numerals, beginning with number 1. Fig(s) ________
16. CORRECTIONS. 37 CFR 1.84(w)
___ Corrections not made from prior PTO-948 dated ________
17. DESIGN DRAWINGS. 37 CFR 1.152
___ Surface shading shown not appropriate. Fig(s) ________
___ Solid black shading not used for color contrast.
Fig(s) ________

COMMENTS

REVIEWER WJS DATE 3/2/00 TELEPHONE NO. 7033058404

ATTACHMENT TO PAPER NO. 9

INFORMATION ON HOW TO EFFECT DRAWING CHANGES

1. Correction of Informalities--37 CFR 1.85

File new drawings with the changes incorporated therein. The application number or the title of the invention, inventor's name, docket number (if any), and the name and telephone number of a person to call if the Office is unable to match the drawings to the proper application, should be placed on the back of each sheet of drawings in accordance with 37 CFR 1.84(c). Applicant may delay filing of the new drawings until receipt of the Notice of Allowability (PTOL-37). Extensions of time may be obtained under the provisions of 37 CFR 1.136. The drawing should be filed as a separate paper with a transmittal letter addressed to the Drawing Processing Branch.

2. Timing for Corrections

Applicant is required to submit **acceptable** corrected drawings within the three-month shortened statutory period set in the Notice of Allowability (PTOL-37). If a correction is determined to be unacceptable by the Office, applicant must arrange to have acceptable corrections resubmitted within the original three-month period to avoid the necessity of obtaining an extension of time and paying the extension fee. Therefore, applicant should file corrected drawings as soon a possible.

Failure to take corrective action within set (or extended) period will result in **ABANDONMENT** of the Application.

3. Corrections other than Informalities Noted by the Drawing Review Branch on the Form PTO-948

All changes to the drawings, other than informalities noted by the Drawing Review Branch, MUST be approved by the examiner before the application will be allowed. No changes will be permitted to be made, other than correction of informalities, unless the examiner has approved the proposed changes.

Notice of References Cited

Application No.	Applicant(s)
09/478,315	MR. LYNAM
Examiner	**Group Art Unit**
R.D. SHAFER	2872

Page 1 of 1

U.S. PATENT DOCUMENTS

*		DOCUMENT NO.	DATE	NAME	CLASS	SUBCLASS
	A	3,104,274	9-1963	KING	359	864
	B	3,389,952	6-1968	TOBEN, JR.	359	864
	C	4,258,979	3-1981	MAHIN	359	868
	D	4,306,770	12-1981	MARHAUER	359	866
	E	4,331,382	5-1982	GRAFF	359	868
	F	4,678,294	7-1987	VAN NOSTRAND	359	864
	G	4,727,302	2-1988	MIZUTA ET AL	359	877
	H	4,859,046	8-1989	TRAYNOR ET AL	359	866
	I	5,107,374	4-1992	LUPO ET AL	359	841
	J	5,225,943	7-1993	LUPO	359	841
	K	5,579,133	11-1996	BLACK ET AL	359	866
	L	5,796,532	8-1998	KANAZAWA	359	864
	M	6,199,993	3-2001	MOU	359	864

FOREIGN PATENT DOCUMENTS

*		DOCUMENT NO.	DATE	COUNTRY	NAME	CLASS	SUBCLASS
	N	0051637	4-1980	JAPAN	KATSUMATA	359	866
	O	2092534	8-1982	UNITED KINGDOM	HAGIRI	359	868
	P	3302735	8-1984	WEST GERMANY	SCHULZE	359	866
	Q	0551802	1-1992	EPO	JONSSON	359	864
	R						
	S						
	T						

NON-PATENT DOCUMENTS

*		DOCUMENT (Including Author, Title, Source, and Pertinent Pages)	DATE
	U		
	V		
	W		
	X		

* A copy of this reference is not being funished with this Office action.
(See Manual of Patent Examining Procedure, Section 707.05(a).)

U.S. Patent and Trademark Office
PTO-892 (Rev. 9-96)

Part of Paper No. 9

*U.S. GPO: 1998-454-457/97506

SAFETY ATTACHMENT FOR REAR VIEW VEHICLE MIRRORS

Filed March 5, 1963 3 Sheets-Sheet 3

FIG. 8.

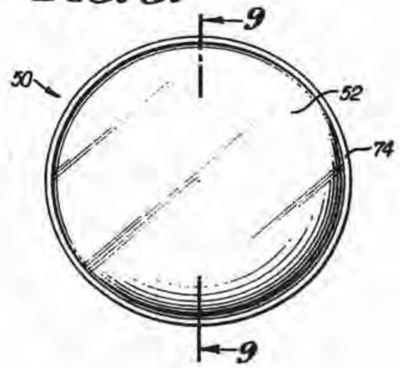


FIG. 9.

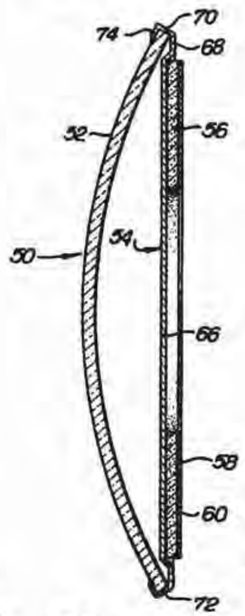


FIG. 10.

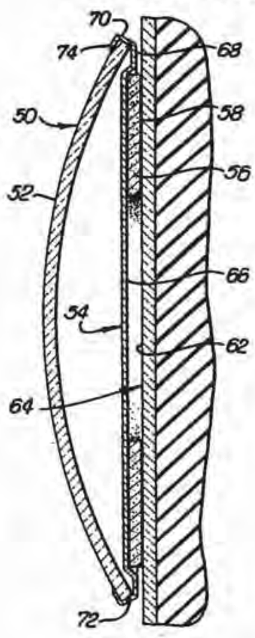
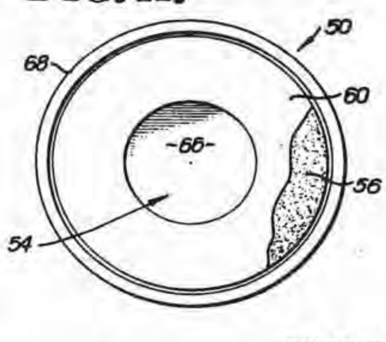


FIG. 11.



INVENTOR.
GARNER W. KING
BY
Huebner & Worrel
ATTORNEYS.

United States Patent Office

3,104,274
Patented Sept. 17, 1963

3,104,274
SAFETY ATTACHMENT FOR REAR VIEW VEHICLE MIRRORS

Garner W. King, 15609 Van Buren, Gardena, Calif.

Filed Mar. 5, 1963, Ser. No. 263,384
3 Claims. (Cl. 88—87)

This is a continuation-in-part of my copending application for Safety Attachment for Rear View Vehicle Mirrors, Serial No. 163,465, filed January 2, 1962, now abandoned.

The present invention relates to rear view vehicle mirrors and more particularly to a mirror having generally a convex configuration, which is adapted to be applied to a presently existing flat rear view vehicle mirror to provide a mirror combination which simultaneously affords undistorted rear view vision of limited angular scope and wide angle rear view vision.

It is an object of the present invention to provide a generally convex mirror which is adapted to be fixedly secured to the planar front face of a presently existing flat rear view vehicle mirror to enlarge the rear view field of vision so that a sufficiently large portion of the road may be viewed in order to avoid hazards which may develop from the approaching and passing vehicle and further to obtain an adequately enlarged field of vision so that passing of another vehicle and turning corners may be accomplished with a maximum degree of safety.

Another object is to provide a convex mirror attachment for a flat rear view mirror which, when attached, produces a combination mirror arrangement having the combined advantages of undistorted rear vision with accurate depth perception in the flat part, and increased field of vision in the convex part, so that a vehicle operator can more readily avoid hazards to the rear and close to the side of the vehicle while the vehicle is traveling either forwardly or in reverse, and so that the operator can even see obstructions which might be in the path of the wheels of the vehicle when the vehicle is being backed up.

A further object of this invention is to provide a convex mirror of the character described wherein the mirror has applied to the back side thereof a pressure sensitive adhesive which facilitates the application and removal of the convex mirror to the flat vehicle mirror and which provides a feature whereby the operator of the vehicle may apply the concavo-convex mirror to the flat mirror in a position of his choice; this attachment of the convex mirror to the flat mirror by adhesive bonding completely eliminating the need of separate mounting brackets for the convex mirror which would otherwise add to the expense of the installation, reduce the stability of mounting and add impediments to visibility at the sides of the vehicle.

A yet further object of this invention is to provide a convex mirror of the character described wherein tenacity of adherence of the mirror to the flat vehicle mirror is enhanced by a flat adhesive covered back which is affixed to the back of the concavo-convex mirror.

A more specific object of this invention is to provide a convex rear view mirror of the character described wherein the radius of curvature and diameter of the mirror are such that vision to the rear is not unduly distorted and the reflection of objects to the rear is sufficiently large so that relatively instant recognition is obtained as to the identity, nature and number of the objects.

A still more specific object of this invention is to provide a mirror of the character described wherein the convex mirror is applied to the side mirrors located outside the vehicle, and particularly to the right-hand side mirror, and in so applying the convex mirror the horizontal and vertical field of vision of the vehicle operator

is enlarged so that the usual blind spots along the sides and immediately to the rear of the vehicle which are not visible in the flat mirrors are eliminated, enabling the driver to see the wheels on the right-hand side of the vehicle, and affording a substantial reduction in certain types of accidents, such as running over pedestrians or children or bicycles or tricycles, squeeze and sideswipe accidents involving small vehicles, driving over curbs or other objects when making right turns, and other similar accidents.

An additional object is to provide a novel combination of a flat rear view vehicle mirror and a convex rear view mirror wherein the convex mirror is rigidly bonded to the exposed planar face of the flat mirror so as to position the convex mirror in an optimum exposed viewing position immediately forward of the forwardmost surface of the flat mirror, and so as to provide the convex reflecting surface with the same mounting stability as the flat mirror, with the convex and flat mirror reflecting surfaces supported in the same relative positions regardless of changes in position of the flat mirror on its supporting structure.

Further objects and advantages of this invention will appear during the course of the following part of this specification wherein the details of construction and mode of operation of a first and a second embodiment are described with reference to the accompanying drawings, in which:

FIG. 1 is a top plan view of a truck having the present invention installed on the exterior side mirrors thereof, and illustrating the relatively restricted horizontal rear view field of vision obtained with the flat vehicle mirror defined by the dotted lines and the enlarged, horizontal rear view field of vision provided by the present invention as defined by the solid lines;

FIG. 2 is a side view of a truck having the present invention installed on the exterior side mirrors thereof and again providing a comparison between the vertical field of vision obtained with a flat mirror again identified by dotted lines, and the enlarged field of vision achieved with the present invention, identified by solid lines;

FIG. 3 is a perspective view illustrating the present invention applied to a flat exterior rear view vehicle mirror;

FIG. 4 is a fragmentary front elevation view showing one form of the present invention applied to a flat vehicle rear view mirror;

FIG. 5 is a vertical sectional view taken on line 5—5 of FIG. 4;

FIG. 6 is a vertical sectional view similar to FIG. 5, but illustrating a second form of the invention;

FIG. 7 is a fragmentary section illustrating a third form of the invention;

FIG. 8 is a front elevation view showing a fourth form of the convex mirror structure of the present invention;

FIG. 9 is a vertical sectional view taken on line 9—9 of FIG. 8;

FIG. 10 is a fragmentary vertical section showing the convex mirror structure of FIGS. 8 and 9 affixed to a flat vehicle rear view mirror; and

FIG. 11 is a rear elevation view of the form of convex mirror structure shown in FIGS. 8, 9 and 10.

Referring initially to FIGS. 4 and 5 of the drawings wherein may be seen one form of a circular rear view vehicle mirror **8** having a concavo-convex body **10** which is applied to an exteriorly-located flat, rear view mirror **12** of a truck, bus, automobile or other vehicle **14**. Preferably, the mirror **8** is removably applied to mirror **12**. In order to achieve rapid identification of objects as viewed in the mirror **8**, it is preferred that the mirror body **10** have a radius of curvature between about 4 inches to 7 inches and optimum identification of objects is achieved when the body has a radius of curvature of about 5 inches. With the mirror body **10** having a radius of curvature of

Sept. 17, 1963 G. W. KING 3,104,274

SAFETY ATTACHMENT FOR REAR VIEW VEHICLE MIRRORS

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FIG. 1.

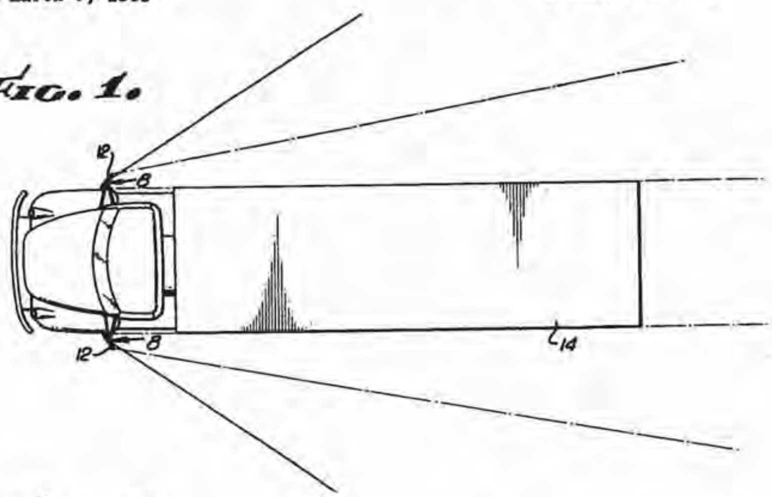


FIG. 2.

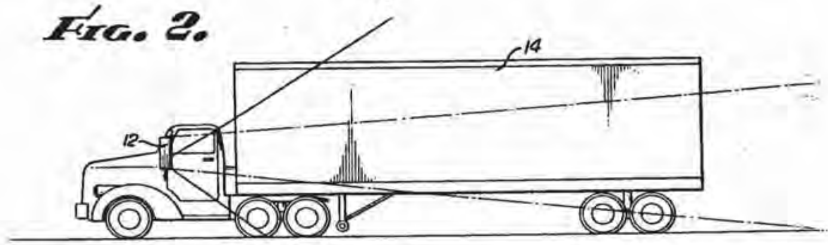
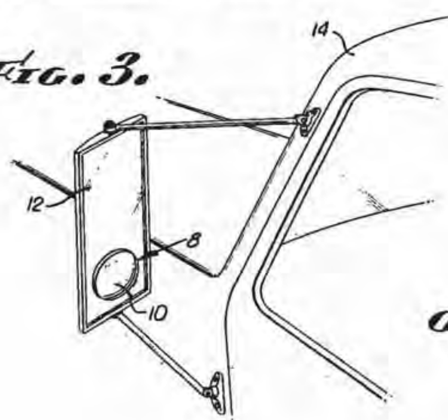


FIG. 3.



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backing 54, a resilient foam plastic cushioning sheet 56 bonded to the rear surface of the metal backing 54, and a layer 58 of pressure sensitive adhesive on the rear surface of the cushioning sheet. A paper covering sheet 60 is provided over the adhesive layer 58 as shown in FIG. 9 prior to mounting of the mirror unit 50 on a flat mirror, but this sheet 60 is peeled off for pressure adhesion of the mirror unit 50 onto the exposed or front planar surface 62 of a flat rear view vehicle mirror 64 as shown in FIG. 10. When the convex mirror unit 50 is adhesively secured to the flat mirror 64, the central axis of the convex mirror will be normal to the flat mirror, whereby the enlarged field of vision of the convex mirror unit will completely overlap the field of vision of the flat mirror.

The sheet metal backing 54 is preferably made of a light-weight metal such as aluminum which is readily formed and has good weather resisting qualities. Other suitable material may, of course, be used. As best seen in FIGS. 9 and 10, the backing 54 has a flat, disc-shaped central portion 66 occupying most of the rear portion of the mirror unit 50, with a narrow, flat annular peripheral portion 68 that is parallel and slightly rearwardly offset with respect to the central portion 66. At the outer edge of the peripheral portion 68 the backing is formed forwardly in a peripheral flange 70. This flange 70 encompasses and extends forwardly of the peripheral edge 72 of the body 52 of the mirror, and its outer edge is spun or crimped over in front of the periphery of the convex forward face of body 52 in a retaining lip 74. By this means, the backing 54 and body 52 are permanently secured together, with the generally irregular and often sharp-cornered peripheral edge 72 of the mirror body 52 completely encompassed by the wrap-around type periphery of the backing 54.

While the backing 54 with the retaining lip 74 spun or crimped directly over the periphery of the forward surface of body 52 is preferred, an alternative construction can be employed, if desired, wherein the lip is slightly larger in diameter than the peripheral edge 72 of the body, and the body is retained in the lip by means of a snap ring.

There are several important advantages to wrap-around type backing 54 shown in FIGS. 8–11, in addition to its economy and simplicity. One advantage is that by recessing the flat, central portion 66 of the backing, the foam plastic cushioning sheet 56 may be employed, while the mirror unit 50 may still be mounted very close to the exposed forward surface 62 of the flat mirror 64. The cushioning layer 56 is helpful in obtaining a full-surface bond of the pressure sensitive adhesive layer 58 against the flat mirror surface 62, and it will distort sufficiently to accommodate any slight irregularities between the opposed surfaces of the backing 54 and flat mirror surface 62.

The wrap-around type backing 54 has a further, unobvious advantage in the application of the convex mirror unit 50 to a flat mirror surface. Thus, the turned-in flanged edge, while securely holding the body 52 therein, nevertheless permits a gradual equalization of the air pressure within the mirror unit and the external atmospheric pressure, whereby the flat back portion 66 will not tend to bow outwardly as the vehicle climbs from one elevation to a higher one. This can be a serious problem with a fully bonded connection between the body and the metal backing.

The sheet metal backing of the mirror unit 50 shown in FIGS. 8–11 has the further advantage of sealing the periphery of the body 52 sufficiently against the weather so that the mirror finish on the concave side of the body 52 will not tend to flake off. Also, this metal backing only touches the body 52 at the periphery thereof, so that it does not come into contact with the mirror coating on the concave surface of the body 52 and will not damage

the mirror coating by chemical action, abrasion or otherwise.

It will be noted from FIGS. 9, 10 and 11 that the foam plastic cushioning sheet 56 and pressure sensitive adhesive layer 58 are in the shape of a flat ring. This will normally provide adequate bonding area for good adhesion to the flat mirror, although a full disc foam sheet and adhesive layer may be employed, if desired.

It is to be understood that the entire back surface of the metal backing may be made in one plane, if desired, without having a recessed central portion of the backing, and in such case the foam cushioning may be employed if desired, or it may be eliminated, with the pressure sensitive adhesive layer being applied directly to the metal backing in the manner shown in FIG. 5 of the drawings.

While the instant invention has been shown and described herein in what are conceived to be the most practical and preferred embodiments, it is recognized that departures may be made therefrom within the scope of the invention, which is therefore not to be limited to the details disclosed herein, but is to be accorded the full scope of the claims as to embrace any and all equivalent devices.

What I claim is:

1. A safety mirror device comprising in combination a flat rear view vehicle mirror comprising an exposed continuous flat front viewing surface, a convex mirror unit including a circular concavo-convex mirror body having a convex reflecting surface and also including a generally flat circular sheet metal backing covering the back portion of said body, said sheet metal member being peripherally attached to said body, said attachment being air permeable to permit pressure equalization between the concavity within said convex mirror unit and the atmosphere externally of said convex mirror unit, a thin annular sheet of cushioning material affixed to the rear surface of said backing and covering at least a substantial area thereof, and an adhesive material applied to the rear surface of said annular sheet for securing said annular sheet to said flat front surface of the vehicle mirror in full contacting engagement so as to rigidly secure said convex mirror unit to said vehicle mirror with said convex reflecting surface disposed in fixed position in front of said flat front surface of said vehicle mirror, the portion of said vehicle mirror not covered by said convex mirror unit affording a vehicle operator an undistorted rear view field of vision, and said convex mirror unit affording the operator a field of vision which overlaps said vehicle mirror field of vision but is materially larger both horizontally and vertically.

2. The device of claim 1 wherein said annular sheet of cushioning material is substantially entirely recessed in a depressed central portion which comprises substantially the entire rear surface of said sheet metal backing.

3. The device of claim 1 which includes a forwardly extending peripheral flange extending from said sheet to surround the periphery of said body, said peripheral flange including an inturned outer lip portion extending across the peripheral edge of the front surface of said body to secure said body to said backing.

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SAFETY ATTACHMENT FOR REAR VIEW VEHICLE MIRRORS

Filed March 5, 1963 3 Sheets-Sheet 2

FIG. 4.

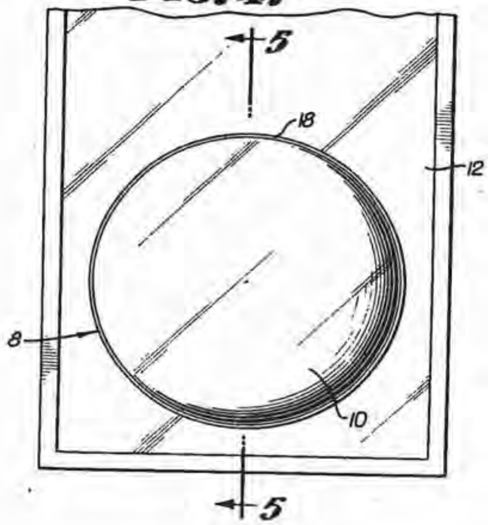


FIG. 7.

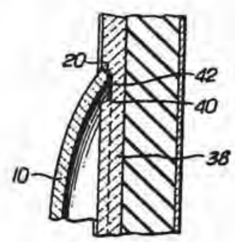


FIG. 5.

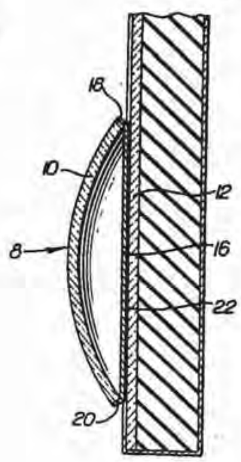
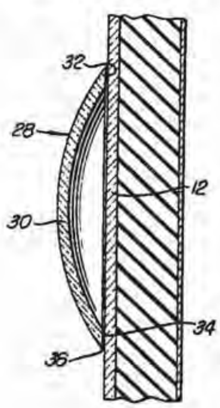


FIG. 6.



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Huebner & Worrel
ATTORNEYS.

about 4 inches, a 3-foot object can be readily and rapidly identified 100 feet to the rear of the vehicle. If the curvature is too flat, or the radius of curvature is too great, the operator of the vehicle is deceived into believing that distances can be accurately judged when in reality they cannot. Within the dimensions given the radius of curvature of the mirror body **10** depends on the size of the flat vehicle mirror **12** to which the concavo-convex mirror is applied.

It is further preferred that the diameter of the mirror body **10** be between about 2 inches to 4 inches. The diameter of the mirror body **10** depends on the size of the flat vehicle mirror **12** to which it is applied. For example, for a flat, round vehicle mirror having a diameter of 4 inches, a mirror **8** applied thereto which has about a 2-inch diameter will be satisfactory. If the flat vehicle mirror **12** has dimensions between 3 inches to 4 inches wide and 4 inches to 8 inches high, a suitable mirror **8** may have a diameter of about 3 inches. On the other hand, if the flat vehicle mirror **12** has a width between 4 inches to 5 inches and a height of about 16 inches, then a concavo-convex mirror **8** having a diameter of about 4 inches will be suitable.

