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SYLVIA HOLLEY
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08/976217
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ISSUE CLASSIFICATION

SCANNED

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08/976,217	11/21/97	345	P	~~2775~~ 2778	Kovalick

APPLICANTS: HIROYASU YAMADA, TOKYO, JAPAN; TOMOYUKI SHIRASAKI, TOKYO, JAPAN; YOSHIHIRO KAWAMURA, TOKYO, JAPAN.

CONTINUING DATA*******************
VERIFIED JVK No

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Foreign priority claimed [X] yes [ ] no / 35 USC 119 conditions met [X] yes [ ] no / Verified and Acknowledged JVK Examiner's Initials	AS FILED	STATE OR COUNTRY	SHEETS DRWGS.	TOTAL CLAIMS	INDEP. CLAIMS	FILING FEE RECEIVED	ATTORNEY'S DOCKET NO.
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ADDRESS:
FRISHAUF HOLTZ GOODMAN LANGER & CHICK
767 THIRD AVENUE 25TH FLOOR
NEW YORK NY 10017

TITLE: DISPLAY APPARATUS

U.S. DEPT. OF COMM./PAT. & TM—PTO-436L (Rev. 12-94)

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Kim Parnell
Applications Examiner

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Vincent E. Kovalick
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BIPIN SHALWALA
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(FACE)

65705 U.S. PTO
08/976217

PATENT APPLICATION SERIAL NO. 11/21/97

U.S. DEPARTMENT OF COMMERCE
PATENT AND TRADEMARK OFFICE
FEE RECORD SHEET

01/21/1998 BALEXAND 00000010 08976217
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PTO-1556
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FRISHAUF, HOLTZ, GOOD[illegible] [illegible], LANGER & CHICK, P.C.
ATTORN[illegible] AT LAW
767 THIRD AVENUE, NEW YORK, N.Y. 10017-2023

STEPHEN H. FRISHAUF
LEONARD HOLTZ
HERBERT GOODMAN
WILLIAM R. WOODWARD (1914-1994)
THOMAS LANGER
MARSHALL J. CHICK
RICHARD S. BARTH
DOUGLAS HOLTZ
ROBERT P. MICHAL
TELEPHONE: (212) 319-4900
FACSIMILE: (212) 319-5101

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No.: M 013 058 619 US

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Barbara Villani

Barbara Villani

Assistant Commissioner for Patents
Washington, D.C. 20231

Attorney Docket No. 970719/LH

Transmitted herewith for filing is the patent application of

Inventor(s): Hiroyasu YAMADA
Tomoyuki SHIRASAKI
Yoshihiro KAWAMURA

65705 U.S. PTO
08/976217
11/21/97

Title:
"DISPLAY APPARATUS"

Priority Claim (35 U.S.C. 119) is made, based upon:

Japan	No. 331388/1996	November 28, 1996
Japan	No. 331389/1996	November 28, 1996

Enclosed herewith are:

[X] Specification (Description, Claims, Abstract): Pages 1 - 33; Number of claims 1 - 17

[X] Declaration and Power of Attorney [X] executed; [ ] unexecuted (supplied for information purposes)

[X] 21 Sheets of drawings, Figures 1 - 23 [X] Formal [ ] Informal

[X] Assignment and "Patents" Recordation Form Cover Sheet (PTO-1595)

[X] Certified copy (ies) of priority document(s) identified above

[ ] Information Disclosure Statement; [ ] Form PTO-1449

[ ] Preliminary Amendment

[ ] Verified Statement(s) Claiming Small Entity Status

[X] Receipt Postcard

	Number Filed	Number Extra	Rate	Calculations
Total Claims	17 -20 =	0	x $22.00 =	$
Independent Claims -	2 -3 =	0	x $82.00 =	$
MULTIPLE DEPENDENT CLAIMS			+ $270.00 =	$
			BASIC FEE	$ 790.00
ASSIGNMENT RECORDING FEE				$ 40.00
			Total of above Calculations	$ 830.00

To the extent not tendered by check, authorization is given to charge any fees under 37 CFR 1.16 and 1.17 during pendency of the application, or to credit any overpayment, to Deposit Account No. 06-1378. Duplicate copy of this letter is enclosed.

FRISHAUF, HOLTZ, GOODMAN, LANGER & CHICK, P.C.

By: LEONARD HOLTZ, Reg. No. 22,974

LH:bv
10//97

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ATTO S AT LAW

767 THIRD AVENUE, NEW YORK, N.Y. 10017-2023

11/21/97

N.R. FRISHAUF
HOLTZ
GOODMAN
R. WOODWARD (1914-1994)
LANGER
J. CHICK
D S. BARTH
DOUGLAS HOLTZ
ROBERT P. MICHAL
TELEPHONE: (212) 319-4900
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Assistant Commissioner for Patents
Washington, D.C. 20231

Attorney Docket No. 970719/LH

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FRISHAUF, HOLTZ, GOODMAN, LANGER & CHICK, P.C.

By: ____________________
LEONARD HOLTZ, Reg. No. 22,974

LH:bv
10//97

APPLICATION FOR

UNITED STATES LETTERS PATENT

S P E C I F I C A T I O N

Inventors: Hiroyasu YAMADA
Tomoyuki SHIRASAKI
Yoshihiro KAWAMURA

DISPLAY APPARATUS

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a display apparatus, and more particularly to an electroluminescent (hereinafter referred to as EL) display apparatus with a matrix display panel including EL elements.

Description of the Related Art

An EL display apparatus with organic EL elements, that is, display elements which emit light spontaneously and which are arranged in a matrix pattern, is known conventionally. A passive matrix type EL display apparatus is available as such an EL display apparatus. In this type of EL display apparatus, parallel cathode lines serve as common lines, while parallel anode lines which are perpendicular to the cathode lines and which are made of ITO (indium tin oxide) serve as data lines. An organic EL layer is arranged between the set of the cathode lines and the set of the anode lines. A positive voltage is applied to the data lines in each of cathode selection periods, thereby driving organic EL elements located at the intersections of the common lines and the data lines. The display apparatus displays an image which corresponds to the voltage applied to the data lines. In the case of the passive matrix type EL display apparatus which displays an image by driving such organic EL elements, the larger the number of common lines and/or the number of data lines, the shorter the selection period (duty H) per pixel. The period of time over which the organic EL layer keeps emitting light even after the application of a voltage between the set of the cathode lines and the set of the anode lines is short. In consideration of this, according to the conventional passive matrix type EL display apparatus, the instantaneous luminance of the organic EL layer of each pixel during the selection periods is intensified so that the organic EL layer apparently emits light over 1 frame period. The organic EL layer can emit light at a high instantaneous luminance by applying a high voltage to the organic EL layer. In this

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case, however, the organic EL layer can easily deteriorate.

In the passive matrix type EL display apparatus, the larger the number of common lines and data lines, the more possibility of the occurrence of crosstalk. This makes it difficult to enable the passive matrix type EL display apparatus to display a highly precise image.

Proposed as a display apparatus free from the above-described problems is an active matrix type display apparatus which includes, as shown in Fig. 22, pairs of thin film transistors which confer a voltage storing capability on the pixels. Each of the pairs of thin film transistors consists of a selection transistor T1 and a drive transistor T2. The selection transistor T1 is connected to a data line DL for supplying a data signal and a gate line GL for supplying a gate signal. The gate electrode of the drive transistor T2 is connected to the selection transistor T1. The source of the drive transistor T2 is connected to a constant voltage line VL. In this display apparatus, as shown in Fig. 23, the thin film transistors T1 and T2 are formed in a pixel area on a glass substrate 101, and the gates of the thin film transistors are covered with a gate insulation film 102. In an area adjacent to the thin film transistors T1 and T2, a transparent anode electrode 103 is provided on the gate insulation film 102. The transparent anode electrode 103 is connected to the drain of the drive transistor T2. A passivation film 104 covers the thin film transistors T1 and T2. A contact hole extending up to the transparent anode electrode 103 is formed in that part of the passivation film 104 which is located on the transparent anode electrode 103. An organic EL layer 106, which absorbs the energy generated due to the recombination of electrons and holes when a current flows, is deposited in the contact hole 105 extending up to the transparent anode electrode 103. A cathode electrode 107, which reflects visible light and which extends over a plurality of pixels, is laminated on the passivation film 104 and the organic EL layer 106. In this EL display apparatus, the efficiency of the injection of carriers into the organic EL layer 106 depends on the ionization potential of the anode electrode 103 and the electron affinity (the work function) of the cathode electrode 107. In order to improve the light emitting efficiency of the organic EL layer 106 which depends on the carrier injection efficiency, the cathode electrode 107 is formed using a material whose work function is low. Since the cathode electrode 107 is normally formed of a metal such as magnesium whose work function is low, the cathode electrode 107 reflects light having a wavelength in a range of wavelength of light which the organic EL layer 106 emits. Due to this, in the above EL display apparatus, the light emitted by the organic EL layer 106 travels through the anode electrode 103 and the substrate 101. The organic EL layer 106 is arranged so as not to overlap the thin film transistors T1 and T2. The purpose of thus arranging the organic EL layer 106 is to prevent the light emitted by the organic EL layer 106 from entering the thin film transistors T1 and T2. If the emitted light entered the thin film transistors T1 and T2, unnecessary photoelectromotive force would be generated in the channel regions of the thin film transistors T1 and T2, which entails the possibility of the thin film transistors T1 and T2 malfunctioning.

