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(54) **DISPLAY DEVICE BASED ON FRUSTRATED TOTAL INTERNAL REFLECTION**

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(58) **Field of Search** 359/228, 245, 359/250, 252, 253, 263, 290, 295, 296, 297, 359/529, 530, 619, 621, 625, 832; 345/48, 345/55, 84, 85, 107; 349/86, 89; 430/32, 430/34, 35

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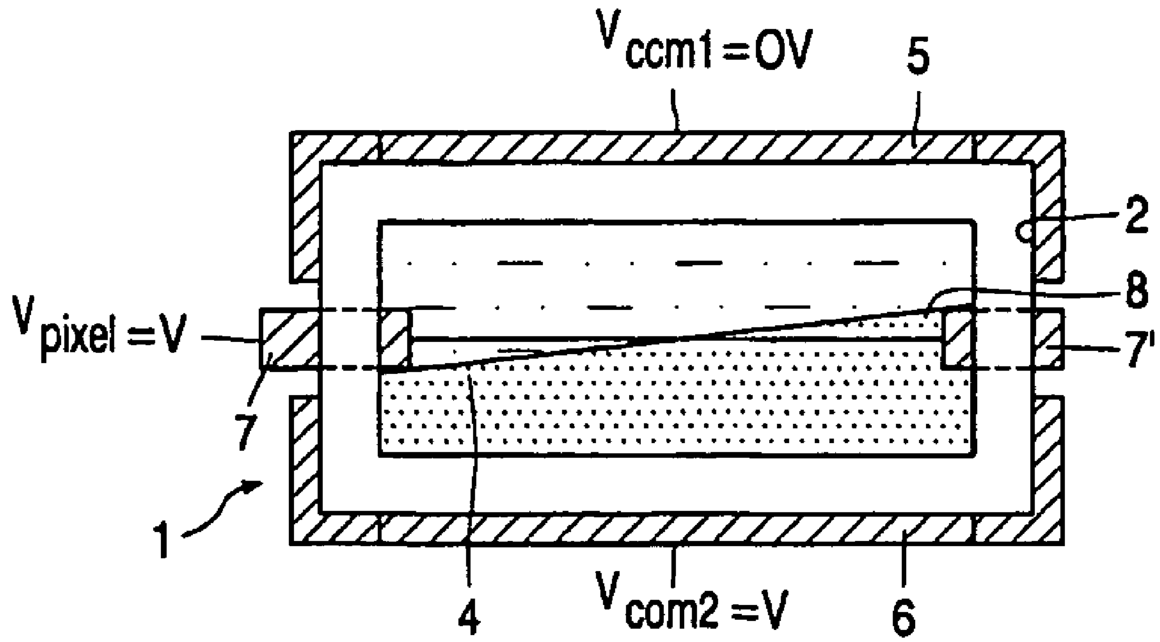
(57) **ABSTRACT**

Pixels of a display device include a reservoir containing two immiscible fluids. Switching of a pixel state is based on redistribution of the fluids within the reservoir due to electrostatic forced applied onto electrodes, and a potential applied to one of the fluids which is electrically conducting.