In the form of the invention shown in FIGS. 4 and 5 a flat back **16** is applied to the mirror body **10** as best seen in FIG. 5. The application of the flat back **16** to the mirror body **10**, in effect, converts the mirror body from a concavo-convex configuration to a planar-convex configuration. The back **16** has a circular configuration defined by an outwardly flared annular flange **18** which encircles the mirror body **10** and is in full contacting engagement with the circumferential edge **20** thereof. Affixing of the back **16** to the mirror body **10** is achieved by applying an adhesive either to the circumferential edge **20** or to the flange **18**, and it is preferred that the adhesive be weather resistant and particularly moisture or water resistant.

To achieve the affixing of the mirror **8** to the existing vehicle mirror **12**, which in many instances will already be mounted on a vehicle, it is preferred that a pressure sensitive adhesive **22** be employed, and this may be distributed over the entire exterior surface of the back **16**, and in this manner a firm face-to-face bonding between back **16** and mirror **12** is accomplished. By using a suitable pressure sensitive type of adhesive, the attachment of mirror **8** to the face of mirror **12** may be releasable for removability of the mirror **8** from the mirror **12** for moving the mirror **8** to a more desirable position on the face of mirror **12**, or to replace mirror **8**.

Although the mirror body **10** may be fabricated of any suitable material having a mirror finish, such as brightly polished metals, or plastics which have applied thereto a substance to produce a mirror surface, it is preferred that the mirror body **10** be fabricated of glass which has been "silvered" to produce the desired mirror surface. The back **16** also may be fabricated of many materials, but metal, such as aluminum, is preferred.

Referring now to FIG. 3 wherein it may be seen that the mirror **8** is applied to the lower portion of vehicle mirror **12**, positioning of mirror **8** on the vehicle mirror **12** is entirely optional with the vehicle operator, but it has been found that the position illustrated in FIG. 3 is preferred. However, the pressure sensitive adhesive **22** which imparts the property of being able to remove mirror **8** from mirror **12** at the discretion of the vehicle operator, provides the operator the opportunity of selecting, by trial and error, the position most desirable from his view point.

FIGS. 1 and 2 serve to illustrate the advantages achieved by applying mirror **8** to mirror **12**. In FIG. 1, which is an overhead or an aerial view of a truck, the dotted lines define the limited horizontal rear view field of vision achieved with the flat vehicle mirror **12**; whereas the solid lines in FIG. 1 illustrate that mirror **8** con-

siderably enlarges the horizontal field of vision to the rear and side to afford a more accurate and complete determination of road conditions.

The enlarged horizontal rear view field of vision achieved with mirror **8**, as illustrated in FIG. 1, provides the vehicle operator with the opportunity of quickly and accurately ascertaining the conditions adjacent the side of the vehicle with respect to vehicles approaching and passing wide from the rear; whereas the flat vehicle mirror **12** fails to provide this information. In other words, mirror **8** would eliminate certain "blind areas" which heretofore were present. Therefore, the flat mirror **12** in combination with the convex mirror **8** provides the vehicle operator with a greatly extended horizontal rear view field of vision.

FIG. 2 is a side view of a truck which serves to illustrate by representative dotted and solid lines the vertical rear view field of vision achieved with the flat vehicle mirror **12** and the convex mirror **8**, respectively, the latter not being seen in FIG. 2, due to the position of the mirror **12**. It may be seen that the vehicle operator can only see as low as the tops of the rear trailer wheels when mirror **12** is used and the top of the truck cannot be seen at all. But mirror **8** enlarges this vertical field of vision to such an extent that the operator can see the rear wheels of the tractor portion of the truck and the top of the truck adjacent the cab. This enlarged vertical rear view field of vision is of great benefit to vehicle operators because it removes critical "blind spots" to such an extent that compact automobiles and the like can be more readily seen. Of particular importance, with the present invention the operator is able to see pedestrians or children on bicycles and tricycles near the right-hand rear tractor and trailer wheels, and is also able to see curbs, fire hydrants and the like at the right-hand side of the vehicle.

FIG. 6 illustrates a second form of a circular rear view vehicle mirror **28** having a concavo-convex body **30** which may be removably applied to a flat vehicle mirror **12**. The body includes a flat annular surface **32** which is perpendicular to the axis of said body. When preferably a pressure sensitive adhesive **34** is applied to surface **32** and the body **30** is removably affixed to flat vehicle mirror **12**, a reliable face-to-face bond will be achieved between surface **32** and the vehicle mirror **12**. With body **30** shaped in the manner defined, the peripheral edge **36** thereof blends or tapers into the mirror **12**.

In all other respects mirror **30** is substantially identical to mirror **8** and produces substantially identical results.

FIG. 7 shows a third form of the invention wherein the mirror body **10** is attached to a flat rear view mirror **38** by providing a circular recess **40** in the face of mirror **38**, and seating the circumferential edge **20** of mirror body **10** therein, with a suitable bonding material being distributed about the edge **20**. The circular recess **40** has an outwardly flaring outer defining edge **42** that is complementary to and slightly larger than the circumferential edge **20** of mirror body **10**, and preferably the mirror body **10** is composed of substantially thinner glass than the mirror **38** so that the circumferential edge **20** can be completely recessed within the circular recess **40** so that the surface of mirror body **10** blends smoothly into the surface of mirror **38**. Although the circular recess **40** is shown in FIG. 7 as a circular channel, it is to be understood that the recess **20** could be enlarged to include the entire area circumscribed by the outer edge **42**.

Although it is preferred to employ a pressure sensitive type of adhesive to secure mirror **8** or mirror **28** to the flat existing vehicle mirror **12**, it is to be understood that any other suitable bonding material may be employed within the scope of the invention.

FIGS. 8–11 illustrate a further form of the convex rear view vehicle mirror unit **50** which comprises a circular concavo-convex body **52**, a generally flat sheet metal

United States Patent [19] [11] 4,258,979
Mahin [45] Mar. 31, 1981

[54] **REAR VIEW MIRROR ASSEMBLY**

[76] Inventor: **William E. Mahin**, 155 Ashland Acres Rd., Ashland, Oreg. 97520

[21] Appl. No.: **967,601**

[22] Filed: **Dec. 8, 1978**

[51] **Int. Cl.**[3] **G02B 5/10**
[52] **U.S. Cl.** **350/293**; 350/303
[58] **Field of Search** 350/293, 303

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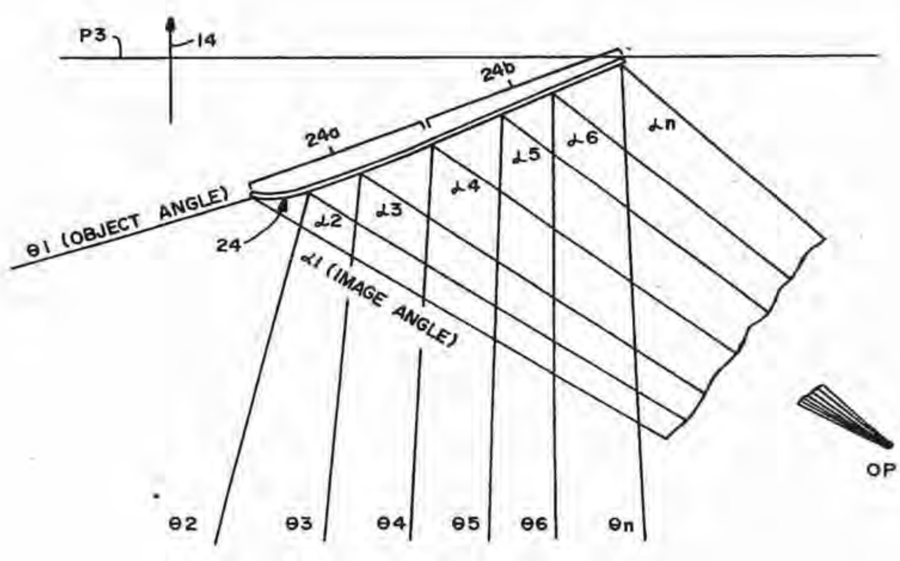
Primary Examiner—F. L. Evans
Attorney, Agent, or Firm—Flehr, Hohbach, Test

[57] **ABSTRACT**

A rear view mirror assembly mounted to one side of a given vehicle is disclosed herein and includes a mirrored surface supported in a fixed position relative to a predetermined observation point for viewing a second trailing vehicle. This mirrored surface includes a first segment horizontally and/or vertically curved in accordance with changing magnification ratios, preferably in a way which defines a substantially linear relationship between the position of the trailing vehicle and the horizontal and/or vertical position of its image on the curved surface segment. In this way, as the trailing vehicle approaches the lead vehicle from behind, horizontal and/or vertical movement of its image across the curved segment is controlled, preferably to a speed linearly proportionate to the speed of the trailing vehicle relative to the lead vehicle. At the same time, the mirrored surface provides a view incorporating the rear section of the lead vehicle including its rear tires on the mirror supported side.

28 Claims, 19 Drawing Figures



350-303 AU 257 EX
CCC21 XR 4,258,979

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 4,258,979
DATED : March 31, 1981
INVENTOR(S) : William E. Mahin

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In Column 23, Line 8 (Claim 20), delete "18" and insert therefor --28--.

Signed and Sealed this

Twenty-fourth **Day of** *May 1983*

[SEAL]

Attest:

DONALD J. QUIGG

Attesting Officer — *Acting Commissioner of Patents and Trademarks*

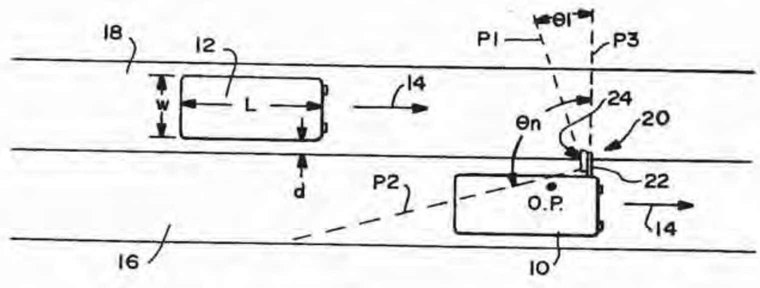


FIG.—1

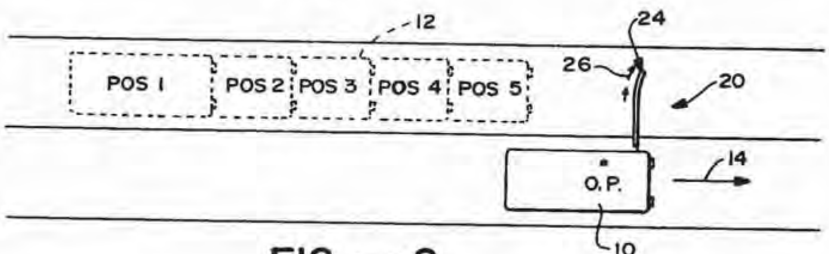


FIG. — 2

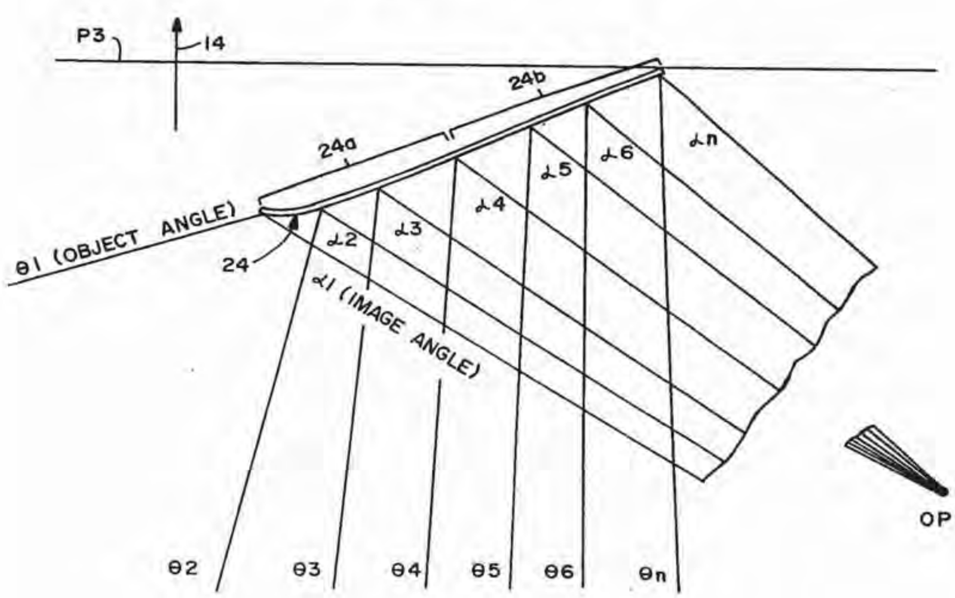


FIG.—3

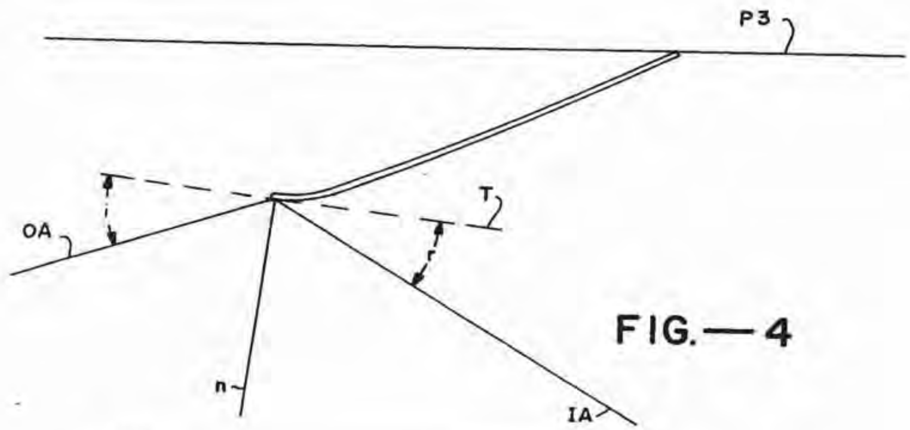

P3
T
OA
n
IA

FIG.—4

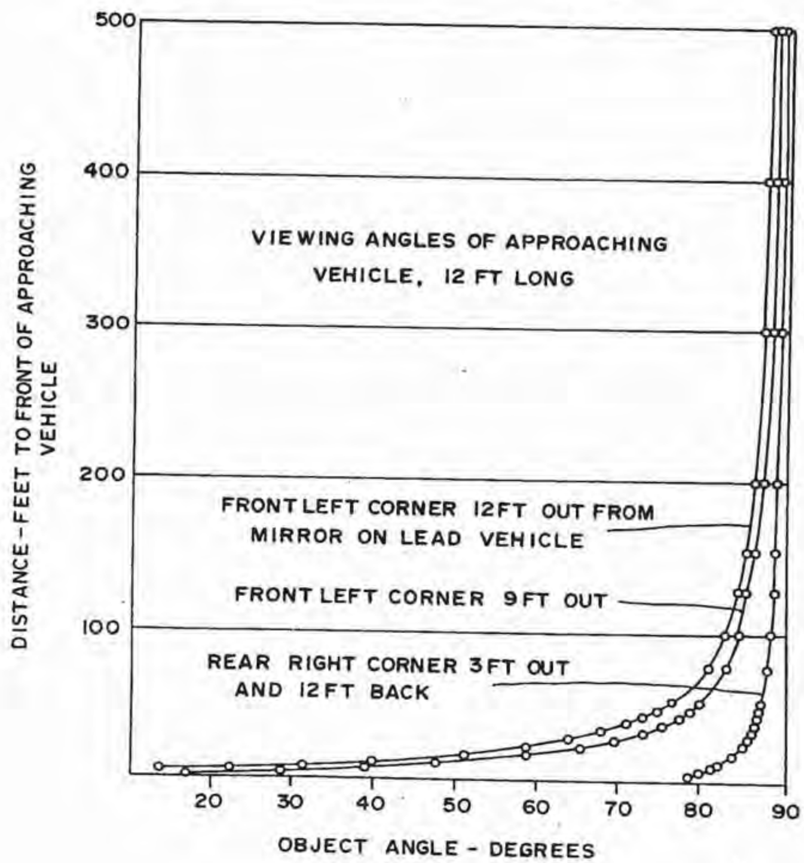

500
400
300
200
100
DISTANCE - FEET TO FRONT OF APPROACHING VEHICLE
VIEWING ANGLES OF APPROACHING VEHICLE, 12 FT LONG
FRONT LEFT CORNER 12 FT OUT FROM MIRROR ON LEAD VEHICLE
FRONT LEFT CORNER 9 FT OUT
REAR RIGHT CORNER 3 FT OUT AND 12 FT BACK
20
30
40
50
60
70
80
90
OBJECT ANGLE - DEGREES

FIG.—5

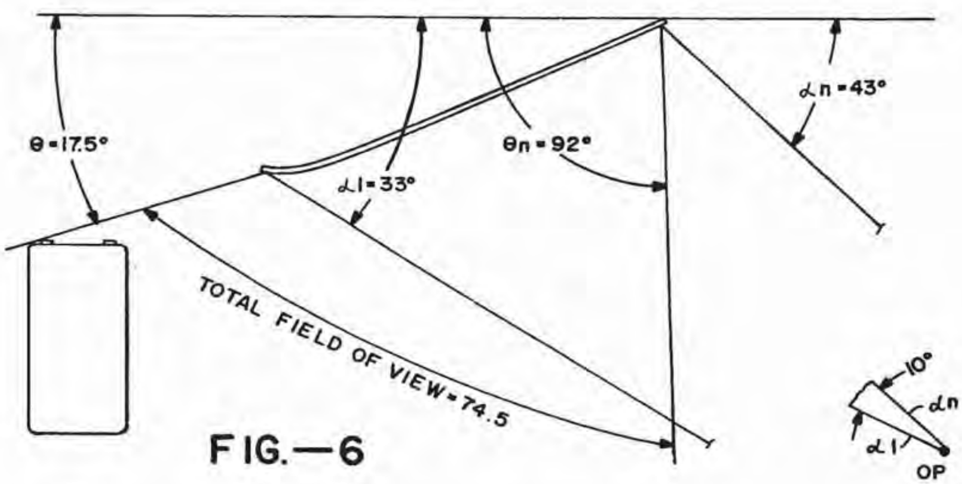

θ=17.5°
α1=33°
θn=92°
αn=43°
TOTAL FIELD OF VIEW=74.5
10°
αn
α1
OP

FIG.—6

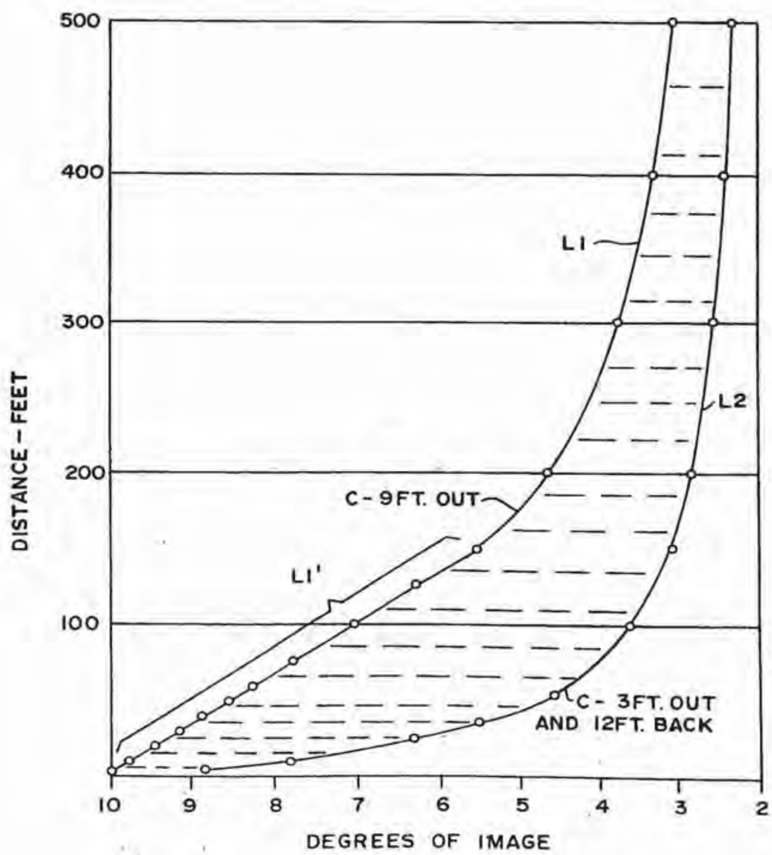

500
400
300
200
100
DISTANCE - FEET
L1
L2
C - 9FT. OUT
L1'
C - 3FT. OUT
AND 12FT. BACK
10
9
8
7
6
5
4
3
2
DEGREES OF IMAGE