In the active matrix type EL display apparatus described above, the light emitting area of each pixel in which a part of the organic EL layer 106 is located is limited to an area in which the thin film transistors T1 and T2 are not located, and therefore the ratio of the light emitting area to the pixel area is small. If the light emitting area is enlarged and if a voltage applied to the organic EL layer 106 is intensified to attain the desired luminance, the organic EL layer 106 will be considerably deteriorated. The cathode electrode 107 is made of a metal, while the organic EL layer 106 is made of an organic material. Hence, it is difficult to join the cathode electrode 107 and the organic EL layer 106 together in a preferred condition. As time passes, a gap can easily occur between the cathode electrode 107 and the organic EL layer 106, which entails the possibility that the organic EL layer 106 may become emit no light. The organic EL layer can emit light at the same luminance as that of an inorganic EL layer even when the organic EL layer is formed as thin as 40nm to 250nm. The thicker the organic EL layer 106, the higher

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APPLICATION NUMBER	PATENT NUMBER	GROUP ART UNIT	FILE WRAPPER LOCATION
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The following fields have been set to Customer Number 1933 on 04/22/2005

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an effective voltage/current for causing the organic EL layer to emit light at the desired luminance. This limits the range of value at which the thickness of the organic EL layer can be set. Meanwhile, the thickness of the passivation film 104, which covers the thin film transistors T1 and T2, is set at such a value as to prevent the occurrence of a parasitic capacitance in the thin film transistors T1 and T2. Owing to a difference in thickness between the passivation film 104 and the organic EL layer 106, a step is present on the upper surfaces of the passivation film 104 and organic EL layer 106. There is the possibility that the cathode electrode 107 may break at that step. If the cathode electrode 107 breaks, the display apparatus cannot perform a display operation.

SUMMARY OF THE INVENTION

It is accordingly one object of the present invention to provide a display apparatus which has a light emitting area enlarged so as to emit light at a satisfactorily high luminescence even though a voltage applied to an EL layer is low, and which has a long luminance life.

It is another object of the present invention to provide a display apparatus which prevents light from entering active elements such as transistors, to thereby avoid the malfunction of the active elements.

In order to achieve the above objects, a display apparatus according to one aspect of the present invention comprises:

a substrate;

active elements which are formed over the substrate and which are driven by an externally supplied signal;

an insulation film formed over the substrate so as to cover the active elements and having at least one contact hole;

at least one first electrode formed on the at least one insulation film so as to cover the active elements, and connected to the active elements through the at least one contact hole, the at least one first electrode being made of a material which shields visible light;

an electroluminescent layer formed on the at least one first electrode and including at least one layer which emits light in accordance with a voltage applied to the at least one layer; and

at least one second electrode formed on the electroluminescent layer.

In this display apparatus, the at least one first electrode is formed so as to cover the active elements, and the electroluminescent layer and the at least one second electrode are laminated sequentially on the at least one first electrode. Under those conditions, the area occupied by an electroluminescent element, which is formed of the at least one first electrode, the electroluminescent layer and the at least one second electrode, is not limited by the active elements, and a light emitting area can be enlarged accordingly. This enables the electroluminescent layer to emit light at the same luminescence as that of a conventional display apparatus, even though a voltage applied to the electroluminescent layer is low. In this case, the load on the electroluminescent layer is small, which ensures a long life to the display apparatus. Since the at least one first electrode is made of a material which shields visible light, the light emitted by the electroluminescent layer does not enter the active elements, and therefore the active elements do not malfunction due to the light.

In order to achieve the above-described objects, a display apparatus according to the second aspect of the present invention comprises:

a substrate;

selection transistors formed over the substrate and arranged in a matrix pattern;

drive transistors formed over the substrate and arranged in a matrix pattern, each of the drive transistors being connected to one of the selection transistors;

address lines connected to the selection transistors and through which a signal for turning on the selection transistors is supplied;

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data lines connected to the selection transistors, a signal which corresponds to image data being supplied to the drive transistors through the data lines and the selection transistors while the selection transistors is on;

an insulation film formed over the substrate so as to cover the drive transistors, the address lines and the data lines, the insulation film having contact holes formed in correspondence with the drive transistors;

first electrodes made of a material which shields visible light, and formed on the insulation film so as to cover the election transistors and the drive transistors, the first electrodes being arranged in a matrix pattern in areas surrounded by the address lines and the data lines, and being connected to the drive transistors through the contact holes;

an electroluminescent layer formed on the first electrodes and including at least one layer which emits light in accordance with an applied voltage;

a second electrode formed on the electroluminescent layer;

a first driver circuit for selectively supplying the address signal to the address lines in sequence; and

a second driver circuit for supplying the image data to the data lines.

In this display apparatus, the first electrodes are arranged in the areas surrounded by the address lines and the data lines. Under this condition, electroluminescent elements, each being formed of one of the first electrodes and the electroluminescent layer and the second electrode, do not overlap the address lines or the data lines. Consequently, no parasitic capacitance occurs between the address/data lines and the electrodes of the electroluminescent elements, thus preventing signal transmission from being slowed down.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a plan view of an display apparatus according to one embodiment of the present invention;

Fig. 2 is a cross section taken along the line ~~A-A~~ 2-2 show in Fig. 1;

Fig. 3 is an equivalent circuit diagram showing an EL display circuit corresponding to one pixel;

Fig. 4 is an equivalent circuit diagram which specifically shows the structure of the EL display circuit;

Fig. 5 is a graph showing the electric characteristic of a drive transistor Q2;

Fig. 6 is a graph showing the luminance of an organic EL element;

Fig. 7 is a diagram illustrating driver circuits used in the display apparatus depicted in Fig. 1;

Fig. 8 is a diagram showing waveforms for driving the display apparatus;

Fig. 9 is a sectional view of a display apparatus which includes cathode electrodes, an organic EL layer, and a dielectric film between the organic EL layer and the cathode electrodes;

Fig. 10 is a sectional view of a display apparatus having R, G and B wavelength range conversion layers;

Fig. 11 is a sectional view of a display apparatus having R and G wavelength range conversion layers;

Fig. 12 is a sectional view of a display apparatus having R, G and B wavelength range conversion layers and color filter layers;

Fig. 13 is a sectional view of a display apparatus having color filter layers;

Fig. 14 is a sectional view of a display apparatus having R and G wavelength range conversion layers and color filter layers;

Fig. 15 is a sectional view of a display apparatus having concave R, G and B wavelength range conversion layers and color filters;

Fig. 16 is a diagram showing driver circuits used in a display apparatus which includes drive transistors Q2 and anode electrodes connected to the drive transistors Q2;

Fig. 17 is a plan view of a display apparatus according another embodiment of the present invention;

Fig. 18 is a cross section taken along the line ~~B-B~~ 18-18 shown in Fig. 17;

Fig. 19 is a cross section taken along the line ~~C-C~~ 19-19 shown in Fig. 17;

Fig. 20 is a diagram showing driver circuits used in the display apparatus illustrated in Fig. 17;

Fig. 21 is a sectional view of a display apparatus including a cathode electrode having a rough surface;

Fig. 22 is a plan view of a display apparatus according to the related art; and

Fig. 23 is a sectional view of the display apparatus illustrated in Fig. 21.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Display apparatuses according to embodiments of the present invention will now be described in detail, with reference to the accompanying drawings.