20 Claims, 3 Drawing Sheets



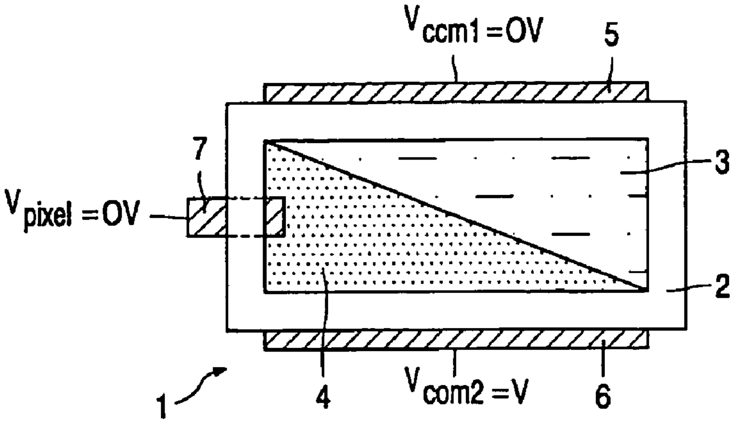


FIG. 1a

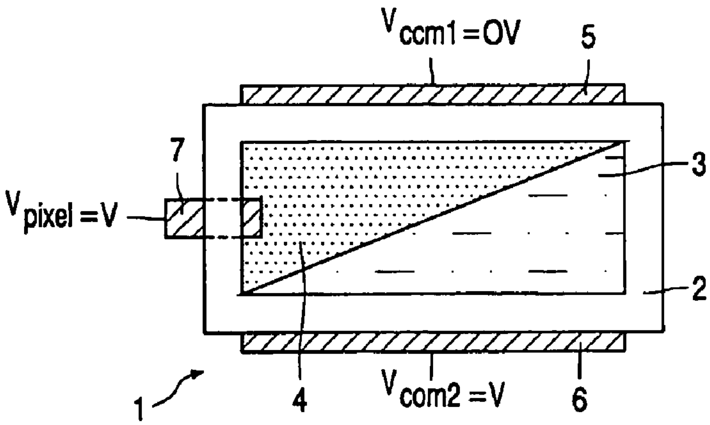


FIG. 1b

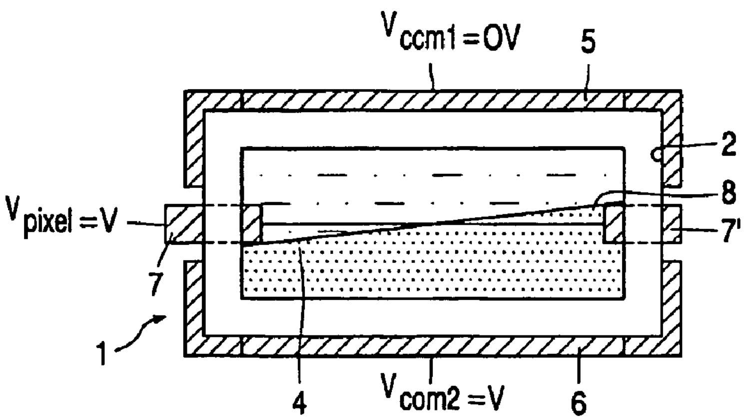


FIG. 2

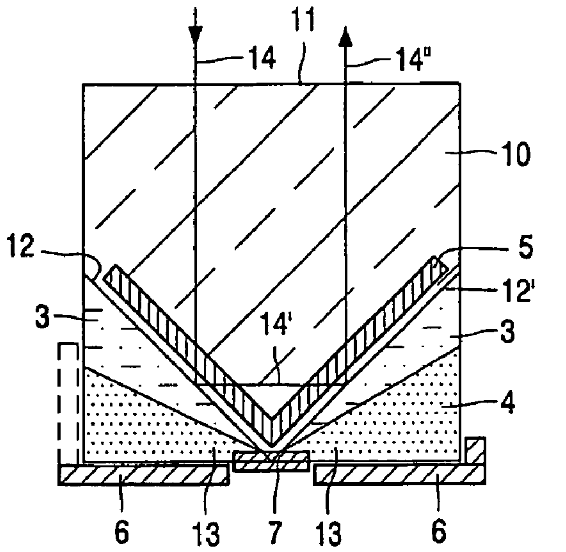


FIG. 3a

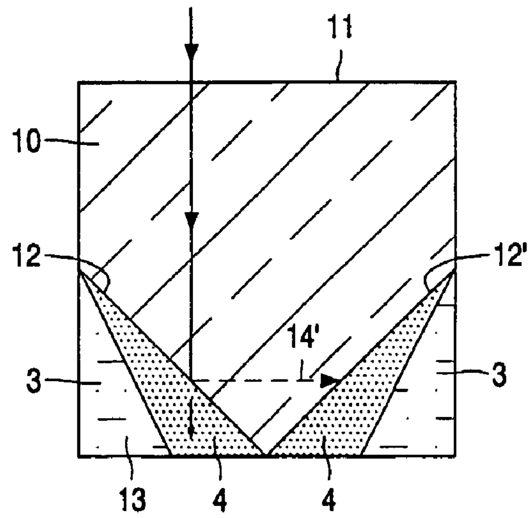


FIG. 3b

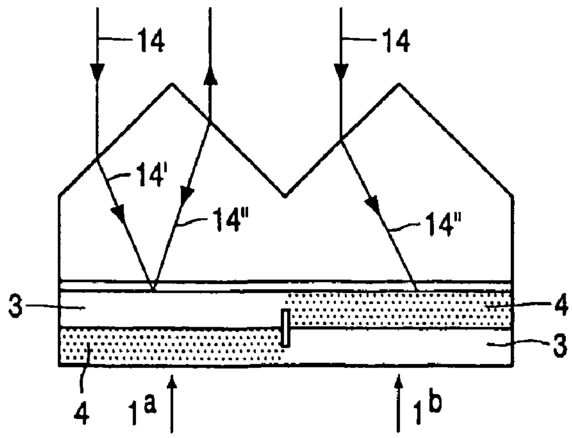


FIG. 4

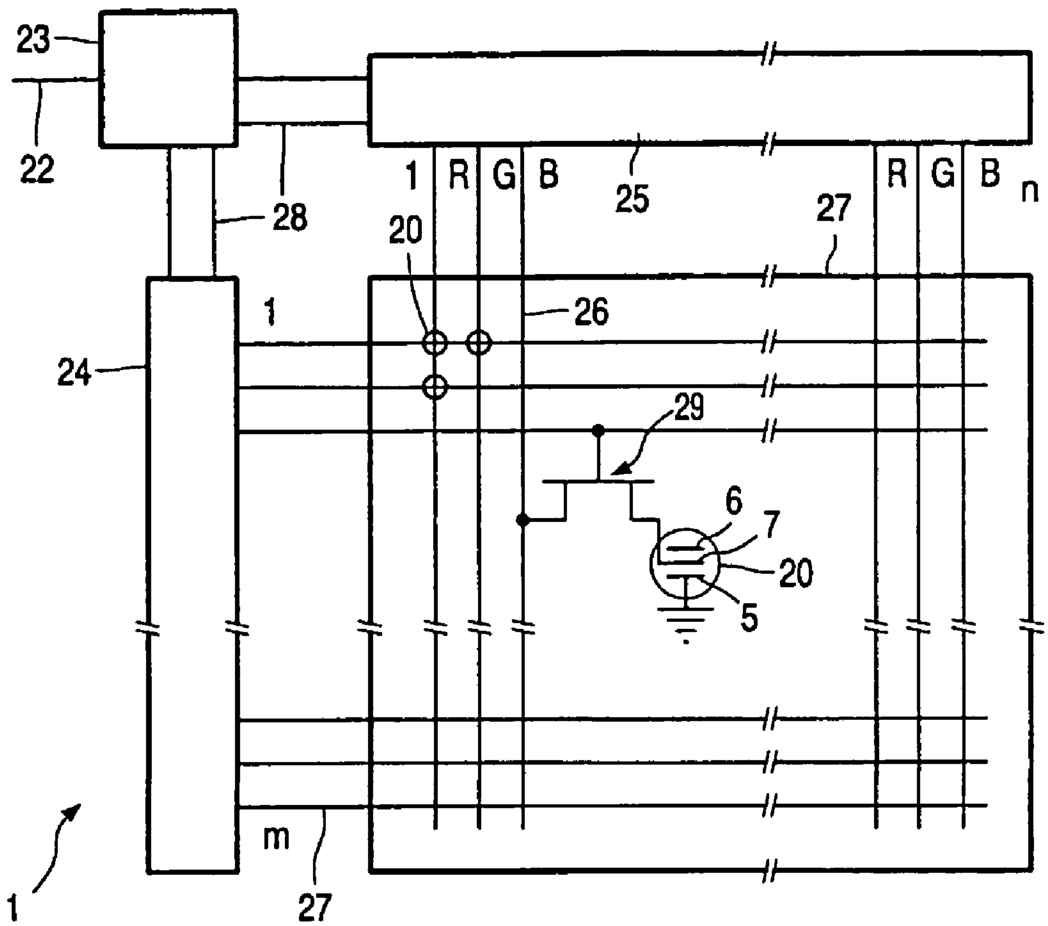


FIG. 5

DISPLAY DEVICE BASED ON FRUSTRATED TOTAL INTERNAL REFLECTION

The invention relates to a display device comprising a substantially transparent substrate having a substantially flat surface and a substantially prismatic surface facing said flat surface.

A display device of this type is described in, for example, the article in "New Reflective Display Based on Total Internal Reflection in Prismatic Microstructures" Proc. 20th IDRC conference, pp. 311–314 (2000). This article describes the principle of total internal reflection based on controlled frustration. The total internal reflection is made impossible in one state by moving light-absorbing particles towards the prismatic surface by means of electrophoresis.

Electrophoretic display devices are based on the movement of charged, usually colored particles under the influence of an electric field between two extreme states having a different transmissivity or reflectivity. With these devices, dark (colored) characters can be imaged on a light (colored) background, and vice versa.

Electrophoretic display devices are therefore notably used in display devices taking over the function of paper, referred to as "white paper" applications (electronic newspapers, electronic diaries).

The present invention is based on a completely different mechanism for realizing the differences in reflected light in the two (dark and light) optical states.

To this end, a display device according to the invention comprises a reservoir at the location of a pixel, which reservoir contains at least two substantially immiscible fluids having a different refractive index or a different absorption coefficient, and a difference of electric conductivity, said display device also comprising drive means for displacing the fluids with respect to each other.