FIG.—7b

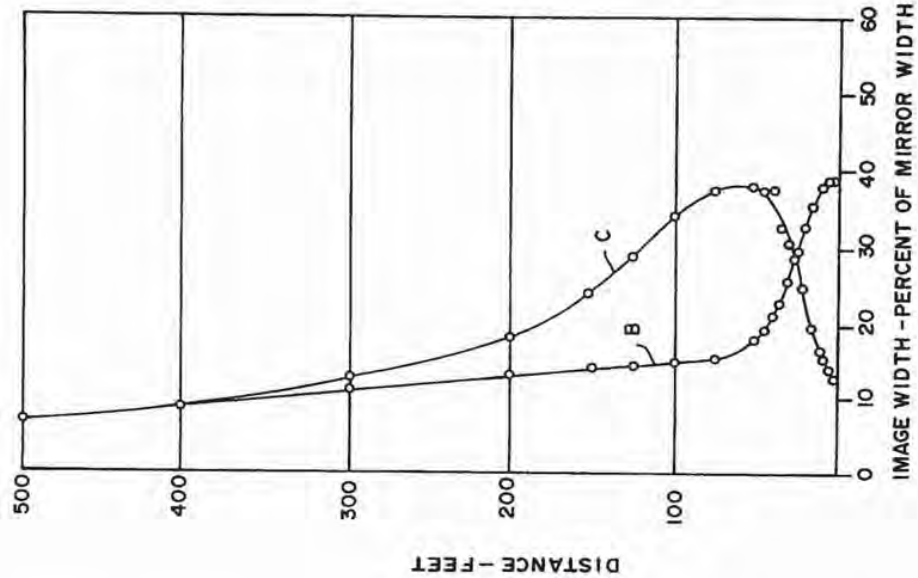

DISTANCE – FEET
500
400
300
200
100
0
10
20
30
40
50
60
IMAGE WIDTH - PERCENT OF MIRROR WIDTH
C
B

FIG. — 7c

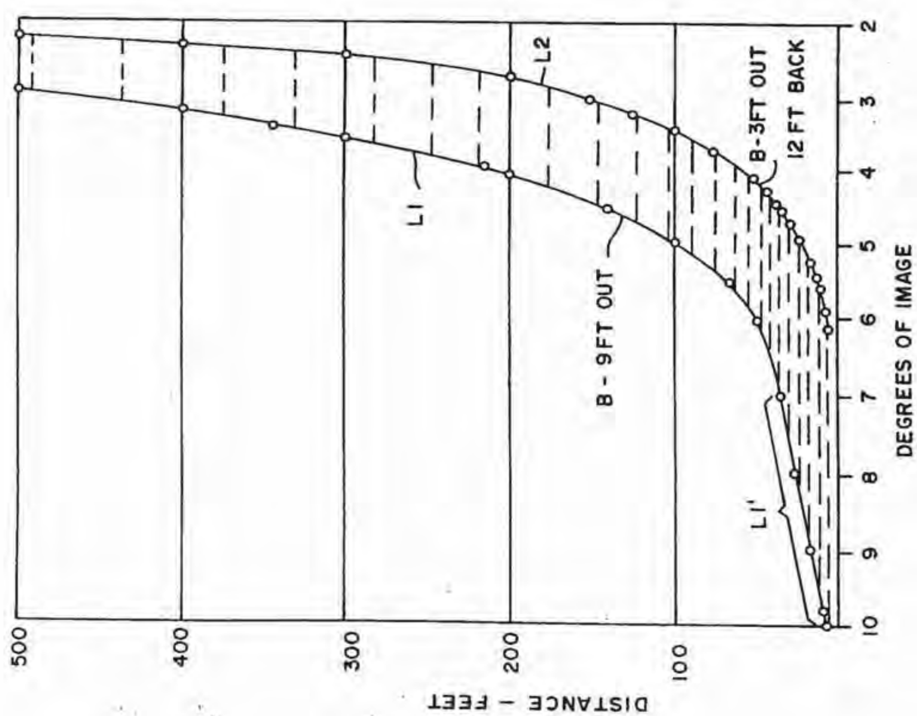
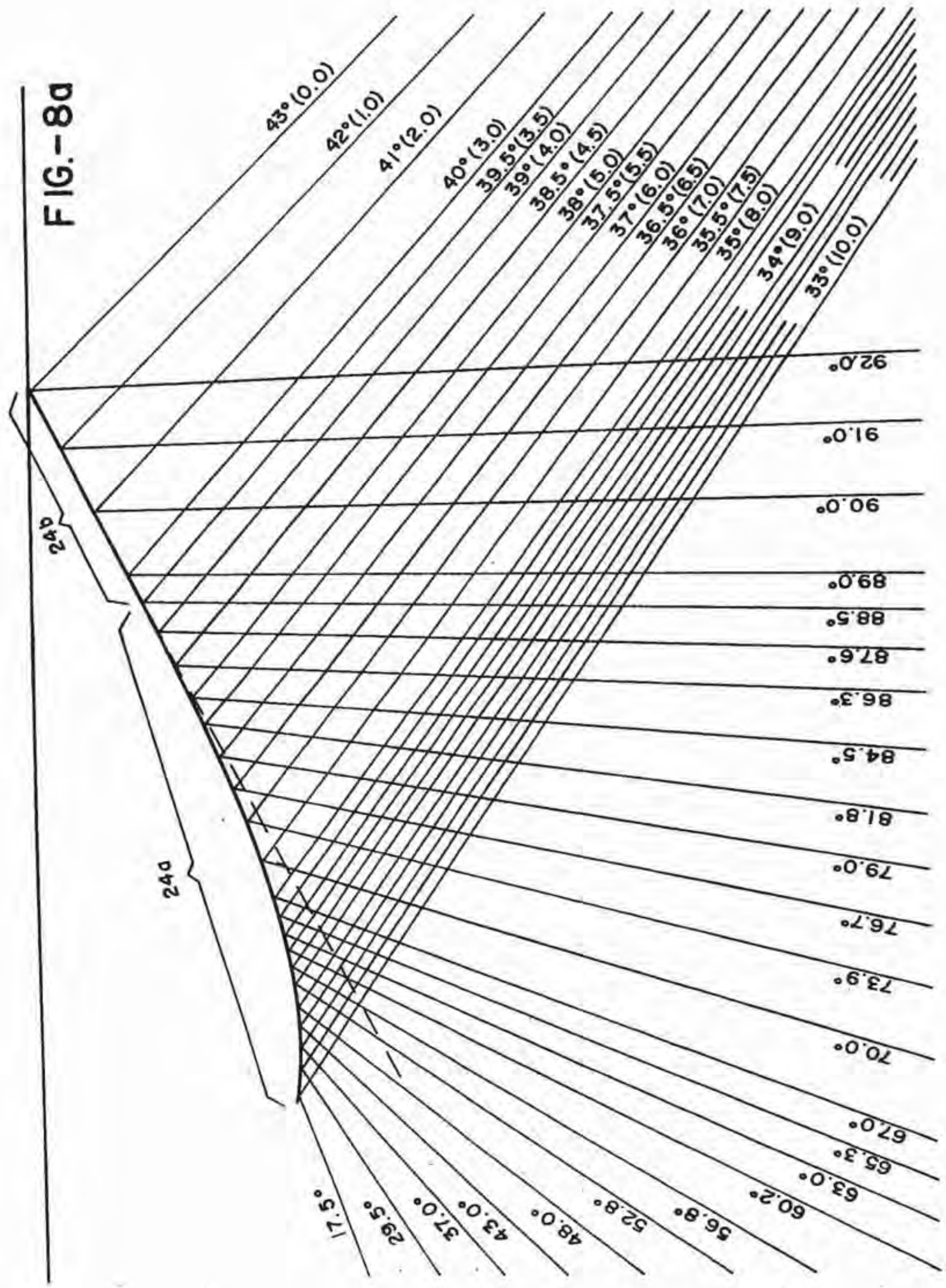

DISTANCE – FEET
500
400
300
200
100
2
3
4
5
6
7
8
9
10
DEGREES OF IMAGE
L1
L2
B - 9FT OUT
B-3FT OUT
12 FT BACK
L1'

FIG. — 7a

FIG.-8a


43°(0.0)
42°(1.0)
41°(2.0)
40°(3.0)
39.5°(3.5)
39°(4.0)
38.5°(4.5)
38°(5.0)
37.5°(5.5)
37°(6.0)
36.5°(6.5)
36°(7.0)
35.5°(7.5)
35°(8.0)
34°(9.0)
33°(10.0)
92.0°
91.0°
90.0°
89.0°
88.5°
87.6°
86.3°
84.5°
81.8°
79.0°
76.7°
73.9°
70.0°
67.0°
65.3°
63.0°
60.2°
56.8°
52.8°
48.0°
43.0°
37.0°
29.5°
17.5°
24b
24a

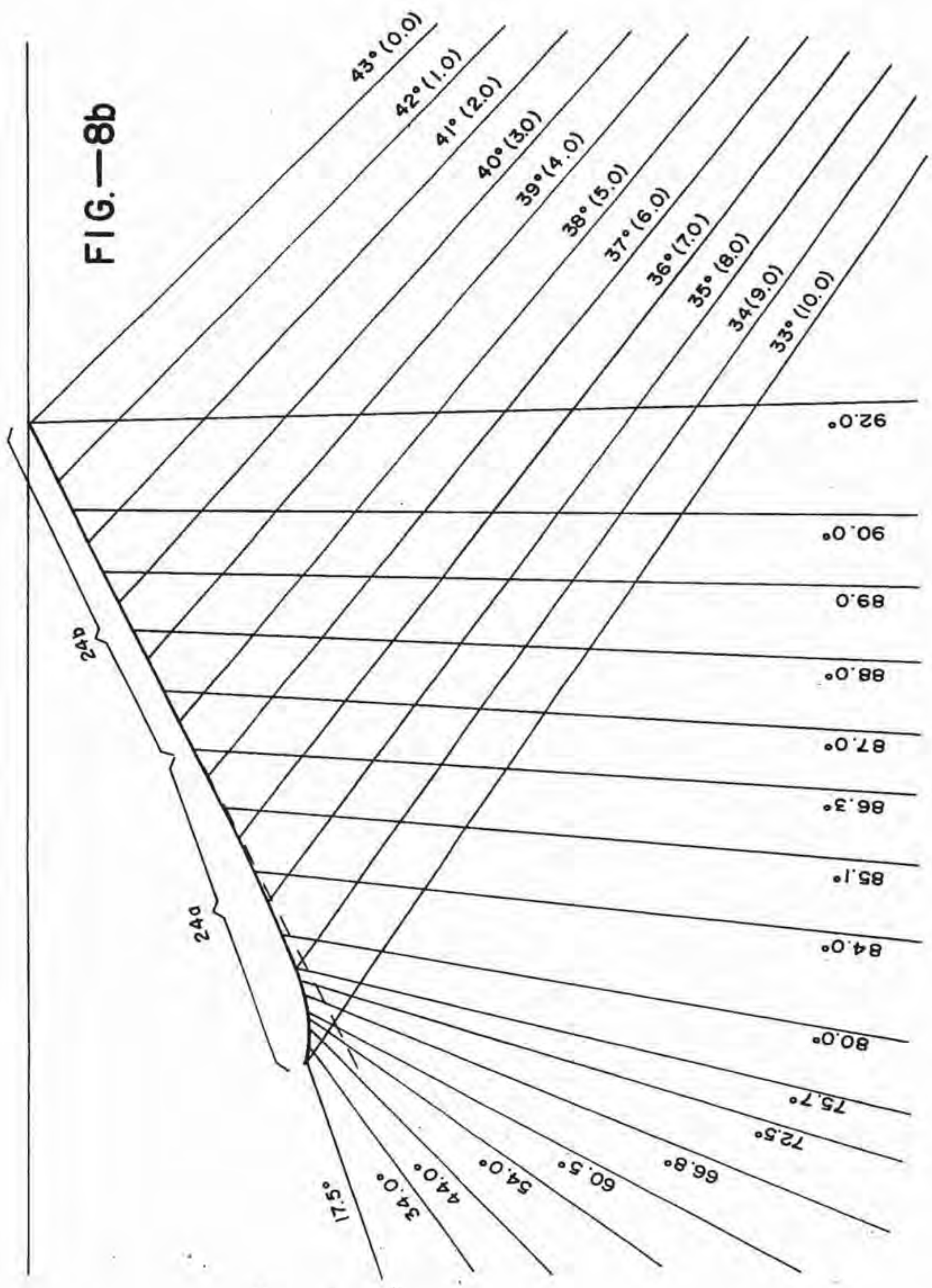

43° (0.0)
42° (1.0)
41° (2.0)
40° (3.0)
39° (4.0)
38° (5.0)
37° (6.0)
36° (7.0)
35° (8.0)
34(9.0)
33° (10.0)
92.0°
90.0°
89.0
88.0°
87.0°
86.3°
85.1°
84.0°
80.0°
75.7°
72.5°
66.8°
60.5°
54.0°
44.0°
34.0°
17.5°
24b
24a

FIG.—8b

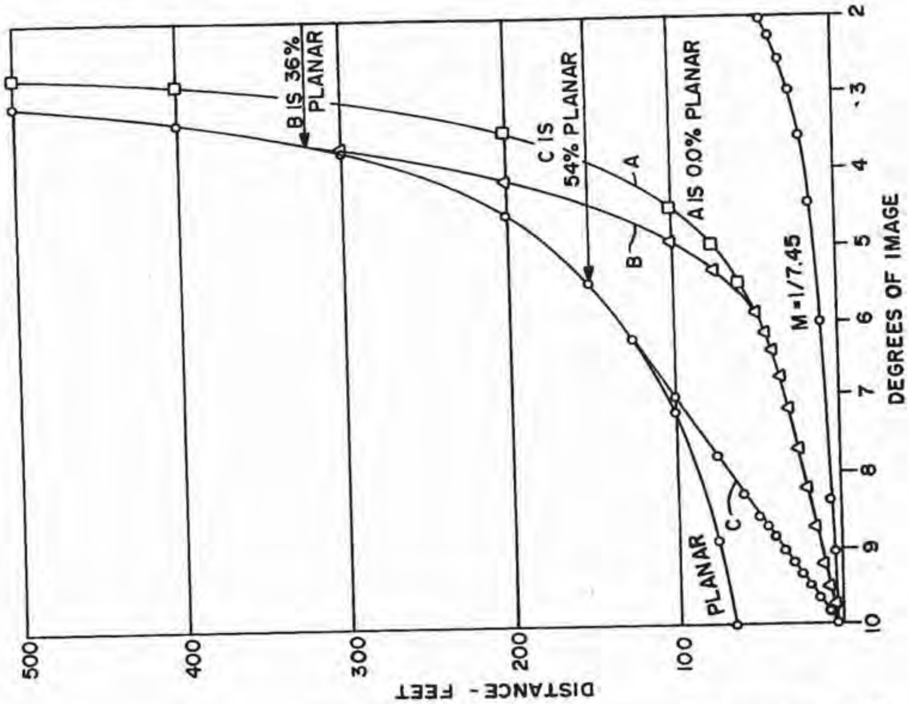

B IS 36% PLANAR
C IS 54% PLANAR
A IS 0.0% PLANAR
A
B
C
PLANAR
M=1/7.45
DISTANCE - FEET
500
400
300
200
100
DEGREES OF IMAGE
2
3
4
5
6
7
8
9
10

FIG.—9b

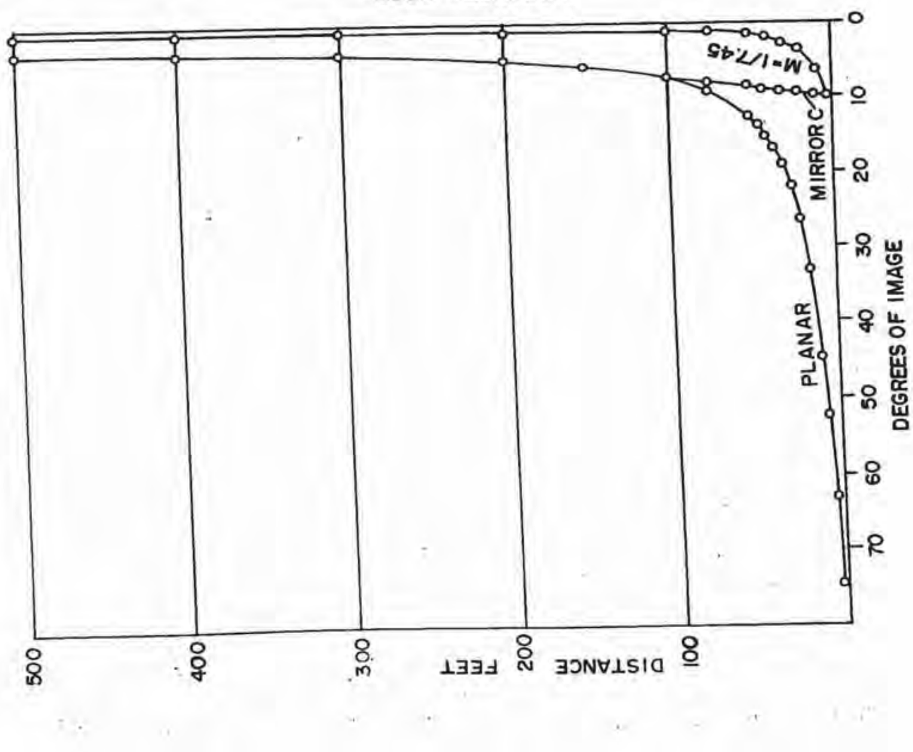

M=1/7.45
MIRROR C
PLANAR
DISTANCE FEET
500
400
300
200
100
DEGREES OF IMAGE
0
10
20
30
40
50
60
70

FIG.—9a

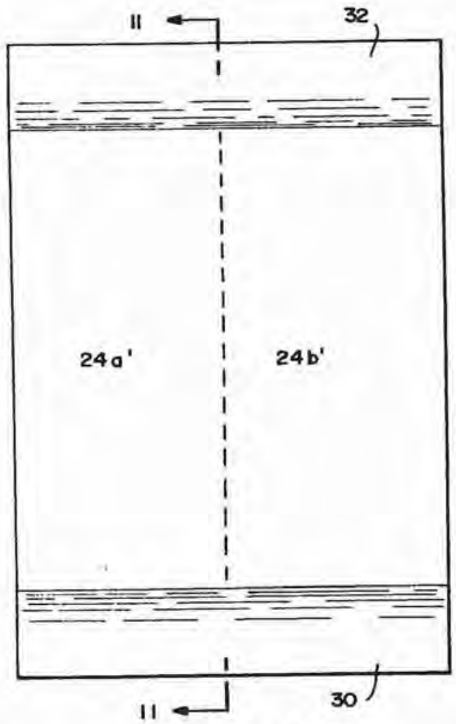


FIG.—10

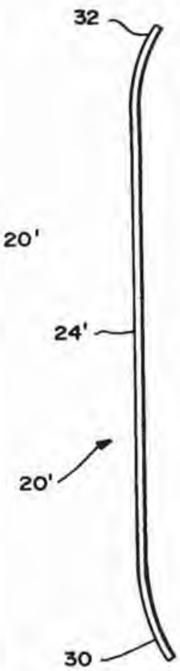


FIG.—11

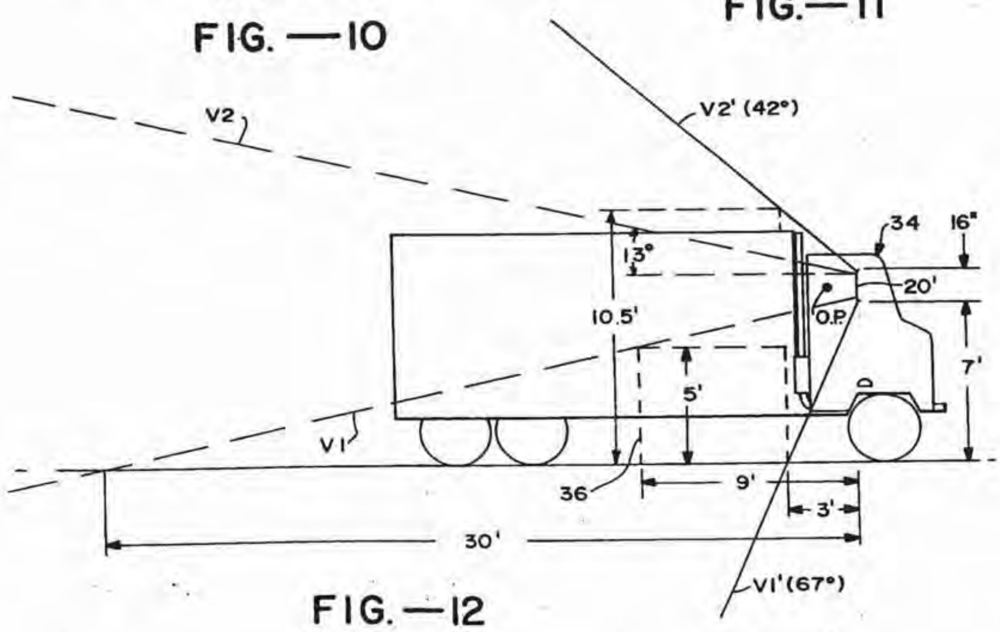
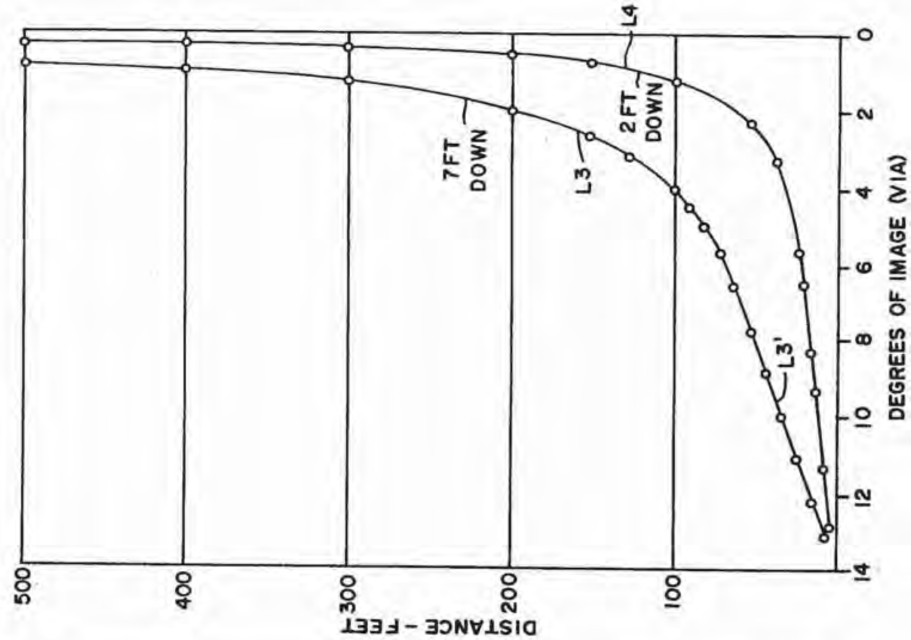
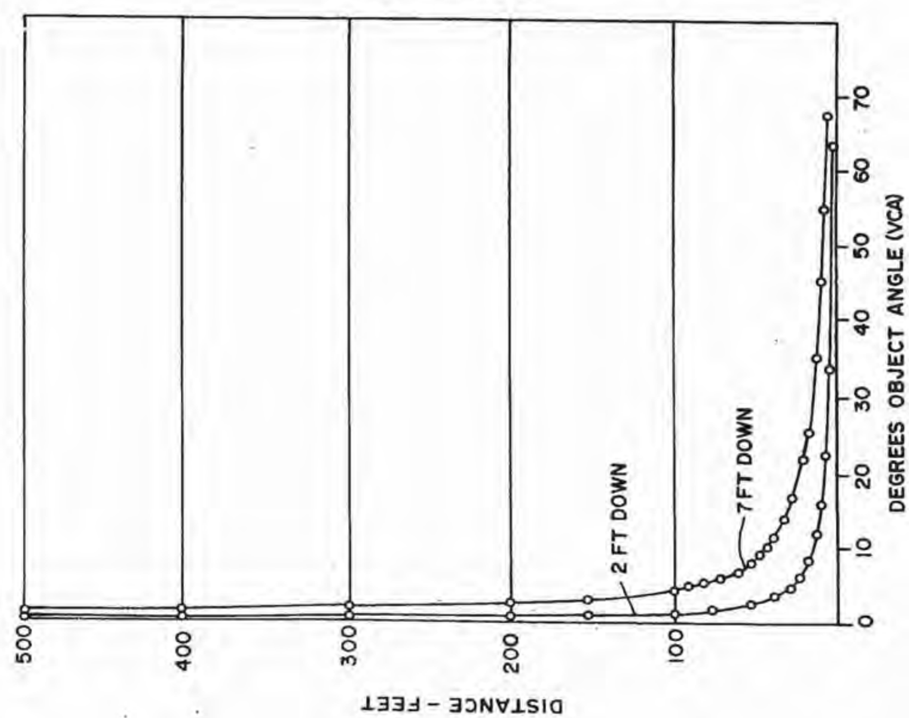


FIG.—12



DISTANCE - FEET
500
400
300
200
100
0
2
4
6
8
10
12
14
DEGREES OF IMAGE (VIA)
7 FT DOWN
L3
2 FT DOWN
L4
L3'

FIG.—14



DISTANCE - FEET
500
400
300
200
100
0
10
20
30
40
50
60
70
DEGREES OBJECT ANGLE (VCA)
2 FT DOWN
7 FT DOWN

FIG.—13

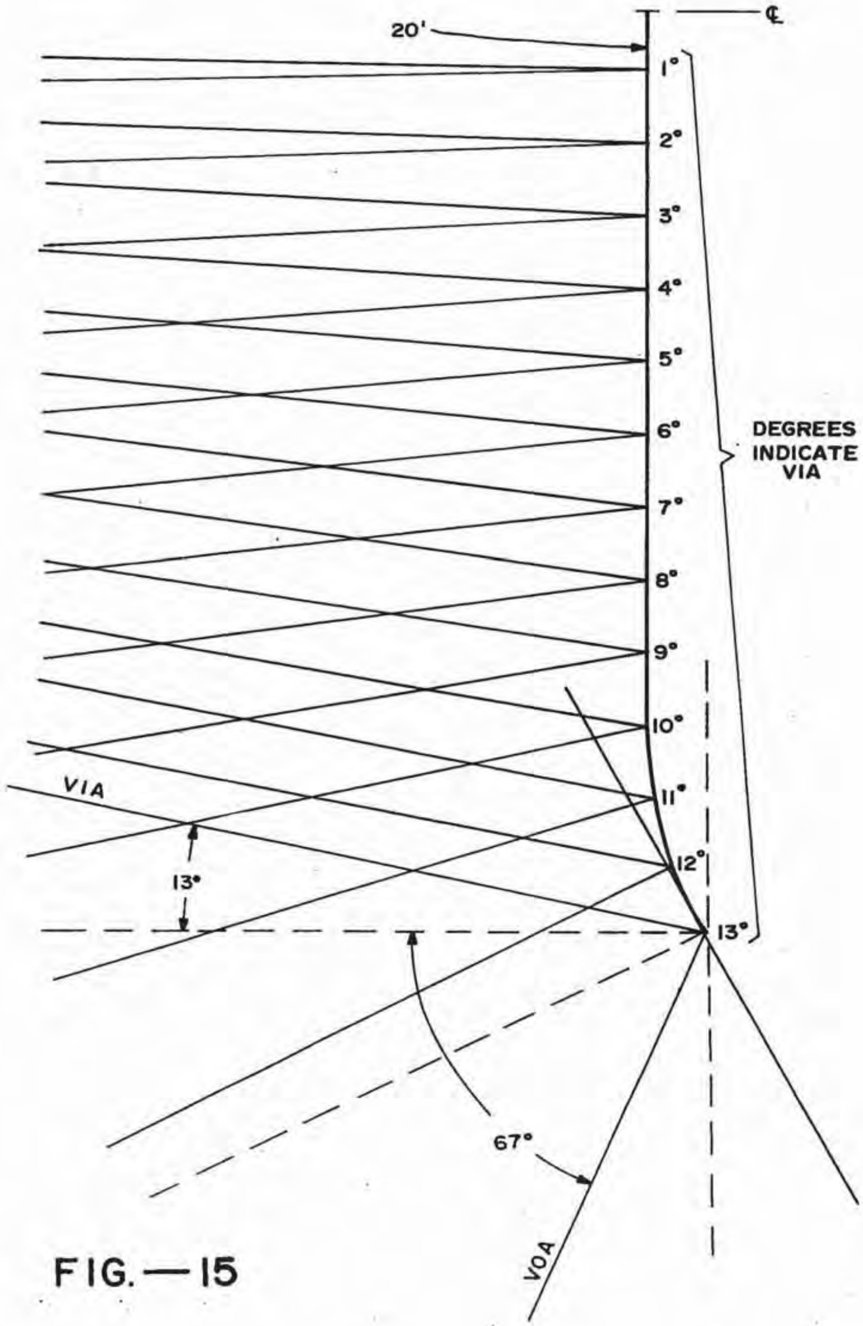


FIG.—15

REAR VIEW MIRROR ASSEMBLY

BACKGROUND OF THE INVENTION

The present invention relates generally to rear view mirrors for vehicles and more particularly to an improved rear view mirror assembly (1) which eliminates the blind spot that normally occurs just before the passing vehicle comes abreast of the lead vehicle (2) which more accurately reflects the position and movement of the passing vehicle as the latter approaches the lead vehicle, and (3) which in one embodiment provides a field of view that not only eliminates the blind spot but also incorporates the rear tires on the mirror supporting side of the lead vehicle.