The structure of the display apparatus according to one embodiment of the present invention will now be described with reference to Figs. 1 and 2. Fig. 1 is a plan view of that part of the display apparatus of this embodiment which corresponds to one pixel. Fig. 2 is a cross section taken along the line ~~K-K~~ 2-2 shown in Fig. 1. In those drawings, a reference numeral 1 denotes the display apparatus. That part of the display apparatus 1 which is illustrated in Figs. 1 and 2 includes a substrate 2, an n-channel transistor Q1, an n-channel transistor Q2, an organic EL element 3, etc. which are formed over the substrate 2. The substrate 2 is made of glass or synthetic resin, and make visible light pass through. The n-channel transistor Q1 serves as a selection transistor, while the n-channel transistor Q2 serves as a drive transistor.

The structure of the display apparatus 1 will be more specifically described. Parallel address lines 4 extending in a predetermined direction are formed at equal intervals on the substrate 2 by patterning a gate metal film which is made of aluminum (Al) or the like. The selection transistor Q1 has a gate electrode 4A formed in integration with one address line 4. The drive transistor Q2 has a gate electrode 4B. Anodic oxidation films 5 are formed on the gate electrodes 4A and 4B and the address lines 4. A gate insulation film 6 which is made of silicon nitride is formed so as to cover the address lines 4, the gate electrodes 4A and 4B and the substrate 2. Semiconductor layers 7A and 7B, which are made of amorphous silicon (a-Si) or polycrystalline silicon (p-Si), are patterned on the gate insulation film 6 covering the gate electrodes 4A and 4B. Blocking layers 8A and 8B are formed on the middle portions of the semiconductor layers 7A and 7B, respectively, and extend in a channel widthwise direction. Ohmic layers 9A and 9B are formed on the semiconductor layer 7A, and are isolated from each other at the blocking layer 8A. The ohmic layer 9A is located on that side (the drain side) of the semiconductor layer 7A which is close to a drain, while the ohmic layer 9B is located on that side (the source side) of the semiconductor layer 7A which is close to a source. Ohmic layers 9C and 9D are formed on the semiconductor layer 7B, and are isolated from each other at the blocking layer 8B. The ohmic layer 9C is located on the drain side of the semiconductor layer 7B, while the ohmic layer 9D is located on the source side of the semiconductor layer 7B. In the selection transistor Q1, a data line 10A is laminated on and connected to the ohmic layer 9A located on the drain side, and a source electrode 10B is laminated on and connected to the ohmic layer 9B located on the source side. The source electrode 10B is connected to a contact hole 11 formed in the gate insulation film 6 of the drive transistor Q2. In the drive transistor Q2, a constant voltage line 12 which is set at a ground potential is laminated on and connected to the ohmic layer 9C located on the drain side, and a source electrode 13 having two ends is laminated on the ohmic layer 9D located on the source side. One end of the source electrode 13 is connected to the ohmic layer 9D, while the other end of the source electrode 13 is connected to one of cathode electrodes15 of organic EL elements 3. The gate electrode 4B, the constant voltage line 12 and the gate insulation film 6 therebetween form a capacitor Cp.

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The structures of the organic EL elements 3 will now be described. In the entire display area of the display apparatus, a flat interlayer insulation film 14 is deposited to a thickness of about 400nm to 1200nm on selection transistors Q1, drive transistors Q2 and the gate insulation film 6. Contact holes 14A are formed in those parts of the interlayer insulation film 14 which are located at end portions of the source electrodes 13 of the drive transistors Q2. Each of the contact holes14A and a corresponding one of the aforementioned end portions of the source electrodes 13 are located almost in the center of one pixel area. The cathode electrodes 15 which are made of MgIn or the like are patterned on the interlayer insulation film 14. Each cathode electrode 15 has an area and a shape (almost square in this embodiment) which are enough to cover the most part of one pixel area surrounded by the adjacent data lines10A and the adjacent address lines 4. The selection transistors Q1 and the drive transistors Q2 are formed under the cathode electrodes 15.

In the entire display area, an organic EL layer 16 is formed on the cathode electrodes 15 and the interlayer insulation film 14, and a transparent anode electrode 17 which is made of ITO (indium tin oxide) or IZnO (indium zinc oxide) is formed on the organic EL layer 16. A driving power source (not shown) is connected to the anode electrode 17.

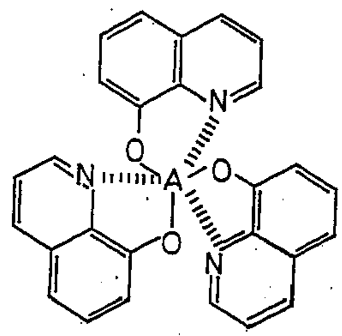
The organic EL layer 16 includes an electron carrying layer, a luminous layer and a hole carrying layer. Of those layers included in the organic EL layer 16, the electron carrying layer is closest to the cathode electrodes 15, and the hole carrying layer is farthest from the cathode electrodes 15. The electron carrying layer is made of aluminum-tris (8-hydroxyquinolinate) (hereinafter referred to as Alq3). The luminous layer is made of 96wt% 4,4'-bis (2,2-diphenylvinylene)biphenyl (hereinafter referred to as DPVBi) and 4wt% 4,4'-bis((2-carbazole)vinylene)biphenyl (hereinafter referred to as BCzVBi). The hole carrying layer is made of N,N'-di(α-naphthyl)-N,N'-diphenyl-1,1'-biphenyl-4,4'-diamine (hereinafter referred to as α-NPD). The thickness of the organic

11

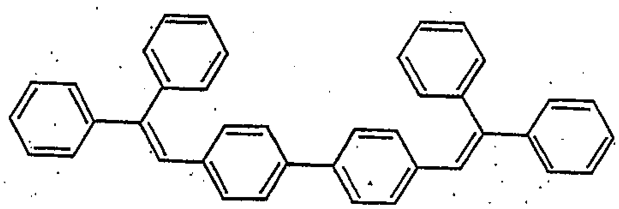
EL layer 16 is on the order of 40nm to 250nm.

The constitutional formulas of Alq3, DPVBi, BCzVBi and α-NPD are shown below:

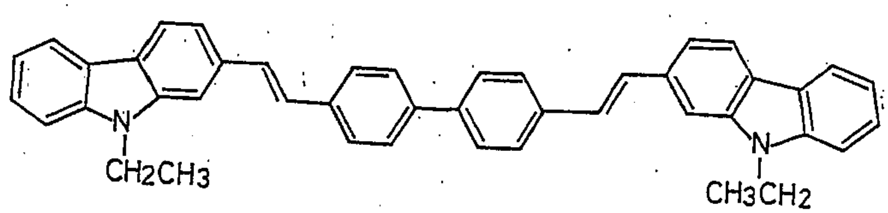
[Formula 1]



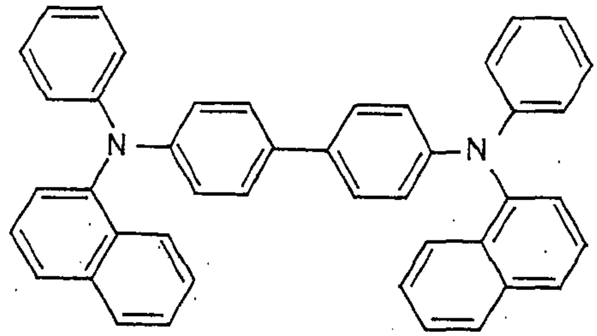
[Formula 2]



[Formula 3]



[Formula 4]

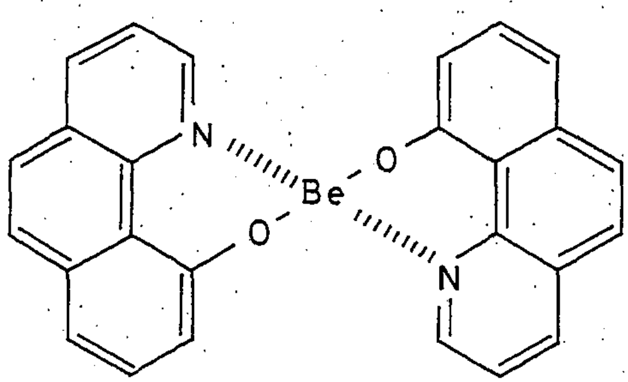


The organic EL layer 16 thus formed emits blue light upon the application of a predetermined voltage.

When the organic EL layer 16 between the anode electrode 17 and the cathode electrodes 15 includes a luminous layer which can carry electrons and which is made of beryllium-bis(10-hydroxybenzo[h] quinolinate) (hereinafter referred to as Bebq2), and a hole carrying layer made of α-NPD, the organic EL layer 16 can emit green light.