As will be explained hereinafter, the light is completely reflected in one of the two states, (by suitable choice of one of the fluids and hence the refractive index), while the light is absorbed by the fluid in the other state (or either or not partly transmitted and absorbed elsewhere).

The substrate surface facing the viewer on the viewing side may be flat, with at least a part of the prismatic surface of the substrate forming part of a wall of the reservoir. Alternatively, it may be prismatic, with at least a part of the flat surface of the substrate forming part of a wall of the reservoir.

In order to displace the fluids with respect to each other, use is made of the difference of electric conductance and, at the area of the wall of the reservoir of a pixel, the drive means comprise at least two electrodes which can be electrically coupled to the fluids.

At the area of the wall of the reservoir of a pixel, the drive means preferably comprise two electrodes which are isolated from the fluids, and a third electrode which is in electric contact with the electrically conducting fluid.

To this end, a matrix device comprises a plurality of pixels at the area of crossings of row or selection electrodes and column or data electrodes, with at least a switching element between an electrode of the pixel and a row or column electrode.

These and other aspects of the invention are apparent

In the drawings:

FIG. **1** shows diagrammatically the principle on which a display device according to the invention is based,

FIG. **2** shows a variant of FIG. **1**,

FIG. **3** shows a possible form of a display cell according to the invention, while

FIG. **4** shows another possible form of a display cell according to the invention, and

FIG. **5** is an electric equivalent diagram of a display device according to the invention.

The Figures are diagrammatic and not drawn to scale; corresponding components are generally denoted by the same reference numerals.

FIG. **1** shows diagrammatically a display cell **1** with two liquids, or fluids, **3**, **4** in a transparent, for example, glass or synthetic material envelope **2**, which fluids do not mix with each other and one of which is electrically conducting and the other is insulating. In this example, the display cell **1** comprises, for example an aqueous (color) solution **4** (electrically conducting), for example, a solution in water of methylene blue or Prussian blue ($C_6Fe_2Kn_6$), while a gas such as nitrogen or a non-polar oil such as an alcane (for example, dodecane or hexadecane), a silicon oil, chloronaphtalene, bromonaphtalene, or 1-bromododecane is chosen as an insulating fluid.

On two sides of the fluids, the display cell **1** comprises insulated electrodes **5**, **6** which are usually fed with voltages V_{com1}, V_{com2} which are common for a plurality of pixels, in the relevant example with voltages of 0 and V. The display cell **1** also comprises an electrode **7** which makes electrically conducting contact through the envelope **2** with the electrically conducting fluid **4**. The electrode **7** is fed with a voltage V_{pixel} by means of which the optical state of the display cell is adjusted. Although, for the sake of understanding the invention, the electrodes **5**, **6** are shown outside the envelope, they are provided within the envelope **2** in practice and insulated from the fluids by means of an insulating coating having a low wetting hysteresis such as a fluoropolymer.

The electrically conducting fluid **4** is attracted by electrostatic forces in the direction of the electrodes **5**, **6**, namely towards the electrode **5** with a force which is proportional to $(V_{pixel}-V_{com1})^2$ and towards the electrode **6** with a force which is proportional to $(V_{pixel}-V_{com2})^2$ due to electrowetting or electrocapillarity. The difference between the respective electrostatic forces defines the position of the fluid **4** in a display cell. In FIG. **1**, $V_{com1}=0$ and $V_{com2}=V$. When $V_{pixel}=0$, the electrically conducting fluid **4** is at the location of electrode **6** (FIG. **1***a*), while the electrically conducting fluid **4** is at the location of electrode **5** (FIG. **1***b*) when $V_{pixel}=V$. By changing the pixel potential V_{pixel}, the location of the electrically conducting fluid **4** can thus be influenced. Although the electrode **7** is shown as a conducting electrode in this example, and, moreover, projects into the fluid, this is not necessary. The potential may also be provided on the conducting fluid via capacitive coupling. In that case, the electrode **7** is arranged, for example, outside the reservoir **2** or provided with an insulating protective coating.

FIG. **2** shows a variant of FIG. **1**, in which the electrode **7**, which is again fed with a voltage V_{pixel} is subdivided into two sub-electrodes **7**, **7**'. The interface between the fluids is now substantially parallel to the upper and lower wall of the envelope **2**, with a small deviation in the plane of the drawing, due to the effect used (in FIG. **2**, this is shown diagrammatically by means of the slanting line **8**).

FIG. **3** shows how the principle described above is used

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