In the past, it has been general practice by most drivers, especially drivers of tractor-trailers and recreational vehicles to use two rear view mirrors on one side of the vehicle, a main mirror and a secondary mirror. Typically, this main mirror is large and planar for providing a view back down the road a substantial distance behind the driver, especially since its usual field of view is limited to about 10°. On the other hand, the secondary mirror is typically smaller and consists of a convex section of a sphere, generally referred to as a "bulls eye" mirror. This latter mirror is utilized to eliminate the blind spot located to one side of the driver of the lead vehicle and its use is limited to that general field of view. As a result, the driver is required to move his eyes from one mirror to the other in order to keep track of the other vehicles on the road. Moreover, because the "bulls eye" mirror is spherical in nature and typically defines a relatively small radius of curvature the image reflected is badly distorted both in its vertical and horizontal planes.

The general effect of the "bulls eye" mirror is to give a distorted view of the size and speed of the oncoming vehicle. More specifically, as this latter vehicle approaches the blind spot of the main mirror, the image in the secondary "bulls eye" mirror is quite small (in all dimensions) relative to the actual size of the vehicle. However, as the oncoming vehicle moves forward and comes nearly abreast of the driver, the image appears to grow in size and "jump out" from the mirror at such a rapid rate as to exaggerate its forward speed. The problem is that the image is at first so small as to make the approaching vehicle appear to be at a considerable distance behind the driver's vehicle until the "jumping out" effect which occurs only when the approaching vehicle is already at an unsafe nearness. Because of this "jumping out" effect and movement of the eyes from one mirror to the other, safety to the drivers of the lead vehicle and passing vehicle as well as others in the near vicinity are threatened by the inability of the driver of the lead vehicle to quickly and accurately judge the situation as it relates to the passing vehicle. Because of these difficulties many drivers choose to ascertain the presence of a passing vehicle by turning their heads for a fraction of a second just before starting to pass another vehicle themselves. This, of course, causes a momentary distraction of the driver's view ahead where new hazards may suddenly occur.

There have been some suggestions in the prior art for eliminating some of the problems discussed above. For example, German Pat. No. 1,921,076, dated Nov. 19, 1970 discloses a rear view mirror including an overall mirrored surface having a planar section and an integral curved section which together presumably provide the same field of view as the planar mirror and separate convex mirror discussed above. While this patent appears to eliminate the problems associated with using two distinct mirrored assemblies for eliminating the blind spot and for viewing substantial distances rearwardly, it does not address itself to the problem of distortion (of speed and size) discussed previously. Specifically, this reference does not teach or suggest any means or method for eliminating the exaggerated way in which the on-coming or trailing vehicle is viewed as the latter approaches the lead vehicle.

Another prior art reference which combines two mirrored surfaces for increasing the field of vision is U.S. Pat. No. 4,012,125 (Hart), dated Mar. 15, 1977. However, like the German patent, this reference does not address itself to the problem of image distortion with respect to size and speed (jumping out effect) as the passing vehicle approaches the lead vehicle. In fact, this patent specifically teaches the utilization of mirrored surfaces each having a constant magnification (which includes demagnification) ratio M, at least in horizontal planes through the mirrored surfaces. One object of the patent was to eliminate angular distortion and this was achieved by maintaining a constant magnification ratio. However, Applicant has found that as the image of an approaching vehicle moves horizontally across the mirrored surface of the lead vehicle it does so at a speed which, by virtue of the constant magnification ratio of the mirrored surface, seems grossly distorted relative to the speed of the oncoming vehicle. In this regard, Applicant has found that a linear relationship between movement of the trailing vehicle and its image across the mirror eliminates such distortion. However, since each of the mirrored surfaces disclosed in the Hart patent is designed with a constant magnification ratio in the horizontal plane, Applicant has also found that there cannot be a linear relationship between the position of the passing vehicle and the horizontal position of its image on the mirrored surface, as viewed from a given observation point, specifically the eyes of the driver of the lead car. This does not mean however, that any mirrored surface having a magnification ratio which varies across its horizontal extent automatically defines the linear relationship just discussed. As will be seen hereinafter, the mirrored surface must be of a particular curvilinear configuration to provide this type of linear relationship as will be described hereinafter. Applicant has discovered that distortion of the type described can thus be reduced by providing a curved surface based on a changing magnification ratio (to be described hereinafter). The rear view mirror assembly constructed in accordance with the present invention includes such a mirrored surface, thereby reducing and preferably eliminating the distortion described above, as will also be seen.

In addition, the assembly of the present invention eliminates the aforedescribed blind spot and, in a particular embodiment, it provides a relatively wide field of view including the rear tires of the mirror-mounted side of the vehicle as well as a tailgating vehicle. This wide field of view is attained even for mirrors mounted relatively high on large trailer trucks and the like by providing a vertical curvature similar to the horizontal curvature described above, as will be seen.

OBJECTS AND SUMMARY OF THE INVENTION

One object of the present invention is to provide a rear view mirror assembly which is uncomplicated in design, economical to provide and yet one which overcomes the various drawbacks discussed previously.

A more specific object of the present invention is to provide a rearview mirror assembly which is adapted for connection to one side of a vehicle and which eliminates the blind spot typically located on that side while, in a particular embodiment, at the same time providing an undistorted field of view to the rear including the rear tires located on the mirror-mounted side of the vehicle, even if the assembly is mounted relatively far from the ground as on a large trailer truck or the like, and the top front edge of the trailer when one is being pulled.

Another specific object of the present invention is to provide a rear view mirror assembly which allows the driver to more reliably judge the position and speed of an oncoming vehicle as the latter approaches from behind.

As will be seen hereinafter, the rearview mirror assembly disclosed herein is one which is adapted for mounting to one side of a given vehicle in a fixed position relative to a predetermined observation point in the vehicle for viewing a second trailing vehicle when the lead vehicle is in one lane and the second vehicle is in the next adjacent lane in a position along a substantially straight line path behind the lead vehicle. As will also be seen, this assembly includes a mirrored surface and a mounting structure adapted for connection to the side of the lead vehicle in the fixed position recited so as to view the oncoming vehicle.

In accordance with one aspect of the present invention, the mirrored surface of one assembly disclosed herein when in the position described provides a rearward field of view including the previously described blind spot at the front edge of the field and also a view of a tailgating vehicle. This is accomplished by designing the mirrored surface to provide a rearward view which, in a horizontal plane through this surface, extends from a forwardmost point about 15° to 20° rearward of a line extending normal to the path of movement of the vehicle and through the mirrored surface to a rearward point about 91° to 93° and preferably about 92° from the same normal line.

In accordance with another aspect of the present invention, the mirrored surface of the one assembly disclosed herein includes a segment which is curved in any horizontal plane therethrough in accordance with decreasing magnification ratios M (to be described) for reducing the previously described image "jumping out effect". In a preferred embodiment this surface segment defines a substantially linear (that is straight-line) relationship between (1) the position of the second vehicle (actually a given point on the second vehicle) when the vehicle (actually the given point) is located along the aforedescribed straight-line path, within a predetermined range of distances from the mirrored surface segment, and (2) the horizontal position of its image on the mirrored surface segment as viewed from the observation point. In this way, the image moves horizontally across the surface segment at a speed substantially linearly proportionate to the speed of the oncoming vehicle relative to the speed of the first vehicle. This in turn allows the driver of the first vehicle to more accurately judge the position and speed of the oncoming vehicle, specifically when the latter is within a predetermined distance range behind the driver. The mirrored surface just recited preferably includes a second segment which is preferably planar and thus has a magnification ratio, M, of 1 and provides an undistorted image of an approaching vehicle that is behind the lead vehicle. The magnification ratio of the first segment varies over a range of values and approaches as a limit at the edge nearest the second segment a value of 1. Thus the image of the trailing vehicle is seen continuously and with magnification decreasing smoothly from a value of 1 to a lesser value (preferably greater than 1/100) until it reaches the unaided peripheral vision of the driver of the lead vehicle.

In accordance with still another aspect of the present invention, the mirrored surface of another assembly disclosed herein not only includes the horizontally curved segment and a planar segment just recited but also a vertically curved segment along a bottom edge portion of the mirrored surface. This latter segment is preferably curved to define the same type of linear relationship, that is, a linear relationship between (1) the position of a given point on a second trailing vehicle when the latter is located along the aforedescribed straight line path, within a predetermined range of distances from the vertically curved segment and (2) the vertical position of its image on this latter segment as viewed from the observation point. This particular feature is especially suitable for mirror assemblies to be mounted relatively far from the ground which is typically the case when used with trailer trucks or the like. In this way, the driver cannot only see his rear tires on the mirror mounted side but he can also see a relatively small vehicle such as a Volkswagen, even when the latter is to one side of the driver. This is to be distinguished from the situation which exists when a vertically planar mirror is utilized with a large vehicle such as a trailer truck or the like. In this latter case, it has been found that a typical vertically planar mirror, for example one having a vertical span of 16 inches and mounted, for example, 7 feet from the ground will not provide a view of a compact vehicle, for example, a Volkswagen, which is 5 feet high and which has its front edge 3 feet back from the mirror, as will be seen hereinafter.

In accordance with yet another aspect of the present invention, the mirrored surface just described is also vertically curved along a top edge portion and is particularly suitable for use with the large vehicle just recited. The particular curvature provided along the top edge portion is one which would include the top front edge of a trailer being pulled and in a preferred embodiment also provides the linear relationship described previously. This is quite helpful for vehicles pulling trailers under a bridge or other such obstructions.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic illustration, in plan view, of two vehicles moving in the same direction on a roadway, the first lead vehicle including a rear view mirror assembly constructed in accordance with the present invention and a second trailing vehicle attempting to pass the lead vehicle.

FIG. 2 is a schematic illustration, in plan view, showing the trailing vehicle in a number of positions behind the lead vehicle and showing the rear view mirror assembly of the lead vehicle exaggerated in size to illustrate how the image of the trailing vehicle moves across the mirrored surface of the assembly.

FIG. 3 schematically illustrates the mirrored surface of the assembly in horizontal cross-section, particularly showing how the image of the approaching vehicle is reflected off of the mirror towards a fixed observation point, specifically the viewing point of the driver in the lead vehicle.

FIG. 4 is a horizontal sectional view of the mirrored surface similar to the view in FIG. 3 but showing specific geometric considerations which are necessary to design the specific curvature of the mirrored surface in accordance with the present invention.

FIG. 5 is a graphic illustration representing the angles of view (object angles) presented by an approaching vehicle as a function of distance.

FIG. 6 is a diagrammatic illustration of the mirrored surface illustrated in FIGS. 3 and 4, particularly showing the overall field of view provided by the mirrored surface as it relates to a passing vehicle which is located in what would otherwise be the blind spot and as it relates to the lead vehicle itself and especially the fact that the field of view includes points directly behind the lead vehicle.

FIGS. 7*a*, *b* and *c* are graphic illustrations of the way in which the image of the passing vehicle moves horizontally across the mirrored surface in two specific embodiments, as this latter vehicle approaches the lead vehicle.

FIG. 8*a* is a horizontal sectional view of a mirrored surface designed in accordance with an actual preferred embodiment of the present invention and illustrating actual object and image angles.

FIG. 8*b* is a horizontal sectional view similar to FIG. 8*a* but of another embodiment.

FIGS. 9*a* and 9*b* are graphic illustrations specifically illustrating the way in which the image of the approaching vehicle moves across the mirrored surface designed in accordance with a number of embodiments including the preferred embodiment (FIGS. 7*a* and 8*a*) as compared to the way in which the image moves across a curved mirrored surface designed in accordance with the prior art and one which is fully planar (if this were large enough).

FIG. 10 is a frontal view of a rear-view mirror assembly constructed in accordance with another embodiment of the present invention.

FIG. 11 is a vertical sectional view of the assembly of FIG. 10, taken generally along line 11—11 in FIG. 10.

FIG. 12 is a schematic illustration in side elevational view, of a relatively large vehicle, specifically a trailer truck or the like utilizing the rear-view mirror assembly of FIGS. 10 and 11 and particularly illustrating the vertical field of view obtained by this assembly as compared to a planar mirror of the prior art.

FIG. 13 is a vertical graphic illustration similar to the horizontal illustration of FIG. 5, but specifically for the rear view mirror assembly utilized with the vehicle illustrated in FIG. 12.

FIG. 14 is a vertical graphic illustration similar to the horizontal illustrations of FIGS. 7*a* and *b*, but specifically for the assembly utilized with the vehicle of FIG. 12.

FIG. 15 is a vertical sectional view of a mirrored surface designed in accordance with an actual embodiment of the present invention, specifically the one especially suitable for use with the vehicle illustrated in FIG. 12.

DETAILED DESCRIPTION AND PREFERRED EMBODIMENTS

Turning now to the drawings, wherein like components are designated by like reference numerals throughout the various figures, attention is first directed to FIG. 1. This figure diagrammatically illustrates two vehicles 10 and 12 moving in the same direction on a roadway, as indicated by arrows 14 but in different lanes generally indicated at 16 and 18. As seen in FIG. 1, lead vehicle 10 includes a rear view mirror assembly 20 which is constructed in accordance with the present invention. This assembly is mounted on the driver's side of the vehicle by means of a conventional mounting structure 22 and includes a mirrored surface 24 which is maintained in a fixed position relative to a predetermined observation point OP within the vehicle, specifically the viewing point of the driver for viewing vehicle 12. In this regard, the mirrored surface is preferably adjustable (by conventional means, not shown) to suit the observation points of different drivers. In addition, the horizontal field of view provided by mirrored surface 24 is specifically illustrated in FIG. 1 as extending between vertical planes P1 and P2 and end at opposite sides of the mirrored surface. As specifically seen in FIG. 1, plane P1 is located at an angle Θ_1 rearwardly of a vertical plane P3 extending through mirrored surface 24 normal to the vehicle's direction of movement. Plane P2 is located at an angle Θ_n behind plane P3.

As stated previously, mirrored surface 24 is designed in accordance with the present invention to provide two special features. First, the overall field of view of this mirrored surface is sufficiently wide horizontally to not only include what is normally the driver's blind spot but also the rear of the mirror-mounted side of vehicle 10 and directly behind the latter. This is accomplished by specifically designing mirrored surface 24 so that plane P1 (which limits the forwardmost field of view) is between about 15° and 20° rearward of plane P3 and preferably about 17.5°. This clearly includes the previously described blind spot. Plane P2 on the other hand is located between approximately 91° and 93° rearward of plane P3, preferably 92° since this is normally all that is required to extend beyond a vertical plane coinciding with the side of vehicle 10 including assembly 20. Hence, as illustrated in FIG. 1, the field of view includes the rear of the mirror-mounted side of vehicle 10 and a portion of tailgating vehicle (not shown). Moreover, the mirrored surface may be of sufficient length vertically or vertically curved as in another embodiment (as will be seen) to incorporate the rear tires on that side within the field of view as seen from point OP.

The second special feature of mirrored surface 24 discussed previously can be initially illustrated best in FIG. 2. As seen in this figure, vehicle 12 is illustrated in a number of different positions as it approaches the lead vehicle 10. In this regard, as stated previously, the overall rear view mirror assembly is shown exaggerated in size. In addition, the arrows 26 extending horizontally across mirrored surface 24 represent the movement of the image of vehicle 12 as viewed at point OP as the on-coming vehicle moves from position 1 to position 2 and so on until it passes beyond plane P1 (not shown in FIG. 2). As will be seen hereinafter, this second special feature of mirrored surface 24 resides in the use of a segment which is specifically designed to minimize the previously described "jumping out effect" by defining a substantially linear relationship between the position of vehicle 12 as it moves from position 1 to position 2 and so on and the horizontal position of its image as it moves in the direction of arrows 26. In this way, the image moves horizontally across the surface segment, as indicated by arrows 26, at a speed substantially linearly proportionate to the speed of vehicle 12 as the latter moves through the various positions shown. As will be seen in a preferred embodiment, this special linear relationship between the oncoming vehicle and its image occurs only when the oncoming vehicle is within a predetermined range of distances from the lead vehicle. The second horizontal segment of the mirrored surface provides rearward viewing beyond this range and specifically includes the rearward section of vehicle 10, as described above.

In order to more fully understand the nature of mirrored surface 24 from a structural standpoint certain positional relationships must be assumed and certain definitions must be provided. With regard to the former, it is to be assumed, at least for the purpose of describing a specific embodiment of the mirrored surface, that vehicle 12 (the trailing vehicle) is relatively small, specifically six feet wide and 12 feet long, which is about the size of a Volkswagen or similar compact automobile. The right side of vehicle 12 (the side closest to vehicle 10) is 3 feet to the left of mirror assembly 20 measuring from the outermost point of the mirrored surface. Moreover the mirrored surface itself in this embodiment is assumed to have a horizontal extent of 7 inches and in some embodiments a vertical extent of 10 inches or more, and it is positioned approximately 30 inches from the driver's eye (the observation point OP). In this way, the maximum angular extent across the mirrored surface from one vertical edge to the other as measured from point OP is approximately 10°, as best seen in FIG. 6. In this regard, for purposes of limited drawing space, the rays (lines) to point OP have been broken away in this figure and in FIG. 3. Obviously, the size of vehicle 10 is not relevant with respect to viewing oncoming vehicle 12 except that it is to be assumed that vehicle 10 contains no obstruction to the rearward field of view other than its rear side illustrated and discussed with respect to FIG. 1. In addition, it should be noted that the rear view mirror assembly of the present invention is especially suitable for use with large vehicles such as tractor-trailer and recreational vehicles. Moreover, whether the rear view mirror assembly is located to the driver's left as illustrated in FIGS. 1 and 2 or to his right just outside the passenger side of the vehicle, the various positional relationships just described would be the same, except of course that the vehicle being viewed would be located to the right of the lead vehicle and the position of the observation point (the driver's view) would change and hence change the total image angle, and therefore, require adjustment of curvature of the mirror to achieve the same object angle relationship.

With regard to specific definitions which are necessary to more fully understand the present invention, attention is directed to FIGS. 3 and 4. FIG. 3 diagrammatically illustrates mirrored surface 24 in horizontal cross-section as it is located relative to plane P3 and observation point OP. This latter figure specifically illustrates a number of object angles Θ_1, Θ_2, and so on through Θ_n and a number of image angles α_1, α_2, and so on through αn. Any of the object angles may be defined as that angle subtended by plane P3 and a line extending from the object point being viewed to the particular point on mirrored surface 24 at which the image appears from observation point OP (in the counter-clockwise direction). On the other hand, the image angle can be defined as that angle subtended by a straight line between the image on the mirrored surface and the observation point OP and plane P3 (in the clockwise direction). As illustrated in FIG. 3, each object angle Θ_1, Θ_2, and so on includes its own associated image angle, α_1, α_2, and so on. It should be apparent that each object angle and associated image angle represent a particular position of a given point on vehicle 12 relative to the mirrored surface and observation point OP in vehicle 10. The horizontal "magnification ratio" (M) at any given section along the mirrored surface is $\Delta IA/\Delta OA$ along that section, i.e., the change in image angle over change in object angle.

Referring to FIG. 4, there are other positional relationships which must be defined. As seen in this latter figure, the particular object angle line and its associated image angle line are shown impinging on a curved segment of mirrored surface 24 at a particular point. A tangent T to the curved surface can be drawn at that point along with a line n normal to the tangent line. In this way, it can be seen that the object angle line and the tangent define an incident angle "i" and the image angle line and the tangent define an equal reflection angle "r".

Based on the foregoing positional relationships and definitions, it will become apparent that a mirrored surface can be designed which meets certain criteria. It will also be seen that the mirrored surface of the present invention is specifically designed to include the various features discussed previously. However, it should be equally apparent from the discussion to follow that a mirrored surface which includes these various features can be readily provided even if the positional relationships described should be different, of course, assuming these relationships are known ahead of time. Moreover, this is true whether the surface being designed is to have a specific horizontal curvature, a specific vertical curvature or both.

As stated above, based on the positional relationship between vehicles 10 and 12 and mirrored surface 24, each of the object angles Θ_1, and Θ_2 and so on represent the actual position of trailing vehicle 12 in lane 18 relative to vehicle 10. Object angle Θ_1 represents the closest position at which the entire vehicle 12 can be viewed by mirrored surface 24 from observation point OP. Note that the outermost part of the front of the vehicle position seen in FIG. 6 is observed at the extreme outer edge of the mirrored surface. Angle Θ_n on the other hand represents the rearwardmost limit of view provided by mirrored surface 24 from observation point OP which, as noted, is at the nearest edge of the mirrored surface. The various object angles between these extremes obviously represent the positions of the vehicle 12 therebetween. This is best seen in FIG. 5 which shows objects angles as a function of distance for three different points on vehicle 12 as indicated on the figure. As stated above, each object angle has an associated image angle. Hence, image angle α_1 which is seen at an extreme far edge of the mirrored surface represents the closest position of vehicle 12 while α_n which is seen at the closest edge of the mirrored surface represents the rearwardmost point of view. As seen in FIG. 6, the entire horizontal extent of mirrored surface 24 in the embodiment illustrated includes a 10° image angle span.