The constitutional formula of Bebq2 is shown below:

[Formula 5]



In the display apparatus 1 of this embodiment, each cathode electrode 15 covers one pixel area surrounded by the adjacent data lines 10A and the adjacent address lines 4, and therefore each EL element 3 emits light over the entirety of one pixel area. This remarkably improves the aperture ratio per pixel in the display apparatus 1 of this embodiment over that of the conventional active matrix type EL display apparatus. The cathode electrodes 15 are formed of MgIn which reflects light. Therefore, the light emitted by the organic EL layer 16 when a voltage is applied between the anode electrode 17 and the cathode electrodes 15 comes out through the anode electrode 17 without leaking downward (toward the substrate 2). Thus, the light does not enter the selection transistors Q1 and the drive transistors Q2, and hence the malfunction of the transistors Q1 and Q2 due to the photoelectromotive force is avoided. The light emitted by the organic EL layer 16 goes out of the display apparatus through the transparent anode electrode 17, without the light being absorbed by the substrate 2, etc., and therefore bright display is realized.

The area of the interface between the organic EL layer 16 and the cathode electrodes 15 is large. This permits the cathode electrodes 15 and the organic EL layer 16 to be joined together in a preferred condition, and ensures to the display apparatus 1 of this embodiment a luminous life improved over that of the conventional active matrix type EL display apparatus. The cathode electrodes 15 are formed on a flat layer having no steps, and therefore are free from the possibility of the cathode electrodes 15 breaking at steps. The cathode electrodes 15 are arranged so as not to overlap the address lines 4 or the data lines 10A. Consequently, the slowing down of signal transmission, caused by a parasitic capacitance which would occur if the cathode electrodes 15 were arranged so as to overlap the address lines 4 or the data lines 10A, is prevented.

When a layer like the organic EL layer 16 is subjected to a temperature higher than a glass-transition temperature for an organic EL material, its light emitting characteristic deteriorates considerably. In consideration of this, according to the display apparatus of this embodiment, the organic EL layer 16 is formed after the selection transistors Q1 and the drive transistors Q2 are manufactured by a heat treatment under a temperature of several-hundred degrees. The organic EL layer 16 is not subjected to a temperature higher than the glass-transition temperature, and therefore the deterioration of the light emitting characteristic does not occur.

The organic EL layer 16 is thinner than an inorganic EL layer. Moreover, the thickness to which the organic EL layer is formed through vapor deposition using the organic EL material can be very easily controlled during the process of forming the organic EL layer. When the organic EL layer 16 is formed to the thickness corresponding to the wavelength at the luminance peak of the light emitted by the organic EL layer 16 (in other words, the wavelength of the most intense component of the light emitted by the organic EL layer 16), the resonance effect which permits light to easily come out from the organic EL layer 16 can be achieved. For example, in the case of an organic EL element which emits blue light, the resonance effect can be attained when it is formed to the thickness of 40nm to 50nm. In the case of an organic EL element which emits green light, the resonance effect can be attained when it is formed to the thickness of 50nm to 60nm.

The driving principle of the display apparatus according to this embodiment will now be described. Figs. 3 and 4 are equivalent circuit diagrams showing that part of the display apparatus 1 which corresponds to one pixel. As shown in Fig. 3, a display circuit in that part of the display apparatus 1 which corresponds to one pixel includes an organic EL element 3 and a voltage controller Cv. As shown in Fig. 4, the voltage controller Cv has a selection transistor Q1, a drive transistor Q2 and a capacitor Cp. The driving power source Ps for supplying a constant voltage Vdd is connected to the anode electrode 17 of the organic EL element 3. The voltage controller Cv is connected to the cathode electrode of the organic EL element 3. The drain electrode of the drive transistor Q2 in the voltage controller Cv is grounded via the constant voltage line 12.

The voltage controller Cv can control a voltage so that the luminance of the organic EL element 3 varies in accordance with gradation data corresponding to image data

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which is input at the time of selection. An address line 4 is connected to the gate electrode 4A of the selection transistor Q1, and a data line 10A is connected to the drain electrode of the selection transistor Q1. The gate of the selection transistor Q1 is turned on in response to a selection signal supplied through the address line 4. While the selection transistor Q1 is on, an image data voltage supplied through the data line 10A is accumulated in the capacitor Cp. The capacitor Cp retains the image data voltage almost over 1 frame period. The resistance in the drive transistor Q2 is controlled by the voltage retained in the capacitor Cp. The organic EL element 3 emits light according to written information, in other words, the retained voltage.

The electric characteristic of the organic EL element 3 will now be described with reference to Figs. 5 and 6. As shown in Fig. 5, the source-drain current Ids of the drive transistor Q2 is shifted in accordance with a gate voltage Vg applied to the gate electrode of the drive transistor Q2. The source-drain current Ids of the drive transistor Q2 becomes saturated when a source-drain voltage Vsd applied between the source and drain of the drive transistor Q2 exceeds approximately 5V. As shown in Fig. 6, the organic EL element 3 has a luminance characteristic according to an anode-cathode voltage Vac (a forward bias is positive). In this embodiment, the luminance (gradation) of the organic EL element 3 is controlled by controlling the anode-cathode voltage Vac in a range of 0(V) to Vdd (V).

The source electrode 10B of the selection transistor Q1 is connected to the gate electrode 4B of the drive transistor Q2 through a contact hole 14B. A writing/deleting voltage is applied to the drain electrode of the selection transistor Q2 through the data line 10A.

Driver circuits used in the display apparatus 1 will now be explained with reference to Fig. 7. As shown in this drawing, one selection transistor Q1, one drive transistor Q2 and one organic EL element 3 are provided in each pixel area. One address line 4 is connected to the gate electrode 4A of each selection transistor Q1. One data line 10A is connected to the drain electrode of each selection transistor Q1. Moreover, as shown in Fig. 8, a selection voltage Vad having a positive potential is applied to a selected one of the address lines 4, and a non-selection voltage Vnad having a ground potential is applied to the other non-selected address lines 4. In the selection periods, a writing voltage Vr according to the luminance is applied to the data lines 10A. The driving power source Ps continually applies the constant voltage Vdd to the anode electrode 17.

The operation of the display apparatus 1 according to this embodiment will now be described.

A gate driver circuit DC1 illustrated in Fig. 7 applies voltages through its terminals X1 to Xm to the address lines 4, thereby sequentially selecting the address lines 4. When selecting one address line 4 connected to the terminal X1, the gate driver circuit DC1 applies the selection voltage Vad to that address line, and applies the non-selection voltage Vnad to the other address lines. At that time, a drain driver circuit DC2 applies the writing voltage Vr through its terminals Y1 to Yn and the data lines 10A to the drain electrodes of those of the selection transistors Q1 which are connected to the address line 4 connected to the terminal X1. In accordance with the writing voltage Vr, a voltage of 0V to Vdd (V) is applied to those of the organic EL elements 3 which correspond to pixels P (1, 1) to P (1, n), and the organic EL elements 3 applied with the voltage emit light at the luminance (gradation) according to the applied voltage. In a non-selection period during which the address line 4 connected to the terminal X1 is not selected, the capacitors Cp connected to that address line retain the writing voltage Vr over 1 frame period. Consequently, currents keep flowing into the drains of drive transistors Q2 and then into organic EL elements 3 over 1 frame period, and those EL elements emit light over 1 frame period. In place of the selection voltage Vad, the gate driver circuit DC1 applies the non-selection voltage Vnad to the address line 4 connected to the terminal X1. In order to select another address line 4 connected to

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the terminal X2, the gate driver circuit DC1 applies the selection voltage Vad to the address line 4 connected to the terminal X2. In the same manner as that descried above, those of the organic EL elements 3 which correspond to pixels P (2, 1) to P (2, n) emit light at the luminance according to the applied voltage.

Thus, in the display apparatus 1 of this embodiment, the organic EL elements 3 can keep emitting light even while their corresponding address lines 4 are not selected. Accordingly, even though the display apparatus 1 is designed to display a highly precise image, the luminance of the organic EL elements 3 need not be set high. For example, in order to attain a luminance of 100cd/m^2 at the surface of the screen of a conventional passive matrix type display apparatus, the organic EL elements have to emit light at a luminance of about 48000cd/m^2. However, in the case of the display apparatus of this embodiment, a luminance of approx. 100cd/m^2 suffices as the luminance of the organic EL elements 3.

According to the display apparatus 1 of this embodiment, unlike in the case of the passive matrix type organic EL display apparatus proposed conventionally, the organic EL elements 3 can keep emitting light over 1 frame period, and the display apparatus 1 can display an image without causing the organic EL elements 3 to emit light at a high luminance. The display apparatus 1 of this embodiment can display a highly precise halftone image, and the expressivity of the displayed image is improved. In order to vary a carrier potential at a high speed, a writing voltage which is applied to the data lines 10A while the organic EL elements 3 are emitting no light can be set at a negative potential in accordance with an increase in the number of address lines 4, insofar as a P-channel current is not adversely affected.

Further, as shown in Fig. 9, a dielectric film having a thickness of 5nm or less and which is formed of at least one material selected from a group consisting of SiO2, Lif, Naf, Caf2 and Mgf2, may be provided between the organic EL layer 16 and the cathode electrodes 15. When a voltage having a predetermined value is applied between the

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anode electrode 17 and the cathode electrode 15, electrons are injected from the cathode electrodes 15 into the organic EL layer 16 through the dielectric film 18 due to the tunneling effect. After the formation of, for example, the cathode electrodes 15 which are easily oxidized, the dielectric film 18 is formed so as to cover the cathode electrodes 15 by a vacuum deposition method or the like. The cathode electrodes 15 covered by the dielectric film 18 are not exposed to the air. Accordingly, the electron injecting capability of the cathode electrodes 15 is maintained in an excellent condition. It is preferred that the dielectric film 18 be one which can be successfully joined with the cathode electrodes 15 and the organic EL layer 16 in a preferred state.

In the multicolor (full-color) type display apparatus 1 illustrated in Fig. 10, wavelength range conversion layers 52R, 52G and 52G, sandwiched between an insulation film 53 formed on the anode electrode 17 and a substrate 51, are provided in one-to-one correspondence with the cathode electrodes 15. A black mask containing chromium oxide is formed in the areas corresponding to the address lines 4 and the data lines 10A. The wavelength range conversion layers 52R have the photoluminescence effect of absorbing light which the organic EL layer 16 emits in a blue wavelength range and emitting light in a longer red wavelength range. The wavelength conversion layers 52G have the photoluminescent effect of absorbing light which the organic EL layer 16 emits in the blue wavelength range and emitting light in a longer green wavelength range. The wavelength conversion layers 52B have the photoluminescent effect of absorbing light which the organic EL layer 16 emits in the blue wavelength range and emitting light in a longer blue wavelength range.

In this display apparatus 1, the organic EL layer which emits blue light of a single color is satisfactory. The wavelength conversion layers 52R convert the blue light emitted by the organic EL layer 16 into red light, and emit the converted red light. The wavelength conversion layers 52G convert the blue light emitted by the organic EL layer 16 into green light, and emit the converted green light. The wavelength conversion

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layers 52B convert the blue light emitted by the organic EL layer 16 into blue light, and emit the converted blue light. Therefore, the display apparatus 1 can easily display a full-color image. The areas occupied by the wavelength conversion layers 52R, 52G and 52B are set equal to those occupied by the cathode electrodes 15, and therefore the light emitting area of each pixel is not small even through the transistors Q1 and Q2 are present. This permits the wavelength conversion layers to perform the energy conversion with efficiency.

It is preferred that a material having a refractive index which approximates to that of the wavelength conversion layers 52R, 52G and 52B, which are in contact with the insulation film 53, be selected as the material of the insulation film 53. This is because when the insulation film 53 is formed of such a material, the degree of the reflection of light at the interface between the insulation film 53 and the wavelength conversion layers 52R, 52G and 52B is small.

The display apparatus 1 illustrated in Fig. 11 includes the wavelength conversion layers 52R and 52G. This display apparatus 1 displays a multicolor (full-color) image, using as is the blue light emitted by the organic EL layer 16.

In the display apparatus 1 illustrated in Fig. 12, color filters 55R, 55G and 55B are provided between a substrate 1 and the wavelength conversion layers 52R, 52G and 52B, respectively. Of the light incident on the color filter layers 52R, the light components in the red wavelength range pass through the color filter layers 52R, but the light components in the other wavelength ranges are absorbed by the color filter layers 52R. Of the light incident on the color filter layers 52G, the light components in the green wavelength range pass through the color filter layers 52G, but the light components in the other wavelength ranges are absorbed by the color filter layers 52G. Of the light incident on the color filter layers 55B, the light components in the wavelength range in which the blue light emitted by the wavelength conversion layers 52B falls pass through the color filter layers 55B, but the other light components are absorbed by the

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color filter layers 55B. In other words, the color filter layers 55B absorb the blue light emitted by the organic EL layer 16, but allow the blue light emitted by the wavelength conversion layers 52B to pass through the color filter layers 55B.

The color filter layers 55R have such a characteristic that they absorb, of the incident light entering the wavelength conversion layers 52R through the substrate 51, the light components in the wavelength range of the light by which the wavelength conversion layers 52R are excited (i.e., the light components in the same wavelength range as that in which excitation light components of the blue light emitted by the organic EL layer 16 fall). Under this condition, the wavelength conversion layers 52R are not excited by the light coming from the outside of the display apparatus 1. The color filter layers 55G have such a characteristic that they absorb, of the incident light entering the wavelength conversion layers 52G through the substrate 51, the light components in the wavelength range of the light by which the wavelength conversion layers 52G are excited (i.e., the light components in the same wavelength range as that in which of the excitation light components of the blue light emitted by the organic EL layer 16 fall). Therefore, the color conversion layers 52G are not excited by the external light coming from the outside of the display apparatus 1. The wavelength conversion layers 52B emit blue light in a blue wavelength range wider than that of the blue light emitted by the organic EL layer 16. The color filter layers 55B have such a characteristic that they absorb the blue light emitted by the organic EL layer 16 but allow the blue light emitted by the wavelength conversion layers 52B to pass through the color filter layers 55B. Consequently, the wavelength conversion layers 52B are not excited by the external light coming from the outside of the display apparatus 1.

When the light emitted by the wavelength range conversion layers 52R, 52G and 52B enter the color filter layers 55R, 55G and 55B, light in narrower wavelength ranges than those of the light emitted by the layers 52R, 52G and 52B and having higher luminance peaks than those of the light emitted by the layers 52R, 52G and 52B, come

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out from the filter layers 55R, 55G and 55B. Accordingly, the color purity of light going outside the display apparatus 1 is high. The black mask 54 shields areas between the color filter layers 55R, 55G and 55B from the external light radiated toward those areas, and therefore the external light do not enter the wavelength conversion layers 52R, 52G and 52B so as to cause the layers 52R, 52G and 52B to perform light emission. The black mask 54 also prevents light from being reflected by the address lines 4 and the data lines 10A. This ensures a considerably excellent display characteristic to the display apparatus 1. Since no light enters also the transistors Q1 and Q2 by virtue of the presence of the black mask 54 and cathode electrodes 17, the malfunction of the transistors Q1 and Q2 does not occur.

As shown in Fig. 13, the organic EL layer 16 may include a red EL layer 16R, a green EL layer 16G and a blue EL layer 16B. It is possible to cause light emitted by those EL layers 16R, 16G and 16B to enter the color filter layers 55R, 55G and 55B, respectively, and to come out therefrom as light having higher luminance peaks.

In Fig. 14, color filter layers 56B have such a characteristic that when the blue light emitted by the organic EL layer 16 enters the color filter layers 56B, blue light in a narrower wavelength range than that of the blue light emitted by the organic EL layer 16 and having a higher luminance peak than that of the blue light emitted by the organic EL layer 16, comes out from the color filter layers 56B. Hence, without using a wavelength conversion layer for blue, the display apparatus 1 illustrated in Fig. 14 can display a full-color image if the wavelength conversion layers 52R and 52B are provided in correspondence with the color filter layers 55R and 55G.

The display apparatus 1 illustrated in Fig. 15 has wavelength conversion layers 57R, 57G and 57B each having a concave surface facing the organic EL layer 16. Even when the light emitted by the organic EL layer 16 is reflected at the interfaces between the insulation film 53 and the wavelength conversion layers 57R, 57G and 57B, the most part of the reflected light is reflected by the cathode electrodes 15. The light reflected

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by the cathode electrodes 15 falls on the interfaces between the insulation film 53 and the wavelength conversion layers 57R, 57G and 57B at an incident angle different from the initial incident angle. Under this condition, it is easy for the wavelength conversion layers 57R, 57G and 57B to catch the light reflected by the cathode electrodes 15. Thus, in the display apparatus 1 illustrated in Fig. 15, the light emitted by the organic EL layer 16 enters the wavelength conversion layers 57R, 57G and 57B without the light being wasted.