Referring to FIGS. 7*a* and *b*, the general way in which the image angle α varies with the position of vehicle 12 relative to mirrored surface 24 (based on the positional relationship described above) is graphically illustrated for two embodiments, specifically for a mirror assembly "B" (FIG. 7*a*) and an assembly "C" (FIG. 7*b*). While the horizontal extent of mirrored surface **24** spans 10° from an image angle standpoint, as just stated, the horizontal axis represented in FIGS. 7*a* and *b* includes only 8° of the mirrored surface. More specifically, while the maximum extent of the viewing image on mirrored surface **24** may be separated into 10° as seen in FIG. **6**, only 8° are required for the graphic illustrations of FIGS. 7*a* and *b*. The vertical axis represents distance between mirrored surface **24** and the front end of vehicle **12**. Lines **L1** and **L2** represent the way in which the image of the front left and the rear right, respectively, of vehicle **12** (the driver's side and passenger side, respectively) move across the mirrored surface from right to left as the vehicle moves closer to vehicle **10**. Referring to FIGS. **8***a* and *b*, in conjunction with FIGS. 7*a* and *b*, in accordance with the present invention, mirrored surface **24** while preferably being an integral surface can be functionally separated into at least two segments **24***a* and **24***b*. In this embodiment, both of these segments are preferably planar in any vertical plane therethrough, thereby eliminating vertical distortion of the image shape (as opposed to distortion in speed and movement). Moreover, segment **24***b* is preferably planar or substantially planar in any horizontal plane therethrough, particularly as this segment extends further from section **24***a*. Thus, section **24***b* which comprises the near horizontal side of the mirrored surface provides substantially or entirely undistorted rearward viewing of shapes at far distances, specifically at positions between object angles Θ_4 and Θ_n in FIG. **3**. In a preferred embodiment, surface section **24***b* comprises approximately 36% of the overall mirror. This section is particularly designed so that the maximum rearward viewing angle Θ_n is greater than 90°, specifically between 91° and 93° and preferably 92° as illustrated in FIG. **6**. In this way, the backside of vehicle **10** can be viewed. Before proceeding with the detailed description of the invention it will be helpful to examine the geometric relationship of an approaching vehicle to the driver's observation of this in a rear view mirror. This was done graphically up to distances of about 100 feet and mathematically thereafter up to 500 feet rearwards of the driver's mirror. The approaching vehicle was a small vehicle 6 feet wide and 12 feet long with its forward left corner being used as one reference angle, called object angle (OA) and this point is 9 feet to left of driver's mirror. Another reference angle is for front left corner 12 feet to left of driver's mirror. A third is the rear right corner 3 feet to left and 12 feet back. FIG. **5** shows how the object angle (OA) follows curves rapidly changing in slope up to a distance back of between 50 and 150 feet. This rapid change in slope is the cause of the "jumping out" effect previously mentioned. Note from FIGS. **9***a* and **9***b* how a planar mirror would have to be approximately 50 inches wide to include the "jumping out" part of the image and the practical impossibility of this is what causes the blind spot or zone near the driver's vehicle. Also note in FIGS. **9***a* and **9***b* how the prior art method of fixed magnification ratio, designed in this case to provide the same angular range of object angle, while solving the blind zone problem, would have the "jumping out" problem.

In a preferred embodiment of this invention designated as Mirror B in FIG. **9***b*, a smooth transition is obtained from planar to curved mirror surface starting at about 300 feet back.

Thus it may be seen that the method taught is to provide controlled curvature and magnification ratio (M value) so as to offset the geometric "jumping out" effect caused by the rapid increase in object angle (OA) as the passing vehicle approaches the driver's mirror. One could say that a special curvature is created so as to balance or offset the increase in OA. In the prior art methods, on the other hand, the constant M naturally leads to the "jumping out" effect which results from rapid change in OA as the pursuing vehicle approaches. In the prior art method using a constant M value means that the curve for image angle (IA) merely parallels the planar curve, at a scale reduced so as to eliminate the need for a mirror 50 inches wide.

FIG. **9***b* offers two additional embodiments, specifically Mirror A and C. Mirror A has no planar part while Mirror C is 54% planar. Both Mirrors A and B have the linear relationship up to about 35 feet rearwards. Mirror C has the linear relationship up to about 150 feet rearwards.

Where section **24***b* is planar, its M at any point along its length (horizontally) is constant, specifically equal to one. This of course is the reason this section provides undistorted viewing of shapes. However, as stated previously, a constant M, even one equal to unity as in a planar mirror, results in excessive image distortion or exaggeration with respect to speed and movement generally of the object being viewed, especially at close range. Therefore, section **24***a* which is provided for close range viewing has a continuously decreasing M, as will be seen, to reduce and preferably eliminate this type of distortion. Mirrored surface **24***a* which, as stated, is responsible for viewing vehicle **12** at close range, specifically as it approaches vehicle **10** (between about object angle Θ_1 and Θ_4), is curved in the horizontal plane. However, as also stated, this latter mirrored section is not curved in just any way but rather in accordance with decreasing Ms (from right to left in FIGS. 7*a* and *b*) so as to define the linear relationship between the position of the second vehicle when the latter is within a predetermined range of the first vehicle and the horizontal position of the image on surface segment **24***a*, as described previously. This is best illustrated in FIGS. 7*a* and *b* by means of the straight line section L1′ of line **L1**. Note that as the object point on vehicle **12** represented by line L1′ moves toward vehicle **10** (down the vertical axis) its image moves linearly across surface segment **24***a* (along the horizontal axis). Also note that this is the only segment of either line (in both figures) which does this. In other words, until the object point being viewed moves into the view of the right position of surface segment **24***a*, represented by L1′ in FIGS. 7*a* and *b*, its position/image relationship is not a linear or straight-line relationship. It should be apparent that because of this linear relationship as the object actually moves, its velocity and the velocity of its image are linearly proportionate. Hence, the driver of vehicle **10** can readily judge the speed and position of the passing vehicle as the latter comes within the view offered by the right portion of segment **24***a*.

It should be apparent from FIGS. 7*a* and *b* that the straight-line relationship illustrated has a fixed slope which is dependent upon the amount of mirrored surface **24** that is linear for a given length of actual movement of trailing vehicle **12**, for example the last 30 feet. Where the slope is at 15°, for example, the image in section 24*a* moves horizontally at a particular speed that is proportional to the speed of the approaching vehicle. On the other hand, where the slope is greater than 15° for the same distance (e.g. 150 feet), the image moves slower while for slopes less than 15°, the image moves faster. However, in each of these cases image movement is always linearly proportionate to movement of the approaching vehicle. Hence, if the latter moves at a constant speed, image speed will be constant. If the approaching vehicle accelerates or decelerates, the image movement will accelerate or decelerate proportionately. This allows the driver to use section 24*a* not only for observing the approaching vehicle but also as a tool for gauging its speed and position as it approaches.

It should also be apparent from FIGS. 7*a* and *b* in conjunction with FIGS. 3 and 8*a* and *b* that the entire mirrored surface 24 is comprised of curved section 24*a* and planar or nearly planar section 24*b*. In this regard, it is to be understood, as stated previously, that the present invention is not limited to this straight-line relationship (although it is preferred) but rather one which is closer to this type of relationship than is obtained when the M of the curve is constant. In any event, this results in decreased M's at successive points along the horizontal extent of the curved surface.

As stated above, mirrored surface 24 is designed with specific parameters in mind, as dictated by the aforedescribed positional relationships including the particular size of the mirrored surface recited. First, angle Θ_1 is approximately 17.5°, as stated. This would just include the left front point of vehicle 12 when the latter is 3 feet behind plane P3 (9 feet from the mirrored surface), clearly eliminating the aforedescribed blind spot. Angle Θ_n is approximately 92°, thereby allowing the mirror mounted side of vehicle 10 to be readily viewed. In this regard, if the mirror is sufficiently long vertically, it can provide a view of the rear tires on this same side which is of particular advantage to the driver of a tractor-trailer, recreational vehicle or other such large vehicle. However, in the specific embodiment described above, the length of mirrored surface 24 is approximately 10", which is not sufficient to provide this particular view, unless the tires are about 30' back or unless the mirrored surface is also vertically curved, as will be discussed hereinafter. Object angle Θ_4 separates the mirrored surface into the segments 24*a* and 24*b*.

In view of the foregoing, it should be readily apparent that mirrored surface 24 can be designed to provide the various parameters recited by means of reverse engineering, that is, by starting with the desired object angles and associated image angles based on mirror dimensions, positional relationships and the definitions discussed previously. The graphic illustration of FIGS. 7*a* and *b* as well as one for object angles (relative to distance) as illustrated in FIG. 5 is helpful to this end. In this regard, attention is specifically directed to FIGS. 8*a* and *b* which illustrate two actual mirrored surfaces 24 one of which is constructed in accordance with the preferred embodiment including the various features discussed above. Also, for purposes of comparison, FIGS. 9*a* and 9*b* illustrate the image angle versus distance for a mirrored surface which is constructed in accordance with a constant M (such as the prior art) but which has the same dimensions and positional relationship as surface 24, as described previously. This prior art type of surface has been specifically designed to have a magnification ratio of about 1/7.45 throughout its horizontal extent whereas this ratio is continuously changing along segment 24*a* of surface 24.

With respect to FIGS. 7*a* and *b*, it is worthy to note first that the lines L1 and L2 represent the horizontal bounds of the image in the mirrored surface constructed in accordance with the present invention. Moreover, it can be seen that line L1 includes a substantially straight section L1' which represents the linear relationship across at least a part of surface segment 24*a*. Note that in FIG. 7*a* this section extends from about 7° across the mirrored surface to the 10° mark which represents the outermost horizontal edge of the mirrored surface. From a distance standpoint, it also extends between about 3 feet and 30 feet back from previously described plane P3. Hence when a vehicle 12 moves through this range, its image is seen moving linearly across mirrored section 24*a*. A similar linear relationship is clearly absent in the prior art mirror as seen in FIGS. 9*a* and 9*b*. In fact, it can be seen that, as the trailing vehicle moves within the range of 3 to 50 feet from the leading vehicle, its image horizontally is clearly nonlinear. This image increases substantially with distance as it moves closer to the lead vehicle, enlarging in size at a rather high nonlinear rate. As a result, the driver of the lead vehicle may easily misjudge the position and speed of the passing vehicle.

As stated at the outset, one of the chief purposes of the present invention is to improve the drivers' ability to judge the position and speed of an approaching vehicle in the adjacent lane, especially when this vehicle is close to the driver's vehicle. It has been amply shown herein that this may be achieved by a mirror design which provides a linear relationship between the position of the approaching vehicle and the position of its image on the drivers' mirror. However, it has been found that another feature of the subject mirror that can easily be overlooked concerns the size of the image laterally, that is, from right to left, as this image moves across the mirror. Ideally, the size should increase in a continuous and predictable manner, preferably the image being at a maximum size just before the approaching vehicle reaches the unaided peripheral vision of the driver.

Referring again to FIG. 7*a* and FIG. 7*b*, as stated previously, L1 and L2 show the extreme edges of the image as the vehicle moves from 500 feet back to the closest position of 3 feet back. In these figures it may be observed, therefore, how the lateral size of the image varies as it moves across the mirror by simply noting the lengths of the horizontal lines terminating at L1 and L2 on these curves. In this regard note the considerable difference between FIG. 7*a* and FIG. 7*b*, the former which is for Mirror B appearing to come much closer to the above stated ideal condition, that is the size of the image increasing continuously as the distance decreases and reaching a maximum size at the closest position. Referring now to FIG. 7*c*, this is simply a presentation of data from FIG. 7*a* and 7*b* but it provides a more easily visible comparison of the image size relationship to distance. More specifically, FIG. 7*c* illustrates image width (horizontal axis) as taken from FIGS. 7*a* and 7*b* as a function of distance (vertical axis). Not only does Mirror B meet the above stated ideal condition but it has one further important advantage. In about the closest 50 feet, the size of the image increases at a faster but still linear rate across the mirror. This greater and linear rate of size increase corresponds in the close range of distance to the L1' part of the curve in FIG. 7*a*.

Mirror C on the other hand, as seen in FIG. 7*b*, has a steeper slope in L1 than that of FIG. 7*a*. In this same closest range of distance in which the size of image for B in FIG. 7*c* is rapidly and nearly linearly increasing, the size of image for C in FIG. 7*c* is rapidly and nearly linearly decreasing, reaching a size at 3 feet back about the same as that size for the same mirror found in FIG. 7*c* at 300 feet back.

The reason for the marked differences in image size—distance relationship between Mirror B and Mirror C lies in the difference in M values for the two mirrors and one indication of this is the considerable difference in slope of L1' between FIGS. 7*a* and 7*b*. Since M is equal to ΔIA/ΔOA, naturally a more gradual slope in L1' means a more gradual change in curvature of the mirror which in turn means a higher minimum M value at the mirror's outer-left-edge. Note in Tables I and II which follow that minimum M value for Mirror B is 1/60 whereas for Mirror C minimum M value is 1/183. Thus it is apparent that minimum M value should probably be greater than 1/100 and preferably greater than 1/70 or about 1/60.

Two other differences between Mirror B and Mirror C are (1) the length of L1' and (2) the percent of Mirror width that is planar. It appears that L1' should represent about 30 or 35 feet distance back and certainly less than 100 feet. Similarly, the percent of mirror that is planar should be about 30 to 40. This is because it is desirable for the mirror to offer a smooth and continuous transition from planar to maximum curvature as the image moves across the mirror.

The actual numerical values set forth in FIGS. 8*a* and *b* should be self-explanatory. For purposes of simplicity, the image angles of 43° to 33° have been converted to the 0° to 10° illustrated. The various calculations associated with FIGS. 7*a* and *b*, 8*a* and *b*, 9*a* and 9*b* for Mirrors B, C and A are set forth in Tables I, II and III below. Table IV offers complete data on object angles generally as used herein, which angles have either been discussed or will be. Table V presents complete data on object and image angles for mirrors B and C.

TABLE I

MIRROR B 36% PLANAR

Feet to Rear (9' out)	Degrees Object Angle (OA)	Degrees* Image Angle (IA)	Mag. Ratio ΔIA/ΔOA M	Degrees* Angle of Incidence Reflection	Degrees*** Tangent Angle
3	17.5	10.0	1/60	25.25	−7.75
5	29.5	9.8	1/44	31.35	−3.7
6.8	37.0	9.6	1/30	35.2	+1.8
8.7	43.0	9.4	1/25	38.3	+4.7
10.6	48.0	9.2	1/24	40.9	+7.1
12.5	52.8	9.0	1/20	43.4	+9.4
14.5	56.8	8.8	1/17	41.5	11.3
16.5	60.2	8.6	1/14	47.3	12.9
18.4	63.0	8.4	1/11.5	48.8	14.2
20.3	65.3	8.2	1/8.5	50.05	15.25
22.2	67.0	8.0	1/7.6	51.0	16.0
27.0	70.8	7.5	1/6.2	53.15	17.65

TABLE I-continued

MIRROR B 36% PLANAR

Feet to Rear (9' out)	Degrees Object Angle (OA)	Degrees* Image Angle (IA)	Mag. Ratio ΔIA/ΔOA M	Degrees* Angle of Incidence Reflection	Degrees*** Tangent Angle
31.5	73.9	7.0	1/5.6	54.95	18.95
39.6	76.7	6.5	1/4.6	56.6	20.1
46.5	79.0	6.0	1/5.6	58.0	21.0
63.0	81.8	5.5	1/5.4	59.65	22.15
96.0	84.5	5.0	1/4.4	61.25	23.25
139	86.3	4.5	1/2.6	62.4	23.9
215	87.6	4.0	1/1.8	63.3	24.3
344	88.5	3.5	1	64.0	24.5
516	89.0	3.0	1	64.5	24.5
1031	89.5	2.5	1	65.0	24.5
00	90.0	2.0		65.5	24.5

*Numbers 1 to 10 used for simplification
Actually 10.0 = 33.0 and 2.0 = 41.0

**Angle of Incidence and Reflection = $\frac{OA + IA}{2}$

***Tangent Angle = OA − Angle of Incidence and Reflection

TABLE II

MIRROR C 54% PLANAR

Feet to Rear (9' out)	Degrees Object Angle (OA)	Degrees Image Angle (IA)	Mag. Ratio ΔIA/ΔOA M	Degrees* Angle of Incidence Reflection	Degrees Tangent Angle	(ΔT)
3	18.0	10.0	1/183	25.5	−7.5	5.47
5	29.0	9.94	1/131	31.03	−2.03	5.21
7.5	39.5	9.86	1/106	36.32	+3.18	4.21
10.0	48.0	9.78	1/100	40.61	+7.39	2.97
12.5	54.0	9.71	1/55	43.64	+10.36	2.45
15.0	59.0	9.62	1/50	46.19	+12.81	1.72
17.5	62.5	9.55	1/37.5	47.97	+14.53	1.46
20.0	65.5	9.47	1/26	49.51	+15.99	1.91
25.0	69.4	9.32	1/22.5	51.54	+17.86	1.72
30.0	73.0	9.16	1/16	53.42	+19.58	1.13
35.0	75.4	9.01	1/12	54.69	+20.71	.87
40.0	77.3	8.85	1/9.3	55.72	+21.58	.62
45.0	78.7	8.70	1/6.25	56.5	+22.20	.40
50.0	79.7	8.54	1/5.67	57.08	+22.62	.70
60.0	81.4	8.24	1/3.96	58.08	+23.32	.71
75.0	83.3	7.76	1/1.83	59.27	+24.03	.35
100.0	84.84	6.92	1/1.43	60.46	+24.38	.16
125.0	85.87	6.20		61.33	+24.44	.04
150.0	86.56	5.44		62.06	+24.50	
200.0	87.42	4.58	1	62.92	+24.50	0
300.0	88.28	3.72	1	63.78	+24.50	0

TABLE II-continued

MIRROR C 54% PLANAR

Feet to Rear (9' out)	Degrees Object Angle (OA)	Degrees Image Angle (IA)	Mag. Ratio ΔIA/ΔOA M	Degrees* Angle of Incidence Reflection	Degrees Tangent Angle	(ΔT)
400.0	88.71	3.29	1	64.21	+24.50	0
500.0	88.97	3.03	1	64.47	+24.50	0
			1			0

*Actually 10.0 = 33.0 and 2.0 = 41.0

**Angle of Incidence and reflection = $\frac{OA + IA}{2}$

***Tangent Angle = OA − Angle of Incidence and Reflection.

TABLE III

MIRROR A 0% PLANAR

Degrees Feet to Rear (9' out)	Degrees Object Angle (OA)	Ratio Image Angle (IA)	Mag.* Degrees ΔIA/ΔOA M	Angle of Incidence Reflection	Degrees Tangent Angle
3	17.5	10.0		25.25	−7.75
			1/57.5		
5	29.0	9.8		31.1	−2.1
			1/31.9		
10	47.5	9.22		40.6	+6.9
			1/22.1		
15	59.0	8.7		46.6	+12.4
			1/13		
20	65.5	8.2		50.1	+15.4
			1/7.8		
25	69.4	7.7		52.3	+17.1
			1/6.8		
30	73.0	7.17		54.4	+18.6
			1/6		
35	75.4	6.77		55.8	+19.6
			1/5.1		
40	77.3	6.4		56.9	+20.4
			1/6.4		
45	78.7	6.18		57.8	+20.9
			1/3.6		
50	79.7	5.9		58.4	+21.3
			1/4.25		
60	81.4	5.5		59.4	+22.0
			1/3.8		
75	83.3	5.0		60.6	+22.7
			1/3.1		
100	84.84	4.5		61.7	+23.1
			1/2.6		

TABLE III-continued

MIRROR A 0% PLANAR

Degrees Feet to Rear (9' out)	Degrees Object Angle (OA)	Ratio Image Angle (IA)	Mag.* Degrees ΔIA/ΔOA M	Angle of Incidence Reflection	Degrees Tangent Angle
200	87.4	3.48		63.5	+23.9
			1/1.8		
300	88.28	3.0		64.1	+24.2
			1/2.1		
400	88.71	2.8		64.4	+24.3
			1/2.6		
500	88.97	2.7		64.6	+24.4

*See footnotes for Tables I and II

TABLE IV

OBJECT ANGLES OF APPROACHING VEHICLE
(Based on Mini-car 12 ft. long, 6 ft. wide and 5 ft. high)

Distance of Vehicle Front Behind Driver Mirror (Feet)	Horizontal Angles*: 3 Feet Out and 12 Feet Back (Deg)	Horizontal Angles*: 9 Feet Out (Deg)	Horizontal Angles*: 12 Feet Out (Deg)	Vertical Angles**: 2 Feet Down (Deg)	Vertical Angles**: 4.5 Feet Down (Deg)	Vertical Angles**: 7 Feet Down (Deg)
3	78.5	17.5	14.0	33.5	56.0	67.0
5	79.75	29.0	22.5	22.0	42.0	54.5
7.5	81	39.5	31.5	15.0	31.0	43.0
10	82	48.0	40.0	11.5	23.0	35.0
15	83.5	59.0	51.5	7.64	17.0	25.0
20	84.75	65.5	59.0	5.73	12.5	19.5
25	85.6	69.4	64.0	4.58	10.3	15.5
30	86.05	73.0	68.0	3.82	8.5	13.2
35	86.4	75.4	71.0	3.27	7.3	11.4
40	86.95	77.3	73.0	2.86	6.5	10.0
45	87.03	78.7	75.0	2.55	5.7	8.9
50	87.3	79.7	76.5	2.29	5.2	7.9
75	88.0	83.3	80.8	1.53	3.44	5.35
100	88.47	84.84	83.12	1.15	2.57	4.01
125	88.74	85.87	84.5	0.92	2.06	3.21
150	88.94	86.56	85.4	0.76	1.72	2.67
200	89.19	87.42	86.57	0.57	1.29	2.01
300	89.45	88.28	87.71	0.38	0.86	1.34
400	89.58	88.71	88.28	0.29	0.64	1.00
500	89.66	88.97	88.63	0.23	0.52	0.80

*Angle to line normal to vehicles motion
**Angle to horizontal line

TABLE V

OBJECT AND IMAGE ANGLES FOR MIRRORS B AND C

Distance of Vehicle Front Behind Driver's Mirror (Feet)	MIRROR B 9 Ft. Out OA	MIRROR B 9 Ft. Out IA	MIRROR B 12 Ft. Back OA	MIRROR B 12 Ft. Back IA	MIRROR B ΔIA	MIRROR C 9 Ft. Out OA	MIRROR C 9 Ft. Out IA	MIRROR C 12 Ft. Back OA	MIRROR C 12 Ft. Back IA	MIRROR C ΔIA
3	17.5	10.0	78.5	6.13	3.87	17.5	10.0	78.5	8.72	1.28
5	29.0	9.8	79.75	5.9	3.9	29.0	9.94	79.75	8.54	1.40
7.5	39.5	9.53	81.0	5.65	3.88	39.5	9.86	81.0	8.32	1.54
10	48.0	9.25	82.0	5.47	3.78	48.0	9.78	82.0	8.12	1.66
15	59.0	8.73	83.5	5.25	3.48	59.0	9.62	83.5	7.65	1.97
20	65.5	8.2	84.75	4.95	3.25	65.5	9.47	84.75	7.01	2.47
25	69.4	7.67	85.6	4.71	2.96	69.4	9.32	85.6	6.47	2.85
30	73.0	7.15	86.05	4.57	2.58	73.0	9.16	86.05	6.09	3.07
35	75.4	6.75	86.4	4.49	2.26	75.4	9.01	86.4	5.75	3.26
40	77.3	6.4	86.95	4.27	2.13	77.3	8.85	86.95	5.10	3.75
45	78.7	6.08	87.03	4.2	1.88	78.7	8.70	87.03	4.95	3.75
50	79.7	5.9	87.3	4.1	1.8	79.7	8.54	87.3	4.75	3.79
75	83.3	5.3	88.0	3.77	1.53	83.3	7.76	88.0	4.0	3.76
100	84.84	4.95	88.47	3.5	1.45	84.84	6.92	88.47	3.53	3.39
125	85.87	4.7	88.74	3.3	1.4	85.87	6.20	88.74	3.26	2.94
150	86.56	4.47	88.94	3.05	1.42	86.56	5.44	88.94	3.06	2.38
200	87.42	4.1	89.19	2.81	1.29	87.42	4.58	89.19	2.81	1.77
300	88.28	3.67	89.45	2.55	1.12	88.28	3.72	89.45	2.55	1.22
400	88.71	3.29	89.58	2.42	0.87	88.71	3.29	89.58	2.42	0.87

TABLE V-continued

OBJECT AND IMAGE ANGLES FOR MIRRORS B AND C										
Distance of Vehicle Front	MIRROR B					MIRROR C				
Behind Driver's	9 Ft. Out		12 Ft. Back			9 Ft. Out		12 Ft. Back		
Mirror (Feet)	OA	IA	OA	IA	ΔIA	OA	IA	OA	IA	ΔIA
500	88.97	3.03	89.66	2.34	0.67	88.97	3.03	89.66	2.34	0.69

Note that Table I shows the data developed for the trailing vehicle which is 12 feet long and 6 feet wide and which is 3 feet to one side of the mirror (embodiment B). The specific point on this vehicle measured is at the left front fender which is actually 9' from the mirror (the 3' spacing plus the 6' width of the vehicle). There are 6 columns in Table I. The first column sets forth the various positions of the trailing vehicle in feet, the second and third columns set forth the object and image angles at these positions, the image angle being converted to a 0° to 10° span. The fourth column shows its magnification ratio. The fifth column illustrates the angle of incidence "i" and angle of reflection "r" shown in FIG. **4**. The next adjacent column lists the tangent angles of the tangent lines illustrated in FIG. **4**, specifically that angle T formed between the tangent and plane **P3** in FIG. **4**.