The display apparatus 1 of the above embodiment has the structure shown in Fig. 7. However, as shown in Fig. 16, the positions of the anode and cathode electrodes can be reversed. In this case, the driving power source Ps continually applies a constant negative voltage (-Vdd) to the cathode electrodes of the organic EL elements 3.

It is possible to provide the dielectric film 18 shown in Fig. 9 between an anode electrode 16 and the cathode electrodes 15 in the display apparatuses 1 illustrated in Figs. 10 to 15.

The structure of a display apparatus according to another embodiment of the present invention will now be described with reference to Figs. 17 to 20. Fig. 17 is a plan view of that part of the display apparatus of this embodiment which corresponds to one pixel. Fig. 18 is a cross section taken along the line B-B shown in Fig. 17. Fig. 19 is a cross section taken along the line C-C shown in Fig. 17.

Reference numeral 21 in the drawings denotes the display apparatus. In the display apparatus 21 of this embodiment, as shown in Figs. 17 to 19, a grounded electrode 23 is formed on a substrate 22 over the entire display area. A base insulation film 24, which is made up of a silicon oxide film and/or the like, is patterned on the grounded electrode 23. Formed on the base insulation film 24 are parallel address lines 48, which are connected each to one of terminals X1 to Xm connected to a gate driver circuit (described later), and which are spaced at predetermined intervals. A first gate insulation film 25 is formed on the address lines 48 and the base insulation film 24.

As show in Figs. 17 and 18, a first semiconductor layer 26 and a second semiconductor layer 27, which are made of amorphous silicon and/or the like, are patterned on the first gate insulation film 25. The first semiconductor layer 26 enables the address lines 48 to function as gate electrodes. A blocking layer 28 is patterned on that part of the semiconductor layer 26 which is the middle portion of the layer 26 in a gate lengthwise direction (a vertical direction in Fig. 17). A second gate insulation film 29 is formed so as to cover the upper and side surfaces of the second semiconductor layer 27. The blocking layer 28 and the second gate insulation film 29 are made of silicon nitride and/or the like, and are formed by a CVD method. A source electrode 30 and a drain electrode 31 are formed on both sides of the first semiconductor layer 26 with respect to a gate widthwise direction so that the source and drain electrodes 30 and 31 are connected to the first semiconductor layer 26 (in Fig. 18, the source electrode 30 is formed on the right part of the first semiconductor layer 26, while the drain electrode 31 is formed on the left part of the first semiconductor layer 26). The address lines 48, the first gate insulation film 25, the first semiconductor layer 26, the source electrode 30 and the drain electrode 31 thus formed constitute a selection transistor Q3. The input impedance of the selection transistor Q3 is set at a large value. The drain electrode 31 shown in Fig. 17 is patterned and formed in integration with a corresponding one of data lines 47, which are connected each to one of terminals Y1 to Yn connected to a drain driver circuit (described later). The source electrode 31 shown in Fig. 17 is patterned and formed in integration with a gate electrode 32 which crosses over the middle part of the second semiconductor layer 27, with the second gate insulation film 29 being located between the second semiconductor layer 27 and the gate electrode 32. The source electrode 30 and the gate electrode 32 are patterned and formed in integration with a capacitor upper electrode 34 included in a capacitor Cp2. The capacitor Cp2 includes the capacitor upper electrode 34, the second gate insulation film 29 formed under the capacitor upper electrode 34, the first gate insulation film 25 and a capacitor lower

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electrode 35. The capacitor lower electrode 35 is connected to the grounded electrode 23 through a contact hole 24A formed in the base insulation film 24.

A source electrode 36 and a drain electrode 37 are formed on both sides of the gate electrode 32 of the second semiconductor layer 27. The second semiconductor layer 27, the second gate insulation film 29, the gate electrode 32, the source electrode 36 and the drain electrode 37 form a drive transistor Q4. The drain electrode 37 shown in Fig. 17 is formed in integration with a power source line 38 which is parallel with the data lines 47 and which applies a voltage for driving organic EL elements 39. The source electrode 36 is connected to an EL upper electrode 40 included in an organic EL element 39. In the display apparatus 21, the selection transistor Q3, the drive transistor Q4 and the capacitor Cp2 form a voltage controller.

As shown in Figs. 17 and 19, each organic EL element 39 includes a light-shielding EL lower electrode 42 made of MgIn and/or the like and serving as a cathode electrode, an organic EL layer 41 formed on the EL lower electrode 42, and a transparent EL upper layer 40 made of ITO and/or the like and formed on the organic EL layer 41. The EL upper electrode 40 serves as an anode electrode.

The organic EL layer 41 includes an electron carrying layer, a luminous layer and a hole carrying layer. Of those layers included in the organic EL layer 41, the electron carrying layer is closest to the EL lower electrode 42, and the hole carrying layer is farthest from the EL lower electrode 42. The electron carrying layer is made of Alq3. The luminous layer is made of 96wt% DPVBi and 4wt% BCzVBi. The hole carrying layer is made of N,N'-di(α-naphthyl)-N,N'-diphenyl-1,1'-biphenyl-4,4'-diamine (referred to as α-NPD).

The organic EL element 39 is formed on an interlayer insulation film 43 which covers the selection transistor Q3 and the drive transistor Q4 and which is formed over the entire display area. The EL lower electrode 42 is connected to the grounded electrode 23 through a contact hole 44 formed in the first gate insulation film 25 and the

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base insulation film 24. Of the area surrounded by a two-dot chain line in Fig. 17, the part except a projecting portion 40A is covered by the EL lower electrode 42. The EL lower electrode 42, which is a rectangular electrode covering the selection transistor Q3, the drive transistor Q4 and the capacitor Cp2, etc., occupy the most part of the area occupied by one pixel. The organic EL layer 41 is a layer extending over the entire display area. The EL upper electrode 40 extends over the area surrounded by the two-dot chain line in Fig. 17. The projecting portion 40A of the EL upper electrode 40 is connected to the source electrode 36 of the drive transistor Q4 through a contact hole 45, as shown in Fig. 17. The power source line 38 is connected to the driving power source Ps which continually applies the constant voltage Vdd.

Fig. 20 is a diagram showing driver circuits included in the display apparatus 21 illustrated in Fig. 17.

A drive method for having the display apparatus 21 of this embodiment emit light will now be described.

A gate driver circuit DC3 is driven to output a selection signal to any one of the address lines 48. In synchronization with the output of the selection signal to one address line 48, a drain driver circuit DC4 is driven to output a data signal to the data lines 47. When the number of address lines 48 is N, 1 scanning period during 1 frame period T is T/N, and the selection signal has such a voltage value as to enable the writing voltage Vr exceeding the gate threshold value Vth of selection transistors Q3 to be applied to the address line 48 during 1 scanning period. Upon the application of the selection signal, selection transistors Q3 in Fig. 20 are turned on, and a voltage according to the data signal output to the data lines 47 is applied to the gate electrodes 32 of drive transistors Q4, and is stored in capacitors Cp2. The capacitors Cp2 retain the voltage according to the data signal over 1 frame period, and the value of the resistance in the drive transistors Q4 is controlled to a substantially constant value until the next selection period by the potential Vc retained in the capacitors Cp. In accordance with the value of the resistance in the drive transistors Q4, the potential Vdd is applied through the power source line 38 to the organic EL layer 41. As a result, a substantially constant current flows through the organic EL layer 41, and the organic EL layer 41 emits light at a substantially constant luminance during 1 frame period. By repeating those operations, the display apparatus 21 can maintain the state of emitting light, and accordingly the contrast in an image displayed on the display apparatus 21 is remarkably improved over the conventional passive matrix type EL display apparatus. Since a current supplied to the organic EL layer 41 can be precisely controlled through the use of the transistors Q3 and Q4, the display apparatus 21 can perform gray-scale display with ease. If wavelength conversion layers and/or color filter layers are used as shown in Figs. 10 to 15, the display apparatus 21 can perform full-color (multicolor) display as well.

In the display apparatus 21 of this embodiment, the area occupied by each EL lower electrode 42 is not limited by the thin film transistors Q3 and Q4. Therefore, the ratio of the light emitting area to each pixel area can be enhanced, with the result that the organic EL elements 39 can emit light at the desired luminance without the application of an excessively high voltage.

Since the EL lower electrodes 42 are made of a light-shielding material, the light emitted by the organic EL layer 41 does not enter the selection transistors Q3 or drive transistors Q4 located below the EL lower electrodes 42. Accordingly, the transistors Q3 and Q4 are prevented from malfunctioning due to such light, and the display apparatus 21 of this embodiment can be reliably driven.

The area of the interface between the organic EL layer 41 and the EL lower electrodes 42 is large. This permits the organic EL layer 41 and the EL lower electrodes 42 to be joined together in a preferred condition, and ensures to the display apparatus 21 of this embodiment a luminous life improved over that of the conventional active matrix type EL display apparatus. The EL lower electrodes 42 are formed on a

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flat layer having no steps, and therefore are free from the possibility of the EL lower electrodes 42 breaking at steps.

The grounded electrode 23 formed over the entire display area is made of a light-shielding metal such as Al, and therefore can shield the light coming from the substrate 22 and can make the light enter the transistors Q3 and Q4.

In the embodiments described above, polycrystalline silicon can be used in place of amorphous silicon in order to form the semiconductor layers of the transistors. However, amorphous silicon elements are preferable to polycrystalline silicon elements.

In the above-described embodiments, impurity-doped silicon nitride films, which has a capability to catch carriers and store a gate voltage, can be employed as the gate insulation films of the drive transistors. By thus conferring the voltage storing capability on the drive transistors themselves in addition to the use of the capacitors, the voltage storing capability of the entire circuitry is improved.

In the above embodiments, the transistors are MOS transistors. However, they may be bipolar transistors. Due to the input impedance of each of the selection transistors being set at a large value, the selection transistors have the effect of suppressing the amount of current flowing through the address lines to a great extent when a selection signal voltages is applied to the bases, even in the case where the number of selection transistors connected to each selection signal line is large. Accordingly, the amount of current which the organic EL elements require can be made small, and the life of the power source can be enhanced. Similarly in the case where a data signal voltage is applied to the drive transistors, the attenuation of the voltage stored in the capacitors can be suppressed to a great extent so as to prolong the period of time over which the data signal voltage is retained, due to the input impedance of those transistors being set at a large value.

The present invention is not limited to the above embodiments, and various changes can be made without departing from the scope of the present invention. For

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example, the cathode electrodes are made of MgIn in the above embodiments. However, a visible-light shielding material having a low work function and containing Mg and/or the like can also be used. It is also possible to form the cathode electrodes 15 so as to have rough surfaces and to form the organic EL layer 16 on those rough surfaces, as shown in Fig. 21. The cathode electrodes 15 having such rough surfaces can be formed using an Mg material doped with Ag. In this case, not only flicker due to the reflection of the external light at the cathode electrodes 15 is suppressed, but also the area of the interface between the organic EL layer 16 and the cathode electrodes 15 is increased such that successful joining is attained between the organic EL layer 16 and the cathode electrodes 15, ensuring a long luminous life to the organic EL elements 3. The display apparatuses according to the above embodiments display images through utilization of the light emitted by the organic EL elements 3 only. However, the display apparatuses may include liquid crystal display panels as shutters.

In the above-described embodiments, the driving power source Ps continually applies a constant voltage to the organic EL elements. However, since the luminance of the organic EL elements is determined by the amount of recombination of electrons and holes, that is, the amount of current, the structure wherein the driving power source Ps applies a constant voltage is particularly advantageous when the areas occupied by the pixels are substantially equal to each other as in the case of matrix panels according to the above embodiments.

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What is claimed is:

1. A display apparatus comprising:

a substrate;

active elements which are formed over said substrate and which are driven by an externally supplied signal;

an insulation film formed over said substrate so as to cover said active elements and having at least one contact hole;

at least one first electrode formed on said at least one insulation film so as to cover said active elements, and connected to said active elements through said at least one contact hole, said at least one first electrode being made of a material which shields visible light;

an electroluminescent layer formed on said at least one first electrode and including at least one layer which emits light in accordance with a voltage applied to said at least one layer; and

at least one second electrode formed on said electroluminescent layer.

2. ~~The display apparatus according to claim 1, wherein said electroluminescent layer is formed of an organic electroluminescent material.~~

~~3.~~ 2. The display apparatus according to claim 1, wherein said at least one first electrode is formed of a conductive material containing magnesium.

~~4.~~ 3. The display apparatus according to claim 1, wherein ~~said at least one~~ first electrode has a rough surface which is ~~in contact with said electroluminescent~~ layer.

~~5.~~ 4. The display apparatus according to claim 1, wherein said active elements are a selection transistor which is turned on in response to an externally supplied address signal and a drive transistor, which is driven by a signal corresponding to image data supplied externally through said selection transistor while said selection transistor is on, for controlling a voltage to be applied to said electroluminescent layer, said selection transistor and said drive transistor forming a pair.

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6. The display apparatus according to claim 5, wherein said at least one first electrode is connected to said drive transistor through said at least one contact hole.

7. The display apparatus according to claim 5, wherein:

said display apparatus further comprises a capacitor for retaining the signal corresponding to the image data externally supplied through said selection transistor while said selection transistor is on; and

while said selection transistor is off, said drive transistor is driven by the signal retained in said capacitor.

8. The display apparatus according to claim 1, wherein:

said active elements are transistors forming pairs and arranged in a matrix pattern, one transistor of each of said pairs being a selection transistor which is turned on in response to an externally supplied address signal, and the other transistor of each of said pairs being a drive transistor, which is driven by a signal corresponding to image data supplied externally through said selection transistor while said selection transistor is on, for controlling a voltage to be applied to said electroluminescent layer;

said selection transistor of each of said pairs is connected to one of address lines and one of data lines, said address lines being formed over said substrate and being supplied with said address signal, and one of said data lines being formed over said substrate and being supplied with said image data; and

said at least one first electrode is plural in number, and the plurality of first electrodes are arranged in a matrix pattern in areas surrounded by said address lines and said data lines.

9. The display apparatus according to claim 1, wherein a constant voltage is applied to said second electrode.

10. The display apparatus according to claim 1, further comprising at least one wavelength conversion layer formed over said at least one second electrode, said at least one wavelength conversion layer emitting light in a first wavelength range by

absorbing light in a second wavelength range emitted from said electroluminescent layer.

11. The display apparatus according to claim 10, wherein said at least one wavelength conversion layer has a concave surface facing said at least one second electrode.

12. The display apparatus according to claim 10, wherein said at least one wavelength conversion layer has at least two of a red conversion layer which emits light in a red wavelength range, a green conversion layer which emits light in a green wavelength range, and a blue conversion layer which emits blue light.

13. The display apparatus according to claim 1, wherein:

said display apparatus further comprises at least one filter formed above said at least one second electrode; and

light lays in a first wavelength range pass through said at least one filter selectively when incident light rays in a second wavelength range including said first wavelength range enter said at least one filter.

14. The display apparatus according to claim 13, wherein

said at least one filter has a red filter which makes light in a red wavelength range pass through, a green filter which makes light in a green wavelength range pass through, and a blue filter which makes light in a blue wavelength range pass through.

15. The display apparatus according to claim 1, wherein said electroluminescent layer has a thickness whose value falls in a range of wavelength of light which said electroluminescent layer emits.

16. A display apparatus comprising:

a substrate;

selection transistors formed over said substrate and arranged in a matrix pattern;

drive transistors formed over said substrate and arranged in a matrix pattern, each of said drive transistors being connected to one of said selection transistors;

address lines connected to said selection transistors and through which a signal for turning on said selection transistors is supplied;

data lines connected to said selection transistors, a signal which corresponds to image data being supplied to said drive transistors through said data lines and said selection transistors while said selection transistors is on;

an insulation film formed over said substrate so as to cover said drive transistors, said address lines and said data lines, said insulation film having contact holes formed in correspondence with said drive transistors;

first electrodes made of a material which shields visible light, and formed on said insulation film so as to cover said election transistors and said drive transistors, said first electrodes being arranged in a matrix pattern in areas surrounded by said address lines and said data lines, and being connected to said drive transistors through said contact holes;

an electroluminescent layer formed on said first electrodes and including at least one layer which emits light in accordance with an applied voltage;

a second electrode formed on said electroluminescent layer;

a first driver circuit for selectively supplying said address signal to said address lines in sequence; and

a second driver circuit for supplying said image data to said data lines.