Tables II and III give similar information for a second and third embodiment which are illustrated in FIGS. **9***a* and **9***b* as Mirror A and Mirror C.

Having described the overall mirror assembly and specific embodiments thereof, it is to be understood that these assemblies can vary in size and position relative to an observation point or to the object being viewed and yet can be readily designed to include the various features recited above, based on the teachings herein. For example, the assembly could be located on the opposite side of vehicle **10**, as stated. The mirrored surface can be larger than the surface described previously and segments **24***a* and **24***b* can vary in size relative to one another. These are of course only examples of the changes which can be provided so long as these changes are compatible with the features of the present invention described previously.

The foregoing has been a description of a rear view mirror assembly including a mirrored surface, specifically surface **24**, which is planar in vertical section. While the mirror described provides a view directly behind the vehicle supporting the assembly unless it is very large vertically and/or relatively close to the ground, it does not provide view of the driver's rear-view tires (on the mirror mounted side). More important, when the assembly is utilized in a conventional position on a relatively large vehicle, as stated, it does not provide a view of smaller vehicles as the latter pass, as will be best seen in FIG. **12**. In order to overcome these problems, a rear view mirror assembly generally designated by the reference numeral **20'** in FIG. **10** may be provided. This assembly includes a mirror surface **24'** which may be identical to previously described surface **24** in horizontal section and hence may be divided into two segments **24***a'* and **24***b'*. The segment **24***a'* corresponds to the horizontally curved segment **24***a* and segment **24***b'* corresponds to the planar segment **24***b*. However, as illustrated best in FIG. **11** in conjunction with FIG. **10**, mirrored surface **24'** is not entirely planar in vertical section but is slightly curved along a bottom edge portion **30** and may also be curved along a top edge portion **32**. Each vertical curve may extend along the entire length of each edge section or only along portions thereof depending upon the field of view desired. As will be seen from the graphic illustrations and tables to follow, these curves provide the same type of linear relationship discussed with respect to the horizontal curvatures.

Turning specifically to FIG. **12**, mirror **20'** is shown mounted to a typical large truck **34** at a point 7 feet above the ground and, while no shown, it is mounted 34 inches from the driver's eye (the observation point). In the embodiment illustrated, the mirror is 16 inches high from its bottom edge to its top edge. It has been found that if this assembly were entirely planar vertically it would provide the vertical field of view indicated by the dotted field of view lines **V1** and **V2**. Note that each of these field of view lines extends at an angle of approximately 13° with the horizontal. Also note that it does not include any part of a compact vehicle generally indicated by the box (dotted) at **36** when the latter is located in the position shown, that is, to one side of the mirrored assembly and 3 feet back therefrom. In addition, if the back of the truck is higher than that shown, for example, 10.5 feet from the ground, as illustrated by dotted lines, the front edge would not be seen at all. However, assembly **20'** is not planar vertically in its entirety, but rather includes previously recited curve section **30** and **32**. Vertically curved section **30** increases the field of view downward to 67° from the horizontal (as compared to 13°) as seen by view line **V1'** and it also increases the field of view upwards to 42°, from the horizontal (as compared to 13°) as seen by view line **V2'**. Thus, it can be seen from FIG. **12** that an object **5'** high such as the front of vehicle **36** begins disappearing from the driver's view in a planar mirror (at ground level) at a distance of 30 feet back from the assembly. From 30 feet to 9 feet back the view becomes more and more limited until at 9 feet, the smaller vehicle leaves the view entirely. However, utilizing mirrored surface **24'**, the rear view mirror assembly will continue to show a full frontal view of the smaller vehicle until its front edge is 3 feet back from the mirror assembly and even the smaller vehicle passes this point, much of its body will still be in view. Note also that the rear tires (on the same side of the assembly) can now be seen where they could not with the planar mirror, of course unless the tires were more than 30 feet back from the mirror assembly. It should also be noted that mirrored surface **24'** can readily show the top of vehicle **24** at a point 3 feet back up to a height of 10.5 feet. This view is often very important to the driver of a high vehicle that is passing under a low object such as a wire, branch, a tunnel or a bridge member.

The assembly just described was designed to give a straight-line relationship between the distance back of the . ailing vehicle and vertical position of its image. To more fully appreciate this, FIGS. **13** and **14** are graphic illustrations of object angle (VOA) and image angle (VIA), respectively, as a function of distance for half of mirrored surface **24'** including bottom curve **30** and are based on Table VI below. The lower half of an actual vertical section of this part of the mirror is shown in FIG. 15. The centerline is horizontally aligned with the driver eye (observation point).

TABLE VI

MIRROR 20' 51.5% PLANAR VERTICALLY

Feet to Rear (9' out)	Degrees Object Angle (OA)	Degrees Image Angle (IA)	Mag. Ratio $\frac{\Delta IA}{\Delta OA}$ M	Degrees Angle of Incidence Reflection	Degrees** Tangent Angle	(ΔT)
3	67.0	13.0		40.0	27.0	
			1/125			6.2
5	54.5	12.9		33.7	20.8	
			1/27			4.1
7	45.0	12.55		28.8	16.7	
			1/29			5.3
10	35.0	12.2		23.6	11.4	
			1/18			3.7
15	25.0	11.65		18.3	6.7	
			1/14			1.6
18	21.5	11.4		16.4	5.1	
			1/7			2.2
23.3	16.5	10.72		13.6	2.9	
			1/4.8			1.2
29.2	13.5	10.05		11.8	1.7	
			1/3.3			0.8
36	11.0	9.28		10.1	0.9	
			1/2.3			0.3
40	10.0	8.8		9.4	0.6	
			1/1.9			0.2
45	9.0	8.27		8.6	0.4	
			1/2.3			0.4
50	7.7	7.7		7.7	0	
			1			0
60	6.5	6.5		6.5	0	
			1			0
70	5.7	5.7		5.7	0	
			1			0
80	5.0	5.0		5.0	0	
			1			0
90	4.45	4.45		4.45	0	
			1			0
100	4.0	4.0		4.0	0	
			1			0
125	3.2	3.2		3.2	0	
			1			0
150	2.7	2.7		2.7	0	
			1			0
200	2.0	2.0		2.0	0	
			1			0
300	1.3	1.3		1.3	0	
			1			0
400	1.0	1.0		1.0	0	
			1			0
500	0.8	0.8		0.8	0	

*Angle of Incidence & Reflection $= \frac{VOA + VIA}{2}$

**Tangent Angle = VOA − Angle of Incidence & Reflection

It should be noted that approximately 50% (actually 51.1%) of the vertical section illustrated is planar and that the curved section provided the straight-line relationship discussed above but only for a certain distance back. This is best illustrated in FIG. 14, where this straight-line relationship is represented by the segment L3' comprising part of the curve L3. Curve L3 represents the vertical image angle as a function of distance at a point on the approaching vehicle 7 feet down, that is, at the bottom of the approaching vehicle and the second curve L4 provides the same graphic illustration at the top of the approaching vehicle, that is, at a point 2 feet down from the assembly. Note that at a distance back of about 50 feet or less, curve segment 30 offers an image of the bottom extremities which follows a straight line down to 3 feet back.

It is to be understood that the particular mirror 20' (as well as 20) are provided for exemplary purposes only

and not to limit the invention. The mirrored surfaces of the present invention are ones which can be provided with the horizontal curvature discussed previously in conjunction with the vertical curvature at its bottom edge and it may or may not include a vertical curvature at its top edge or, as discussed initially, the mirrored surface may not be curved at all vertically. In this regard it should be apparent from the respective discussion of horizontal and of vertical image relationships, that in a mirror which is to "see" up and down as well as sideways at near objects, that there will be portions of such a mirror, that is towards the outer corners, where curvature will be required both vertically and horizontally. This will mean that lower right and/or upper left portions of such a mirror will be rounded in such a way that a given point on the mirror will reflect an image to the O.P. that enables observation corresponding to both types of curvature discussed herein.

In view of the foregoing it should be apparent that the mirrored surfaces previously described can consist of a single planar surface section (horizontally and/or vertically) and a single curved section (horizontally and/or vertically) which meets the afore described linear relationship. However, as also described previously, a third curved section (horizontally and/or vertically) can be provided intermediate the first two sections. This intermediate section would provide a smooth transition between the first two sections and accordingly would not necessarily follow the linear relationships described previously or any other linear relationship.

What is claimed is:

1. A rear view mirror assembly, comprising:

(a) a mounting structure adapted for connection to one side of a first vehicle in a fixed position relative to a predetermined observation point within the vehicle;

(b) a mirrored surface supported by said mounting structure for viewing a second vehicle from said observation point when said first vehicle is in a given lane, said second vehicle being in a next adjacent lane along a substantially straight path behind said mirrored surface; and

(c) said mirrored surface including a segment which is curved in any horizontal plane therethrough, the horizontal curvature of said segment defining cooperating object and image angles associated with each point along its horizontal extent with respect to said observation point, said angles being selected so as to result in a predesigned continuous decrease in the magnification ratio of and along the entire extent of said curvature in the direction away from said observation point, said predesigned decrease in magnification ratio defining a linear relationship between

(i) the horizontal position of the image on the mirrored surface segment of a particular point on a forward portion of said second vehicle as viewed from said observation point when said second vehicle is located along said path within a predetermined range of distances from said mirrored surface segment, and

(ii) the distance back from said mirrored surface of said second vehicle along said path, whereby said image point moves horizontally across said surface segment at a speed substantially linearly proportionate to the speed of said second vehicle relative to said first vehicle as said second vehicle moves along said path within said range.

2. An assembly according to claim 1 wherein said predesigned decrease in magnification ratio causes the horizontal image width of said second vehicle on said segment as viewed from said observation point to increase in size horizontally as the distance back of said second vehicle from said mirrored surface decreases to about 10 feet, said increase in horizontal image width being approximately linearly related to distance from the mirror of said second vehicle when said second vehicle is within said predetermined range.

3. An assembly according to claim 1 wherein said predetermined range is from about 50 feet from said mirrored surface to about 10 feet.

4. An assembly according to claim 1 wherein said range of distances is from about 30 feet from said surface segment to about 3 feet.

5. An assembly according to claim 1 wherein said mirrored surface segment is substantially straight in any vertical plane therethrough.

6. An assembly according to claim 1 wherein said mirrored surface includes a second segment horizontally to one side of said first-mentioned curved segment, said second segment being substantially straight in any horizontal plane therethrough.

7. An assembly according to claim 1 wherein said mirrored surface includes at least one horizontally extending segment including a bottom edge portion which is curved in any vertical plane therethrough so that at least a portion of said last-mentioned segment defines a substantially linear relationship between the position of said particular point on said second vehicle when the latter is located along said path within a predetermined range of distances from the mirrored surface segment, and the vertical position of the image of said point on said edge portion as viewed from said observation point; whereby said image moves vertically across said edge portion at a speed substantially linearly proportionate to the speed of said second vehicle relative to said first vehicle as said second vehicle moves along said last-mentioned path within said range.

8. An assembly according to claim 2 wherein said mirrored surface includes a horizontally extending section having a top portion including a segment which is curved in any vertical plane therethrough for providing a view of an obstruction which is about three feet back of said mirror and about 10.5 feet above the ground.

9. An assembly according to claim 1 wherein said magnification ratio decreases from a value of 1 to a lowermost value not less than about 1/100.

10. An assembly according to claim 9 wherein said lowermost value is not less than about 1/60.

11. An assembly according to claim 1 wherein said mirrored surface includes a horizontally extending section having a bottom edge portion which is curved in the vertical plane therethrough for viewing said second vehicle along a section of said path within a predetermined range of distance from said bottom edge portion, and having a magnification ratio which continuously decreases from the upper horizontal side of the bottom edge portion to the lower horizontal side thereof.

12. An assembly according to claim 6 wherein said mirrored surface includes a third segment located horizontally intermediate said first and second segments, said third segment being curved but not having said predesigned decrease in magnification ratio, said third segment providing an intermediate smooth transition between said first and second segments.

13. An assembly according to claim 12 wherein said mirrored surface consists essentially of said firstmentioned curved segment, said second straight segment, and said third intermediate segment the horizontal extent of said straight segment comprising approximately 36% of the entire horizontal extent of said mirrored surface.

14. An assembly according to claim 12 wherein said second straight mirrored segment is located between said curved segments and said first vehicle when said mounting structure is in said fixed position, said segments together providing a rearward view which, in a horizontal plane through said segments, extends from said mirrored surface to a forwardmost point at an angle of about 15°–20° rearward of a line normal to said path and through said mirrored surface and a rearwardmost point about 92°–95° from said normal line.

15. An assembly according to claim 14 wherein said forwardmost point is between about 17.5° rearwardly of said line and said rearwardmost point is about 92° therefrom.

16. An assembly according to claim 14 wherein said mirrored surface has a horizontal extent of about 5 to 8 inches.

17. An assembly according to claim 16 wherein said horizontal extent is about 7 inches.

18. A rear view mirror assembly, comprising:

(a) a mounting structure adapted for connection to one side of a first vehicle in a fixed position relative to a predetermined observation point within the vehicle;

(b) a mirrored surface supported by said mounting structure for viewing a second vehicle from said observation point when said first vehicle is in a given lane, said second vehicle being in a next adjacent lane along a substantially straight path behind said mirrored surface; and

(c) said mirrored surface including a segment which is curved in any horizontal plane therethrough, the horizontal curvature of said segment defining cooperating object and image angles associated with each point along its horizontal extent with respect to said observation point, said angles being selected so as to result in a predesigned continuous decrease in the magnification ratio of and along the entire extent of said curvature in the direction away from said observation point, said predesigned decrease in magnification ratio

(i) causing the horizontal image width of said second vehicle on said segment as viewed from said observation point to increase in size horizontally as the distance back of said second vehicle from said mirrored surface decreases to about 10 feet, and

(ii) defining a linear relationship between the horizontal position of the image on said curved mirrored surface segment of a particular point on a forward portion of said second vehicle as viewed from said observation point when said second vehicle is located along said path within a predetermined range of distance from said mirrored surface segment, and the distance back from said mirrored surface of said second vehicle along said path, whereby said image point moves horizontally across said surface segment at a speed substantially linearly proportionate to the speed of said second vehicle relative to said first vehicle as said second vehicle moves along said path within said range.

19. An assembly according to claim 18 wherein said mirrored surface includes at least one horizontally extending segment including a bottom edge portion which is curved in any vertical plane therethrough.

20. An assembly according to claim 18 wherein said mirrored surface consists essentially of said first and second segments and wherein said first planar segment comprises at least about 20% of the total horizontal extent of said mirrored surface.

21. An assembly according to claim 18 wherein the image of the outermost point on the front end of said second vehicle is fully visible on said mirrored surface from said observation point when said outermost point is a distance 12 feet laterally of said mirrored surface and five feet back therefrom.

22. An assembly according to claim 20 wherein said curved segment comprises about 64% of the entire horizontal extent of said mirrored surface.

23. An assembly according to claim 20 wherein said first segment is planar in any vertical plane therethrough.

24. An assembly according to claim 21 wherein said last-named image is seen from the observation point at approximately the outer edge of the mirror when said outermost point is at said distance.

25. An assembly according to claim 18 wherein said mirrored surface includes a horizontally extending section having a bottom edge portion which is curved in the vertical plane therethrough for viewing said second vehicle along a section of said path within a predetermined range of distance from said bottom edge portion, and having a magnification ratio which continuously decreases from the upper horizontal side of the bottom edge portion to the lower horizontal side thereof.

26. An assembly according to claim 18 wherein said mirrored surface includes a horizontally extended section having a top portion including a segment which is curved in any vertical plane therethrough for providing a view of an obstruction which is about three feet back of said mirror and about 10.5 feet above the ground.

27. A rear view mirror assembly, comprising:

(a) a mounting structure adapted for connection to one side of a first vehicle in a fixed position relative to a predetermined observation point within the vehicle;

(b) a mirrored surface supported by said mounting structure for viewing a second vehicle from said observation point when said first vehicle is in a given lane, said second vehicle being in a next adjacent lane along a substantially straight path behind said mirrored surface; and

(c) said mirrored surface including a segment which is curved in any vertical plane therethrough, the vertical curvature of said segment defining cooperating object and image angles associated with each point along its horizontal extent with respect to said observation point, said angles being selected so as to result in a predesigned continuous decrease in the magnification ratio of and along the entire extent of said curvature in the direction away from said observation point, said predesigned decrease in magnification ratio

(i) causing vertical image width of said second vehicle on said segment as viewed from said observation point to increase in size vertically as the distance back of said second vehicle from said mirrored surface decreases to about 10 feet, and

(ii) defining a linear relationship between the vertical position of the image on said curved mirrored surface segment of a particular point on a forward portion of said second vehicle as viewed from said observation point when said second vehicle is located along said path within a predetermined range of distances from said mirrored surface segment, and the distance back from said mirrored surface of said second vehicle along said path, whereby said image point moves vertically across said surface segment at a speed substantially linearly proportionate to the speed of said second vehicle relative to said first vehicle as said second vehicle moves along said path within said range.

28. A rear view mirror assembly, comprising:

(a) a mounting structure adapted for connection to one side of a first vehicle in a fixed position relative to a predetermined observation point within the vehicle;

(b) a mirrored surface supported by said mounting structure for viewing a second vehicle from said observation point when said first vehicle is in a given lane, said second vehicle being in a next adjacent lane along a substantially straight path behind said mirrored surface; and

(c) said mirrored surface including a first segment which is planar in any horizontal plane therethrough and a second adjacent segment which is further from said observation point than said first segment and which is curved in any horizontal plane therethrough, the horizontal curvature of said second segment defining cooperating object and image angles associated with each point along its horizontal extent with respect to said observation point, said angles being selected so as to result in a predesigned continuous decrease in the magnification ratio of and along the entire extent of said curvature in the direction away from said observation point, said predesigned decrease in magnification ratio

(i) causing the horizontal image width of said second vehicle on said second surface segment as viewed from said observation point to increase in size horizontally as the distance back of said second vehicle from said mirrored surface decreases to about 10 feet, and

(ii) defining a linear relationship between the horizontal position of the image on said second segment of a particular point on a forward portion of said second vehicle as viewed from said observation point when said second vehicle is located along said path within a predetermined range of distances from said mirrored surface, and the distance back from said mirrored surface of said second vehicle along said path, whereby said image point moves horizontally across said surface segment at a speed substantially linearly proportionate to the speed of said second vehicle relative to said first vehicle as said second vehicle moves along said path within said range.

* * * * *

US005796532A

United States Patent [19]

Kanazawa

[11] **Patent Number: 5,796,532**

[45] **Date of Patent: Aug. 18, 1998**

[54] **BACK MIRROR AND METHOD FOR MANUFACTURING THE SAME**

[75] Inventor: **Toru Kanazawa**, Shida-gun, Japan

[73] Assignee: **Murakami Kaimeido Co., Ltd.**, Japan

[21] Appl. No.: **752,581**

[22] Filed: **Nov. 21, 1996**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 495,854, Jun. 28, 1995.

[30] **Foreign Application Priority Data**

Jul. 13, 1994 [JP] Japan 6-183867

[51] **Int. Cl.**^{6} **G02B 5/10**; G02B 5/08; G02B 5/02; G02B 7/182

[52] **U.S. Cl.** **359/858**; 359/859; 359/853; 359/856; 359/864; 359/866; 359/867; 359/599; 359/883; 359/838

[58] **Field of Search** 359/858, 859, 359/853, 856, 857, 864, 866, 867, 868, 599, 883, 838

[56] **References Cited**

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Japan Published Patent Application, 102415/1994.

Primary Examiner—Paul M. Dzierzynski
Assistant Examiner—Mohammad Y. Sikder
Attorney, Agent, or Firm—Hedman, Gibson & Costigan, P.C.

[57] **ABSTRACT**

A back mirror has plural mirror surface areas of different curvatures disposed side by side or plural mirror surface areas disposed side by side to form discontinuous planes. The back mirror includes a dividing line having a light diffusion effect formed along a border portion of the plural mirror surface areas. The dividing line may be formed by projections and depressions having a light diffusion effect which are formed on at least one of a transparent substrate, reflecting film and a transparent thin film formed on the reflecting film.

5 Claims, 5 Drawing Sheets

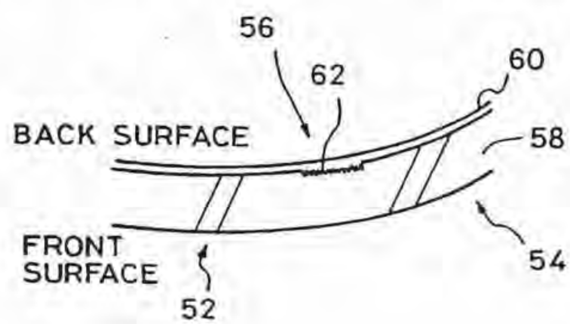


FIG. 1A

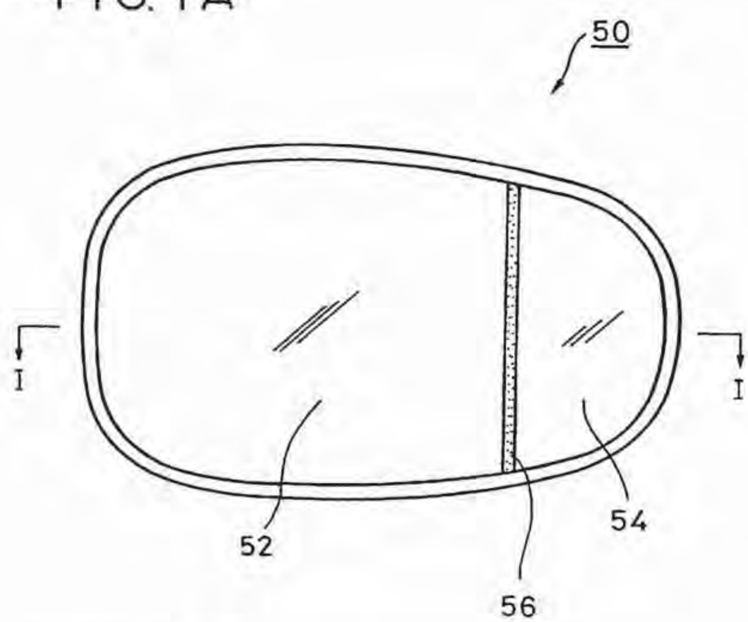


FIG. 1B

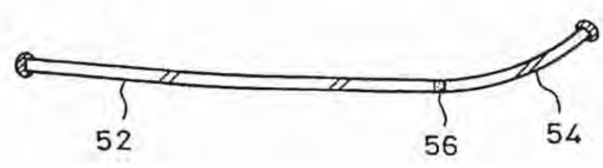


FIG. 2
PRIOR ART

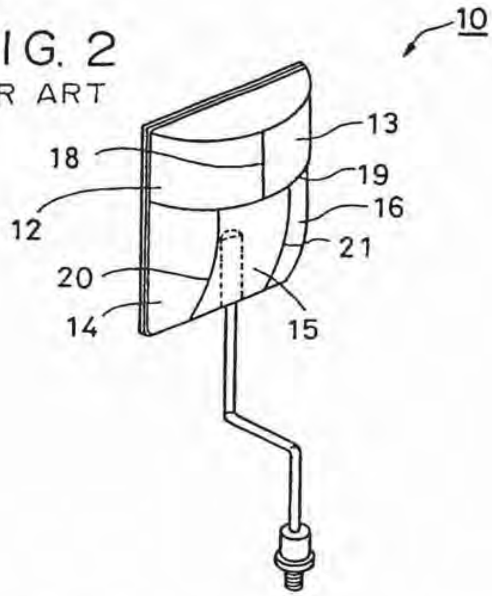
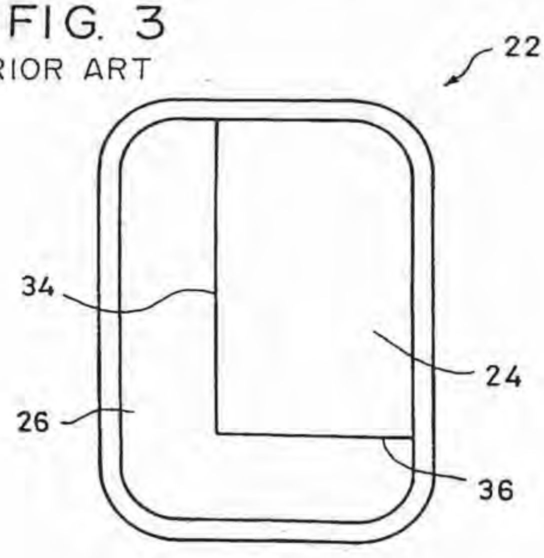


FIG. 3
PRIOR ART



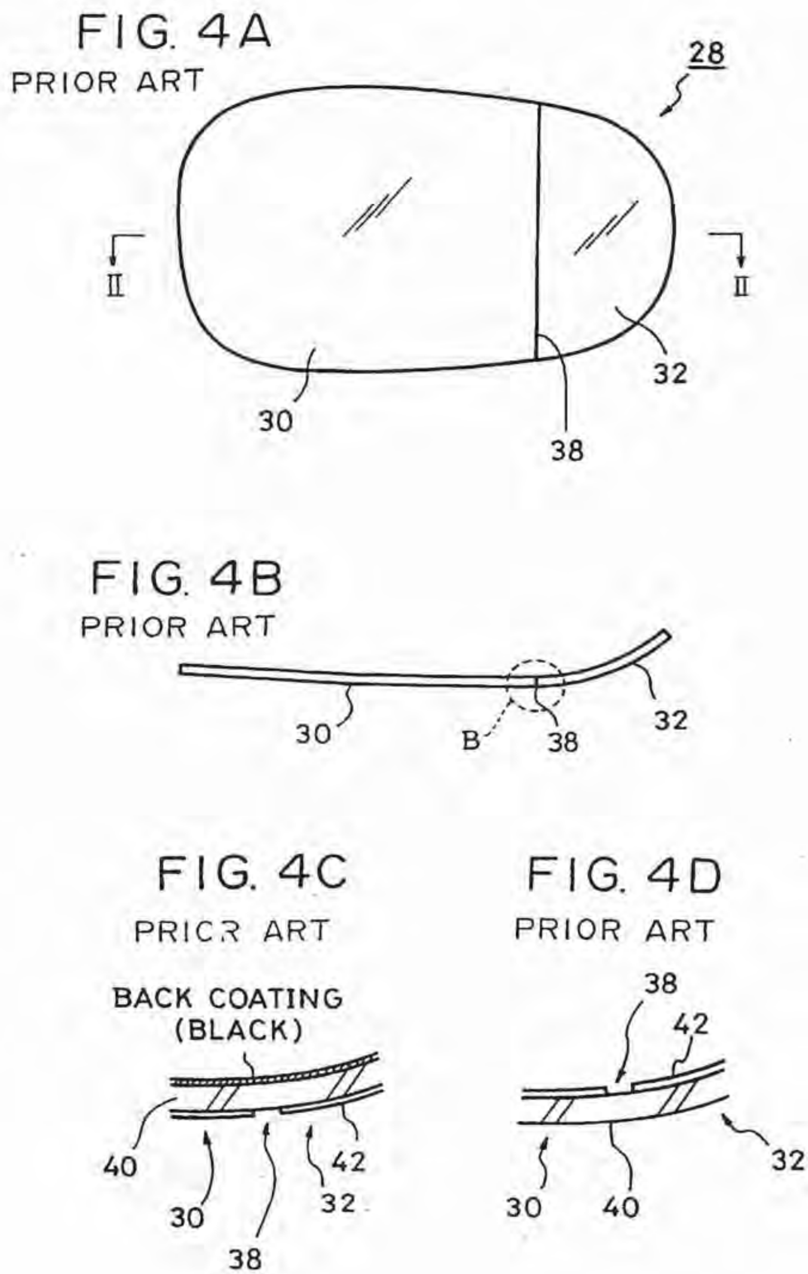


FIG. 4A
PRIOR ART
28
II
II
30
38
32
FIG. 4B
PRIOR ART
30
B
38
32
FIG. 4C
PRICR ART
BACK COATING
(BLACK)
40
30
38
42
32
FIG. 4D
PRIOR ART
38
42
30
40
32

FIG. 5

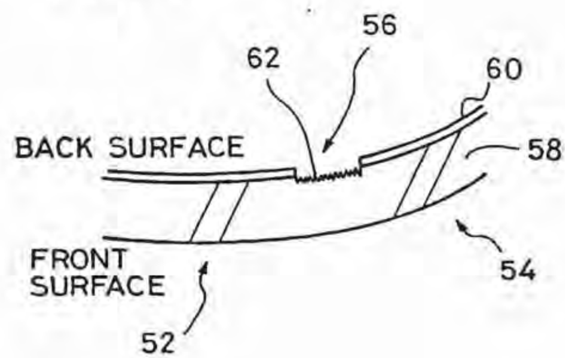

56
62
60
BACK SURFACE
58
FRONT
SURFACE
54
52

FIG. 6

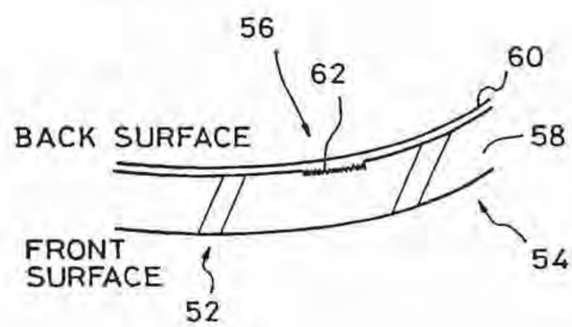
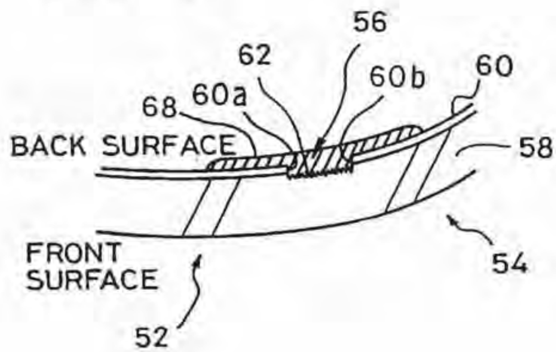

56
62
60
BACK SURFACE
58
FRONT
SURFACE
54
52

FIG. 7



BACK MIRROR AND METHOD FOR MANUFACTURING THE SAME

This invention is a continuation-in-part of application Ser. No. 08/495,854 filed on Jun. 28, 1995.

BACKGROUND OF THE INVENTION

This invention relates to a back mirror capable of having an enlarged visual field by disposing mirror surface areas of different curvatures side by side or disposing mirror surfaces side by side so as to constitute discontinuous planes and, more particularly, to a back mirror of this type in which a border portion of the mirror surface areas can be recognized easily at night. The invention relates also to a method for manufacturing such glass.

A back mirror of a vehicle which is generally made in a convex mirror surface of a constant radius of curvature or in a flat mirror surface has the disadvantage that its visual field is so narrow that it has the dead angle. The visual field can be broadened by reducing the radius of curvature of the mirror surface but this reduces the image magnification and, as a result, it becomes difficult to accurately recognize the distance of the image.

As a back mirror which has a broader visual field and facilitates recognition of distance of the image, there has been proposed a back mirror which has mirror surface areas of different curvature disposed side by side or has mirror surface areas disposed side by side so as to constitute discontinuous planes.

For example, a back mirror disclosed in Japanese Utility Model Publication No. Sho 40-6148 is shown in FIG. 2. The mirror surface of this back mirror **10** is composed of plural mirror surface areas **12** having different curvatures and disposed side by side. For another example, a back mirror disclosed in Japanese Utility Model Publication No. Sho 62-118750 is shown in FIG. 3. The mirror surface of this back mirror **22** is composed of plural mirror surface areas **24** and **26** having different radiuses of curvature from each other and disposed side by side. FIGS. **4A** to **4D** show an example of a back mirror which has been manufactured in the past. In this back mirror **28**, the radius of curvature is gradually changed. The mirror surface of this back mirror **28** has a mirror surface area **30** (a spherical surface) having a constant radius of curvature and a mirror surface area **32** (a non-spherical surface) having a gradually changing radius of curvature.

In the prior art back mirror having plural mirror surface areas, it will be dangerous unless a particular mirror surface area is easily recognized at night as a mirror surface from which an image reflected on the back mirror comes. For this reason, it is necessary to form a dividing line indicating division of the mirror surface areas along the border of the mirror surface areas. In the example of FIG. 2, for example, dividing lines **18** to **21** are drawn with a noctilucent paint. There is however the problem in this prior art back mirror that the dividing lines **18** to **21** become hard to see with lapse of time due to coming off or deterioration of the noctilucent paint. In the example of FIG. 3, dividing lines **34** and **36** are formed by printing. These dividing lines **34** and **36** however are difficult to see at night. In the example of FIGS. **4A** to **4D**, a dividing line **38** is formed, as shown in FIGS. **4C** to **4D**, by cutting off a part of a reflecting film **42** formed on the front or back surface of a glass substrate **40** along the border of the mirror surface areas **30** and **32**. In this example also, it is difficult to see the dividing line **38** at night. Besides, the width of the dividing line **38** is so small that when a driver focuses his eyes on the rear view to look at the rear view through this back mirror **28**, the dividing line **38** becomes dim and hard to see. Moreover, in case an aluminum film is used as the reflecting film **42**, a portion adjacent to the dividing line **38** is eroded due to high heat generated by cutting off of the portion for the dividing line **38** and back coating cannot prevent such erosion.

It is, therefore, an object of the present invention to provide a back mirror according to which a driver can easily recognize a border portion between mirror surface areas at night and a method for manufacturing such back mirror.

SUMMARY OF THE INVENTION

For achieving the object of the invention, there is provided a back mirror having plural mirror surface areas of different curvatures disposed side by side or plural mirror surface areas disposed side by side to form discontinuous planes, said back mirror having a dividing line formed along a border portion between the plural mirror surface areas, wherein said back mirror has a transparent glass substrate having a front surface and a back surface, and a refleing film on said back surface of the transparent glass substrate, said dividing line comprising fine projections and depressions on the back surface of the transparent glass substrate, whereby the fine projections and depressions constituting the dividing line diffuse and reflect incident light entering from the front surface of the transparent glass substrate thereby to cause the diffused and reflected light to pass through the front surface of the transparent glass substrate to an eyepoint of a driver and cause the driver to recognize the dividing line.

According to the invention, the dividing line is formed by forming fine projections and depressions on the back surface of the transparent glass substrate and, therefore, the dividing line glistens at night with the fine projections and depressions diffusing and reflecting head light of a vehicle running in the rear or street light thereby causing the diffused and reflected light to pass to an eyepoint of a driver and causing the driver to easily recognize the dividing line. Accordingly, a border portion between mirror surface areas can be easily recognized and safety in driving can thereby be ensured. Further, since the dividing line is formed by the fine projections and depressions, there is no coming off or deterioration of the dividing line as in the case of the noctilucent paint so that the dividing line can be used for a long time. Further, since the fine projections and depressions are formed on the back surface of the transparent glass substrate, the dividing line can be kept clean and, therefore, deterioration in the light diffusion effect can be prevented.

In one aspect of the invention, by forming the reflecting film on the entire back surface of the transparent glass substrate and covering said dividing line with the reflecting film, it becomes unnecessary to cut off the reflecting film along the dividing line whereby corrosion of the reflecting film at the cut portion can be prevented.

In another aspect of the invention, by cutting off the reflecting film along the dividing line and coating the reflecting film continuously with a back coating on the back surface of the reflecting film in a portion including the dividing line and an area in the vicinity of the dividing line, the dividing line is covered with the back coating and, therefore, deposition of dust on the projections and depressions can be prevented and the dividing line can thereby be kept clean and the function of the dividing line can be maintained semipermanently. Further, cut portions of the reflecting film in the direction of the width of the dividing line are covered with the back coating and, therefore, corrosion of the cut portions can be prevented. Besides, by selecting a coating material of a conspicuous color as the back coating, the dividing line can be made conspicuous even during daytime.

According to this aspect of the invention, since the dividing line is a relatively thick one having the width of 0.5 mm or over, the dividing line can be clearly recognized when the driver look at the rear view, even if the dividing line becomes dim. Also, since the width of the dividing line is 2 mm or less, the dividing line does not cause difficulty in the driver's seeing the rear view.

In still another aspect of the invention, there is provided a method for manufacturing a back mirror having a dividing line formed with projections and depressions and having a light diffusion effect, said method comprising a step of forming the projections and depressions by blasting.

According to this method, since the projections and depressions are formed by blasting according to which a surface is ground by causing small beads or the like material to collide with the surface, a uniform light diffusion effect can be obtained.

Preferred embodiments of the invention will be described below with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings,

FIGS. **1A** and **1B** are views showing an embodiment of the invention in which FIG. **1A** is a front view and FIG. **1B** is a view taken along lines I—I in FIG. **1A**;

FIG. **2** is a perspective view showing a prior art back mirror;

FIG. **3** is a front view showing another prior art back mirror;

FIGS. **4A**,**4B**,**4C** and **4D** are views showing another prior art back mirror in which FIG. **4A** is a front view, Fig. **4B** is a sectional view taken along lines II—II in FIG. **4A**.

FIG. **4C** is a partly enlarged sectional view, FIG. **4D** is a partly enlarged sectional view;

FIG. **5** is a partly enlarged sectional view showing specific example of the structure of a dividing line in FIG. **1**;

FIG. **6** is a partly enlarged sectional view showing other example of the structure of the dividing line **56** FIG. **1**; and

FIG. **7** is a partly enlarged sectional view showing other example of the structure of the dividing line **56** FIG. **1**.

DESCRIPTION OF PREFERRED EMBODIMENTS

Figs. **1A** and **1B** show an embodiment of the invention. The figures show only a mirror portion. A back mirror **50** is of a mirror in which the radius of curvature changes gradually and is formed as a right side outer mirror (e.g., a door mirror or a fender mirror). The invention of course is applicable to other back mirrors. The mirror surface of the back mirror **50** consists of a mirror surface area **52** (a spherical surface) having a constant radius of curvature and a mirror surface **54** having a gradually changing radius of curvature (a gradually changing area or a non-spherical area) disposed side by side. A dividing line **56** having a light diffusion effect is formed in a border portion between the mirror surface areas **52** and **54**.

According to this back mirror **50**, a normal rear view can be seen by the mirror surface area **52** and a right side view of the vehicle can be seen by the mirror surface area **54**. Since the dividing line **56** has a light diffusion effect, the dividing line **56** glistens against the head light of a vehicle running in the rear or street light at night and, therefore, the two areas **52** and **54** can be distinguished easily from each other.

A specific example of the structure of the dividing line **56** is shown in FIG. **5**. A mirror surface is formed by forming a reflecting surface **60** made of chromium or aluminum on the rear surface of a glass substrate **58** by sputtering or vapor deposition. After forming the reflecting film **60**, the reflecting film **60** is cut off in a portion where the dividing line **56** is to be formed. Alternatively, the reflecting film **60** may be originally formed excluding a portion where the dividing line **58** is to be formed. Then, the exposed portion of the rear surface of the glass substrate **58** is ground uniformly by blasting, e.g., by causing fine beads to collide on the exposed glass substrate portion, whereby fine projections and depressions **62** are formed on the exposed rear surface of the glass substrate **58**. Thus, a uniform light diffusion effect over the entire dividing line **62** can be obtained. As the fine beads, beads of aluminum, silicon, iron or glass may be employed. The fine beads should preferably have a diameter within a range between several microns and several hundred microns.

For obtaining an excellent light diffusion effect, the distance between the peak and bottom of the projections and depressions **62** should preferably be within a range between several microns and several hundred microns. By setting the width of the dividing line **56** within a range between 0.5 mm and 2.0 mm, the dividing line **56** can be clearly recognized when the driver sees the rear view and, in this case, the dividing line **56** does not become an obstacle in seeing the rear view. The entire processing including cutting off of the reflecting film **60** and forming of the projections and depressions **62** on the glass substrate **58** may be made continuously by a series of blasting processes. Even if the reflecting film **60** is formed by an aluminum film, erosion which generally occurs in cutting off the film will not occur because the reflecting film **60** is ground by physical collision of beads used in the blasting process without generating a high heat.

Another example of the dividing line **56** is shown in FIG. **6**. This is also of a type in which a mirror surface is formed by forming a reflecting film **60** made of chromium or aluminum on the rear surface of a glass substrate **58** by sputtering or vapor deposition. Before forming the reflecting film **60**, projections and depressions **62** are formed by blasting on the rear surface of the glass substrate **58** in a portion where the dividing line **56** is to be formed. Then, the reflecting film **60** is formed on the entire rear surface of the glass substrate **58**. According to this processing, cutting of the reflecting film **60** is obviated so that occurrence of erosion along the cut off portion can be prevented.

Another example of the structure of the dividing line **56** is shown in FIG. **7**. This is a modified structure of the one shown in FIG. **5** in which the back surface of the mirror is coated with a back coating **68** from the upper end portion to the lower end portion along the dividing line **56** so that the dividing line **56** is coated with the back coating **68** to shield it from the outside air. The back coating **68** is coated with a width which is larger than the width of the dividing line **56** to cover the entire dividing line **56**. A coating of any desired color may be used as the back coating **68**.

According to this arrangement, the dividing line **56** is covered with the back coating **68** and, therefore, deposition of dust on the projections and depressions **62** can be prevented and the dividing line **56** can thereby be kept clean and the function of the dividing line can be maintained semipermanently. Further, cut portions **60a** and **60b** of the reflecting film **60** in the direction of the width of the dividing line **56** are covered with the back coating **68** and, therefore, corrosion of the cut portions **60a** and **60b** can be prevented. Besides, by selecting a coating material of a conspicuous color as the back coating **68**, the dividing line **56** can be made conspicuous even during daytime. In addition, notwithstanding that the projections and depressions **62** constituting the dividing line **56** are covered with the back coating **68**, the projections and depressions **62** still have the light diffusion effect, glistening against head light of a vehicle running in the rear or street light at night and thereby enabling the mirror surface areas **52** and **54** to be distinguished easily from each other. The back coating **68** may be applied not only in a portion in the vicinity of the dividing line **56** but also on the entire back surface of the mirror to cover the entire reflecting film **60**.

In the above described embodiments, the projections and depressions **62** are formed by blasting. The projections and depressions **62** may also be formed by other methods such, for example, as projection of laser beam and stamping using a die having projections and depressions.

In the above described embodiments, the dividing line **56** is formed in the form of a solid line (i.e., a continuous line). Alternatively, the dividing line **56** may be formed with a dotted line or other type of line. It is only essential that the dividing line should distinguish the border between adjacent mirror surface areas. In the above described embodiments, adjacent mirror surface areas have different curvatures. The invention is applicable also to a case where a mirror surface is divided into adjacent areas which have the same curvature but constitute discontinuous planes (i.e. constituting an angle between the adjacent areas). The number of mirror surface areas is not limited to two but it may be three or more. The invention is applicable not only to an outer mirror but also to an inner mirror.

What is claimed is:

1. A back mirror having plural mirror surface areas of different curvatures disposed side by side to form discontinuous planes, said back mirror having a dividing line formed along a border portion between the plural mirror surface areas, wherein said back mirror has a transparent glass substrate having a front surface and a back surface, and

a reflecting film on said back surface of the transparent glass substrate, said dividing line comprising fine projections and depressions formed on the back surface of the transparent glass substrate, whereby the fine projections and depressions constituting the dividing line diffuse and reflect incident light entering from the front surface of the transparent glass substrate thereby to cause the diffused and reflected light to pass through the front surface of the transparent glass substrate to an eyepoint of a driver and cause the driver to recognize the dividing line.

2. A back mirror as defined in claim 1 wherein said reflecting film is formed on the entire back surface of the transparent glass substrate and said dividing line is covered with the reflecting film.

3. A back mirror as defined in claim 1 wherein the reflecting film is cut off along the dividing line and the reflecting film is continuously coated with a back coating on the back surface of the reflecting film in a portion including the dividing line and an area in the vicinity of the dividing line.

4. A back mirror as defined in claim 1 wherein the width of the dividing line is within a range between 0.5 mm and 2 mm.

5. A method for manufacturing a back mirror having plural mirror surface areas of different curvatures disposed side by side to form discontinuous planes, said back mirror having a dividing line formed along a border portion between the plural mirror surface areas, wherein said back mirror has a transparent glass substrate having a front surface and a back surface, and a reflecting film on said back surface of the transparent glass substrate, said dividing line comprising fine projections and depressions formed on the back surface of the transparent glass substrate, whereby the fine projections and depressions constituting the dividing line diffuse and reflect incident light entering from the front surface of the transparent glass substrate thereby to cause the diffused and reflected light to pass through the front surface of the transparent glass substrate to an eyepoint of a driver and cause the driver to recognize the dividing line, said method comprising a step of forming the projections and depressions by blasting.

* * * * *

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Lupo et al.

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[54] REARVIEW MIRROR ASSEMBLY FOR A VEHICLE

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[51] Int. Cl.[5] G02B 5/08; B60R 1/06

[52] U.S. Cl. 359/841; 359/881; 248/478; 248/480; 248/484

[58] Field of Search 350/604, 605, 606, 626, 350/631, 632, 639; 248/475.1, 476, 478, 479, 480, 484, 486, 487

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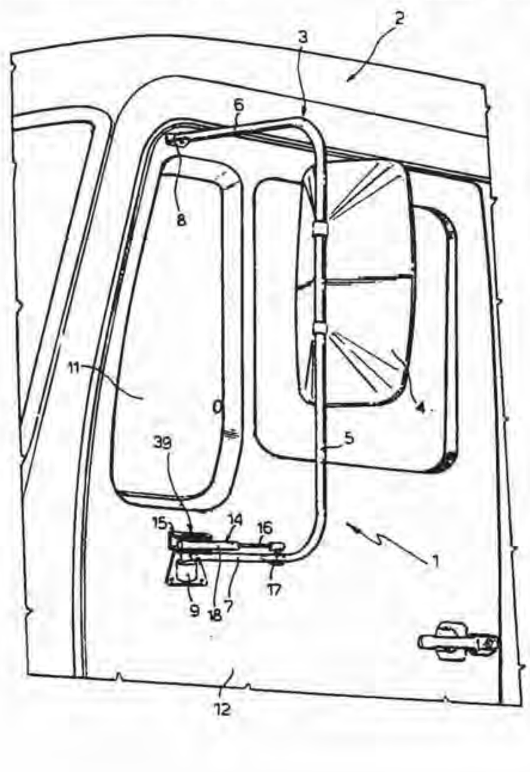
[57] ABSTRACT

A rearview mirror assembly for an industrial vehicle comprising a C-shaped supporting element, a mirror attached to this supporting element, hinging means for attaching the supporting element in a projecting position to the body of the vehicle defining at least one preferential angular position of the supporting element, and a telescopic rod connected to a lower arm of the supporting element and to a bracket fixed to the vehicle body, so as to reduce the vibrations during use of the supporting element and equipped with elastic means exerting a return force on the arm.

10 Claims, 3 Drawing Sheets



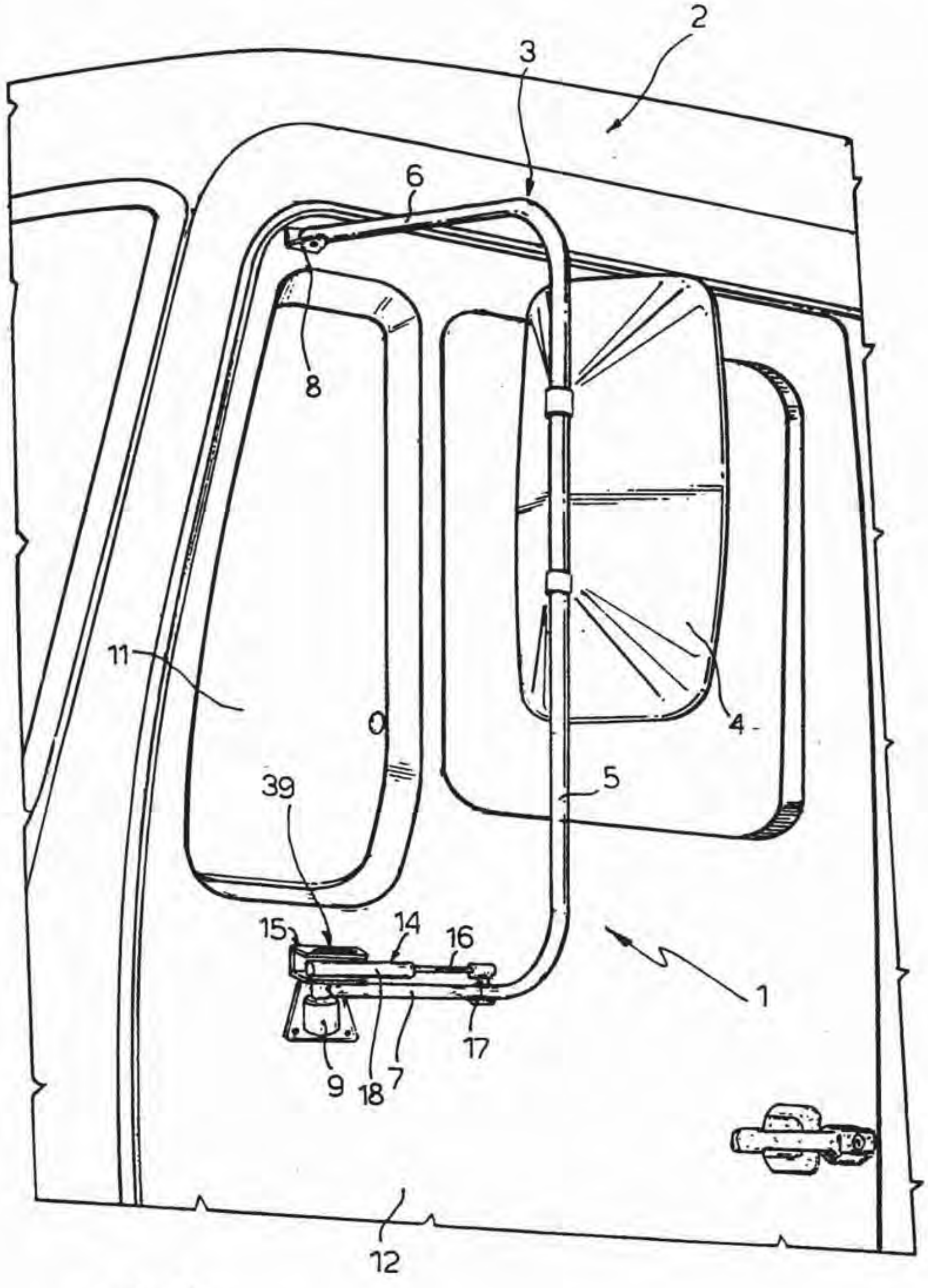


Fig.1

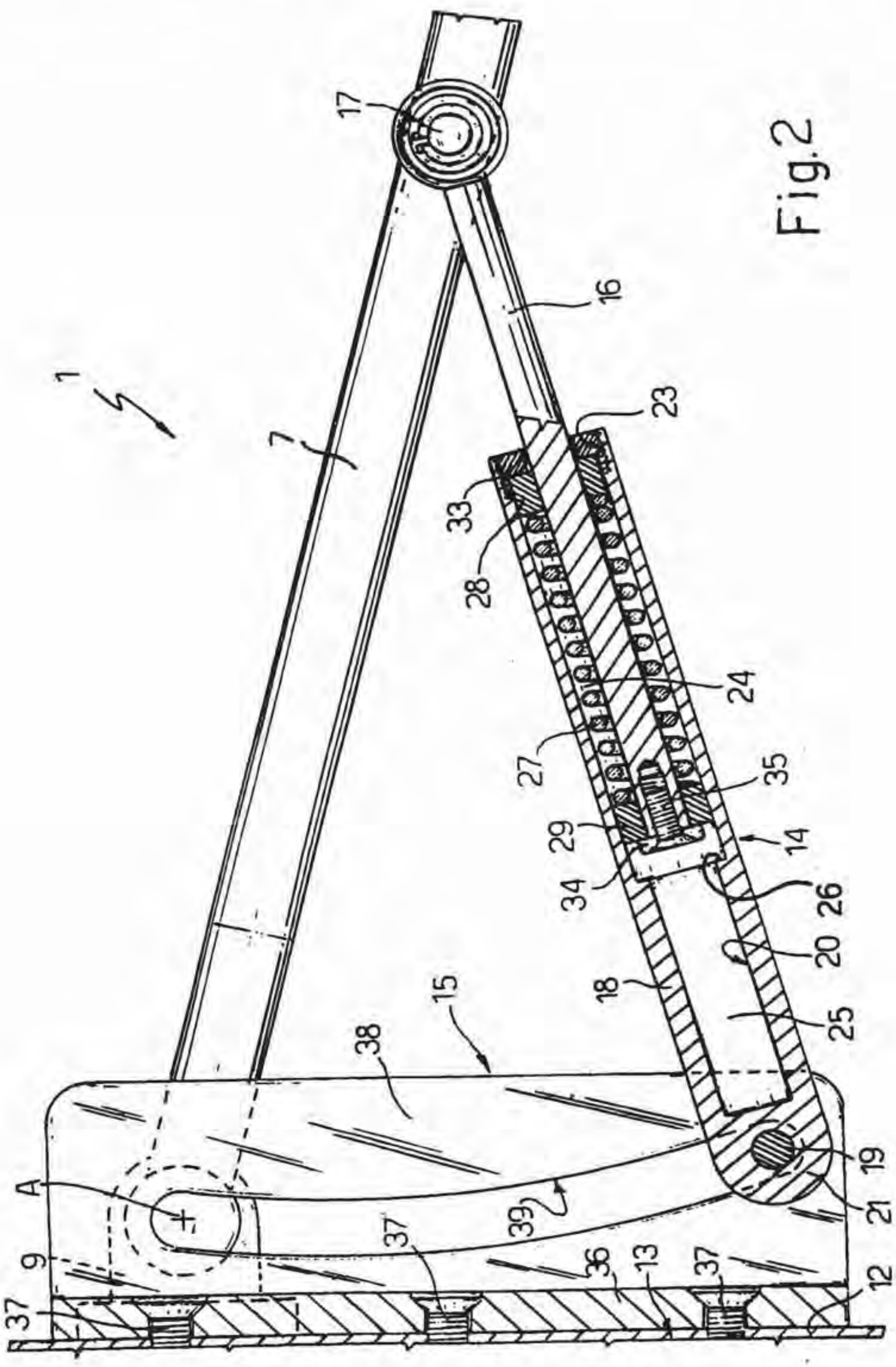

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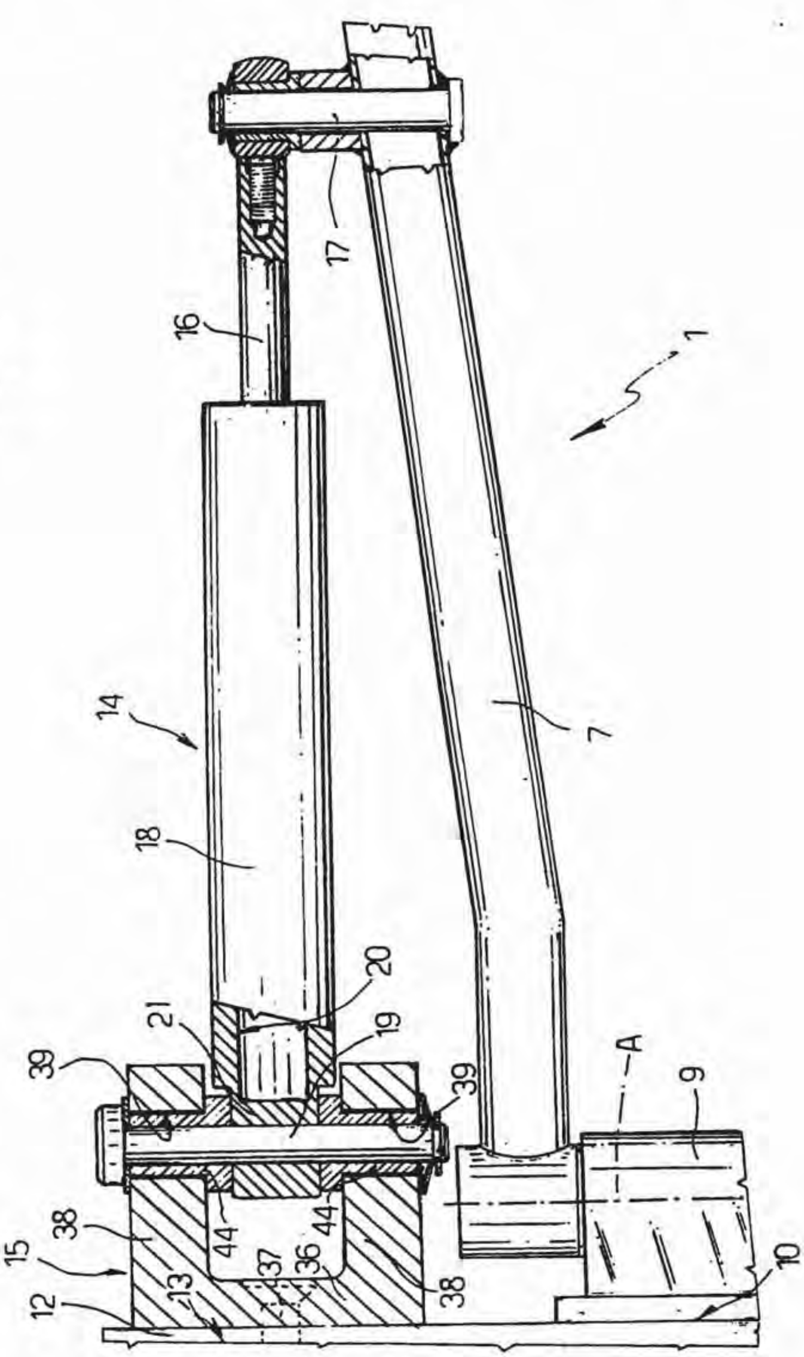
Fig.2

Fig. 3



REARVIEW MIRROR ASSEMBLY FOR A VEHICLE

BACKGROUND OF THE INVENTION

The present invention relates to a rearview mirror assembly, and in particular, but not exclusively, to an external rearview mirror for industrial vehicles. External rearview mirror assemblies for industrial vehicles are known to generally comprise a substantially C-shaped supporting element hinged at its ends to a side part of the vehicle body, and a mirror attached to a central part of the supporting element. At least one of the points at which the supporting element is connected to the vehicle body consists of a hinge adapted to define at least one preferential stable position of the supporting element in relation to the vehicle body.

Known external rearview mirror assemblies described in brief present one drawback. When the vehicle is in motion, vibrations are created and transmitted to the supporting element by the car body; here they are amplified due to its projecting position thus causing the mirror and the image reflected to oscillate.

SUMMARY OF THE INVENTION

The aim of the present invention is to provide an external rearview mirror assembly for industrial vehicles, which overcomes the drawback of the known rearview window assemblies described above.

In accordance with the present invention there is provided a rearview mirror assembly for industrial vehicles, of the type comprising a mirror, a supporting element to which said mirror is attached, and hinging means for the connection of said supporting element in a projecting position to at least a first area of the body of said vehicle, said hinging means defining at least one preferential angular position of said supporting element in relation to said vehicle body, characterized in that it comprises at least one rod defining an auxiliary attachment between said supporting element and a second area of said vehicle body, said rod comprising elastic means exerting a force on said supporting element towards said second area of the vehicle body at least when said supporting element is located near said preferential angular position.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is described in the form of a preferred embodiment by way of example with reference to the enclosed drawings, in which:

FIG. 1 is a perspective view of a rearview window assembly in accordance with the present invention, applied to an industrial vehicle;

FIG. 2 is a view from above, on an enlarged scale, and a sectional view of part of the rearview mirror assembly shown in FIG. 1, and

FIG. 3 is an elevated front view, on an enlarged scale, and a sectional view of part of the rearview mirror assembly shown in FIG. 1.

DETAILED DESCRIPTION OF THE INVENTION

In reference to the figures, the numeral 1 refers to the rearview mirror assembly, in its entirety, adapted to be applied to an industrial vehicle 2, illustrated in part.

Assembly 1 comprises, in a known fashion, a supporting element 3 hinged in a projecting position to the body of vehicle 2, and a mirror 4 attached to supporting element 3.

In particular, supporting element 3 is made of metal tubing bent to form a substantially C shape and comprises a central vertical section 5, to which mirror 4 is attached in an adjustable fashion, and a couple of approximately horizontal upper and lower arms 6, 7, which are hinged at their free ends, respectively, to a bracket 8 and a support 9, fixed to the body of vehicle 2 and defining a rotational axis A (FIG. 2) of supporting element 3.

In particular, support 9, of a known type, is fixed to a first section 10 of the vehicle body, suitably below a side window 11 of a door 12 of the vehicle, and is of the type adapted to define at least one preferential angular position (or for normal use) of supporting element 3 in relation to the body of vehicle 2; this position, shown in the figures, is suitably inclined towards the front, in relation to a plane across the vehicle comprising axis A, preferably at an angle of approximately 14°.

Supporting element 3 can be rotated forwards and backwards with respect to the preferential position, to enable the rearview mirror assembly 1 to be blocked against the vehicle body, accidentally in the event of a bump or voluntarily should the need arise. In accordance with the present invention, assembly 1 comprises an auxiliary rod 14 attaching supporting element 3 to a bracket 15 fixed to a second area 13 of the vehicle body, near support 9.

Rod 14 is telescopic and is comprised of stem 16 hinged to a pin 17 held by lower arm 7 of supporting element 3 and a cylindrical tube 18 hinged at one end 21 to a vertical pin 19 housed and guided in bracket 15, as described later on.

Stem 16 slides inside an internal chamber 20 of tube 18, comprising a first section 24 with a larger diameter to an inlet 23 of chamber 20, and a second section 25 with a smaller diameter, adjacent to end 21; said first and second sections 24, 25 define between them an intermediate shoulder 26.

Around the section of stem 16 housed in the first section 24 of chamber 20, there is a helicoidal spring 27, interacting at its ends with respective bearing rings 28, 29 mounted free to slide along stem 16 and inside section 24, and held along an axis respectively by a nut 33 screwed over inlet 23 and a circular stopping plate 34 secured by screw 35 on the free end of stem 16.

Rings 28, 29 present an external diameter substantially equal to the internal diameter of section 24, plate 34 presents an external diameter substantially equal to the internal diameter of the second section 25 of chamber 20.

Bracket 15 presents a substantially C-shaped cross-section and comprises a central vertical wall 36, fixed by screws 37 to the vehicle body, and a couple of parallel, horizontal walls 38, each of which is fitted with a through slot 39 whose circumference has the form of an arc with the concave section towards the outside of vehicle 2.

End 21 of tube 18, of a flat shape, is housed between walls 38 of bracket 15 and is crossed by pin 19, onto whose end sections are mounted two antiwear bushes 44 that slide along respective slots 39.

Bracket 15 is mounted above support 9 in such a position that respective rear ends (with respect to the direction in which the vehicle is moving) of slots 39 are positioned on the rotational axis A of supporting element 3.

The various parts of rod **14** and spring **27** are of such a size that when supporting element **3** is in the preferential position defined by support **9**, pin **15** is at the opposite end of slots **39** with respect to axis A (FIG. **2**), and spring **27** is compressed.

Rearview mirror assembly **1** operates in the following manner. In the preferential position of supporting element **3**, spring **27** exerts a force on stem **16**, by means of ring **29**, plate **34** and screw **35**, towards the inside of tube **18**, transmitted by stem **16** to supporting element **3**.

The intensity of this force is not sufficient to overcome the stopping force exerted on supporting element **3** by support **9**, but has a stabilizing action on supporting element **3**. Therefore, the further link provided by rod **14** on supporting element **3** drastically limits oscillation, thus increasing the efficiency of rearview mirror assembly **1**.

Rod **14** is designed so that supporting element **3** may be tilted forwards or backwards when forces are applied accidentally or voluntarily in these directions.

In particular, if the arm is pressed forwards with a force that is stronger than the stopping action of support **9**, rotation of supporting element **3** is first favoured by the recalling action of spring **27**, until ring **29** is blocked against shoulder **26**, discharging on said shoulder the action of spring **27**. If supporting element is rotated yet further, stem **16** moves into the second section **25** of chamber **20** of tube **18**, and slides freely without any elastic action. Rod **14** thus has no effect, allowing supporting element **3** to be pressed back completely. In the last stage of rotation, plate **34** strikes against the rear of chamber **20**, thus preventing a further reduction in the length of rod **14**; therefore, from this position on, pin **19** moves along slots **39**.

When forces are applied to rotate supporting element **3** backwards, initial rotation occurs against the action of rod **14**, as stem **16** partially protrudes from tube **18** compressing spring **27** yet further. Subsequently, having reached an angular position in which the force exerted by spring **27** and transmitted by tube **18** to pin **19** presents a component that is at a tangent to slots **39** sufficient to offset friction, pin **19** begins to slide along slots **39** and spring **27** is gradually released, until pin **19** reaches the opposite end of slots **39**. During the last stage of rotation, supporting element **3** and rod **14** are hinged to axis A, and so the force exerted by spring **27** has no effect on this axis and does not substantially obstruct rotation.

An examination of the features of rearview mirror assembly **1** in accordance with the present invention clearly shows the advantages that may be obtained. In particular, rod **14** is an auxiliary means of attaching supporting element **3**, considerably reducing vibration during use, yet maintaining complete freedom of rotation about its hinging axis A.

To assembly **1** described above modifications and variants may be made without exceeding the scope of the present invention. In particular, two rods **14** may be used by applying them to respective arms **6**, **7** of supporting element **3**, the embodiment of rod **14** may be modified as can its connecting means, as well as the form of bracket **15**.

We claim:

1. In a rearview mirror assembly for industrial vehicles, having a mirror, a supporting element to which said mirror is attached, and hinging means for connecting said supporting element in a projecting position with a first area of the body of said vehicle, said hinging

means defining at least one preferential angular position of said supporting element in relation to said vehicle body, wherein the improvement comprises at least one rod providing an auxiliary attachment between said suporting element and a second area of said vehicle body, said rod comprising a tube and a stem, said stem sliding along an internal chamber of said tube, said stem attaching to a first pin on said supporting element to form a first pivot, said tube attaching to a second pin to form a second pivot, said second pin secured to a bracket at said second area of said vehicle body, said bracket comprising at least one substantially horizontal wall with an arc-shape through-slot in which said second pin is mounted to freely slide in a arcuate manner, said rod further comprising a spring disposed within said tube; said spring exerting a force on said stem urging said supporting element towards said second area of the vehicle body when said supporting element is located near said preferential angular position.

2. A rearview mirror assembly for industrial vehicles comprising:

a mirror;

a supporting element to which said mirror is attached;

hinging means for connecting said supporting element in a projecting position to at least a first support means fixed to a first lateral portion of a body of said vehicle;

said hinging means defining at least one preferential angular position of said supporting element in relation to said vehicle body;

a telescopic auxiliary rod connected by respective pins at one end to said supporting element and at the other end to a bracket fixed to a second lateral portion of said vehicle body, said auxiliary rod having a tube and a stem slidingly received in an internal chamber of said tube, said auxiliary rod further having a spring coiled around said stem inside said tube, said spring being compressed between a first stopping means attached to an inlet of said tube and a second stopping means attached to the end of said stem disposed within said tube, said auxiliary rod exerting a force on said supporting element towards said bracket when said supporting element is located near said preferential angular position; and

said internal chamber of said tube having a first section with a first diameter adjacent to said inlet section and slidably receiving said first and second stopping means therein, and a second section having a diameter smaller than the diameter of said stopping means but larger than the diameter of said stem, said second stopping means being slidable along said stem.

3. The assembly as claimed in claim **2**, wherein said bracket presents at least one substantially horizontal wall with a through slot in which said end pin of said rod connected to said bracket is mounted free to slide.

4. The assembly as claimed in claim **3**, wherein said slot is a concave shaped slot with its concave part facing towards the outside of said vehicle.

5. The assembly as claimed in claim **2**, wherein said supporting element comprises a substantially C-shaped member and having a central part to which said mirror is attached in an adjustable fashion, and an upper arm and a lower arm attached by said hinging means to said body of said vehicle; said hinging means attaching said lower arm to said body of said vehicle defining said preferential position of said supporting element with respect to said vehicle body.

6. The assembly as claimed in claim 5, wherein said rod is attached to said lower arm of said supporting element.

7. A rearview mirror assembly for industrial vehicles comprising;

a mirror;

a supporting element to which said mirror is attached;

hinging means for connecting said supporting element in a projecting position to at least a first support means fixed to a first lateral portion of a body of said vehicle;

said hinging means defining at least one preferential angular position of said supporting element in relation to said vehicle body;

a bracket fixed to a second lateral position of said vehicle body, said bracket having a horizontal wall having a through slot, a rear end of said slot located substantially on the rotating axis of said supporting element about said hinging means;

a telescopic auxiliary rod connected by respective pins at one end to said supporting element and at the other end to said bracket, said auxiliary rod having a tube and a stem slidingly received in an internal chamber of said tube; and

said auxiliary rod including resilient means for exerting a force on said supporting element towards said bracket when said supporting element is located near said preferential angular position.

8. The assembly as claimed in claim 7, wherein said auxiliary rod further comprises a spring coiled around said stem inside said tube and is compressed between a first stopping means attached to an inlet of said tube and a second stopping means attached to the end of said stem disposed within said tube.

9. The assembly as claimed in claim 8, wherein said internal chamber of said tube comprises a first section with a first diameter adjacent to said inlet section and slidably receiving said first and second stopping means therein, and a second section having a diameter smaller than the diameter of said stopping means but larger than the diameter of said stem; said second stopping means slidable along said stem.

10. The assembly as claimed in claim 7, wherein said preferential position of said supporting element is tilted forward with respect to a cross plane passing through said rotational axis (A) of said supporting element.

* * * * *