17. The display apparatus according to claim 16, wherein a constant voltage is applied to said second electrode.

ABSTRACT OF THE DISCLOSURE

Selection transistors and drive transistors are formed in individual pixel areas on a substrate. Cathode electrodes which reflect visible light are formed above the selection transistors and the drive transistors so as to cover the pixel areas, with flat insulation films between the cathode electrodes and the selection and drive transistors. An organic EL layer and an anode electrode are sequentially formed on the cathode electrodes.

5/95FHG&W

Attorney Docket ______________

APPLICATION FOR UNITED STATES LETTERS PATENT

Declaration and Power of Attorney

As a below named inventor, I declare that:

my residence, post office address and citizenship are as stated next to my name; I believe that I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural inventors are named below) of the invention which is described and which is claimed in the specification, entitled:

DISPLAY APPARATUS

The specification is attached hereto.

I have reviewed and understand the contents of said specification, including claims.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulation, Section 1.56(a).

I claim foreign priority benefits under Title 35 United States Code, Section 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application(s) for patent or inventor's certificate having a filing date before that of the application on which priority is claimed.

COUNTRY	APPLICATION NUMBER	DATE (day, month, year)	PRIORITY CLAIMED
JAPAN	331388 / 1996	28, 11, 1996	yes X no ___
JAPAN	331389 / 1996	28, 11, 1996	yes X no ___

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

I appoint the following attorneys to prosecute this application and to transact all business in the U.S. Patent & Trademark Office connected therewith: Stephen H. Frishauf, Reg. No. 16,233; Leonard Holtz, Reg. No. 22,974; Herbert H. Goodman, Reg. No. 17,081; Thomas Langer, Reg. No. 27,264; Marshall J. Chick, Reg. No. 26,853; Walter J. Baum, Reg. No. 20,641; and Richard S. Barth, Reg. No. 28,180.

CORRESPONDENCE AND CALLS TO: FRISHAUF, HOLTZ, GOODMAN, LANGER & CHICK, P.C.
767 Third Avenue - 25th Floor Tel.: (212) 319-4900
New York, New York 10017 Fax.: (212) 319-5101

INVENTOR: SIGNATURE	DATE	RESIDENCE AND POST OFFICE ADDRESS
Sign: *Hiroyasu Yamada*	Date: Nov. 14, 1997	3-9-404, Bessho 2-chome Hachioji-shi, Tokyo Japan
Type: Hiroyasu YAMADA	Citizen of: JAPAN	
Sign: *Tomoyuki Shirasaki*	Date: Nov. 14, 1997	1425-3-234, Sakuragaoka 1-chome Higashiyamato-shi, Tokyo Japan
Type: Tomoyuki SHIRASAKI	Citizen of: JAPAN	
Sign: *Yoshihiro Kawamura*	Date: Nov. 14, 1997	14-17, Kita-denen 2-chome Fussa-shi, Tokyo Japan
Type: Yoshihiro KAWAMURA	Citizen of: JAPAN	

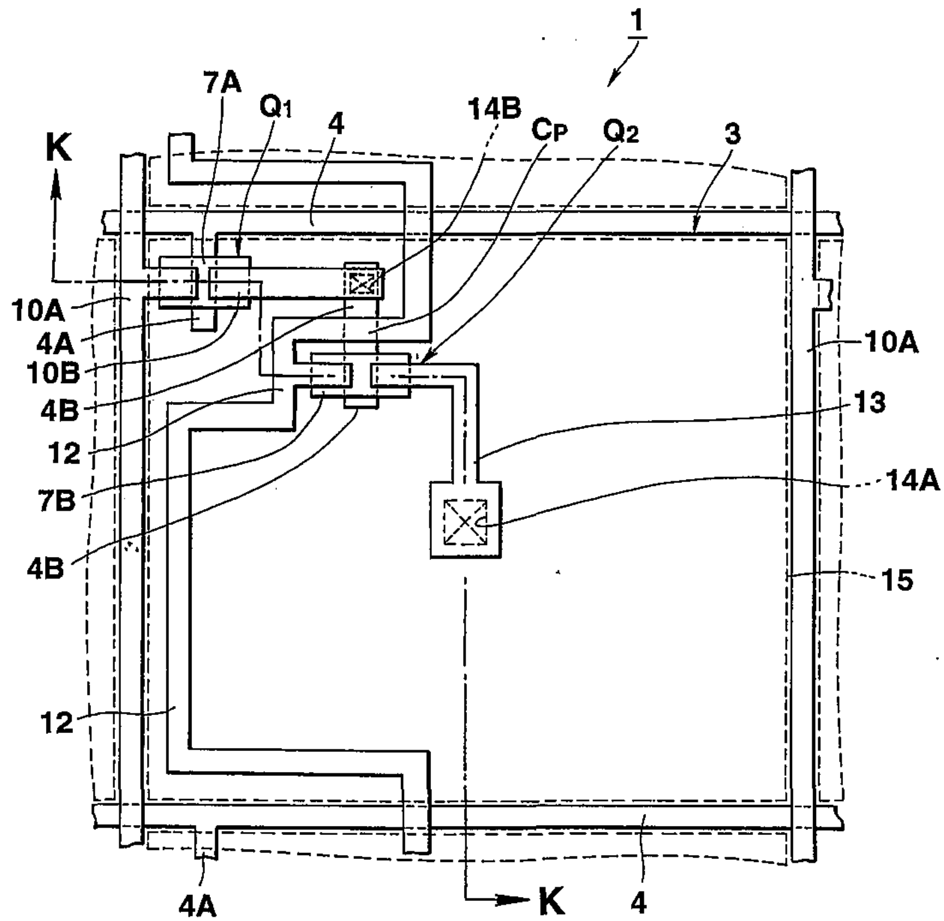


FIG.1

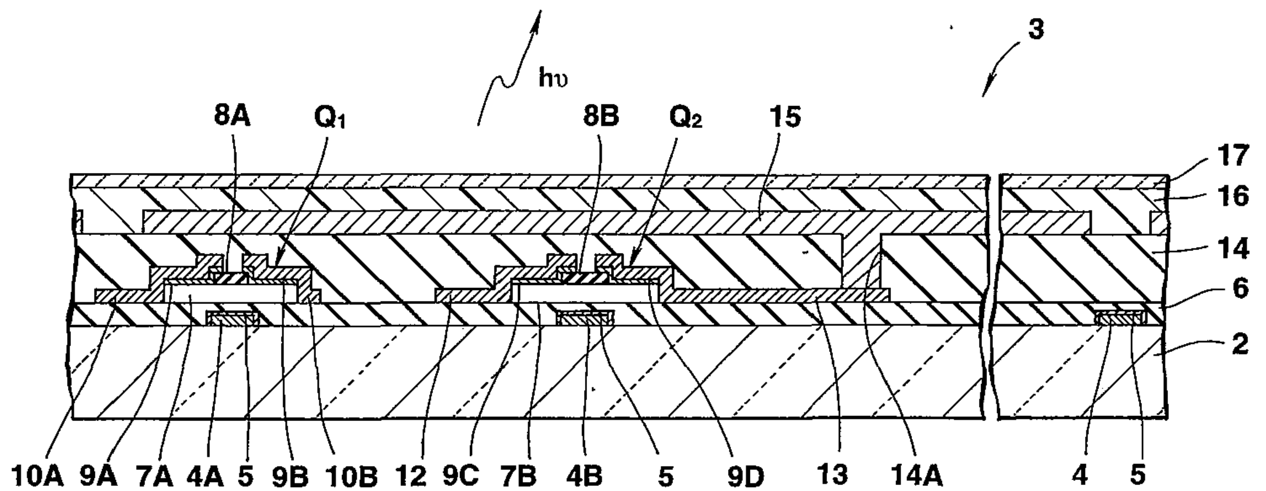

3
hυ
8A
Q1
8B
Q2
15
17
16
14
6
2
10A
9A
7A
4A
5
9B
10B
12
9C
7B
4B
5
9D
13
14A
4
5

FIG.2

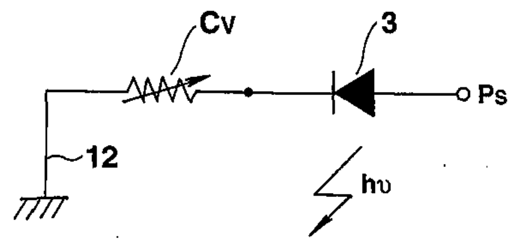


FIG.3

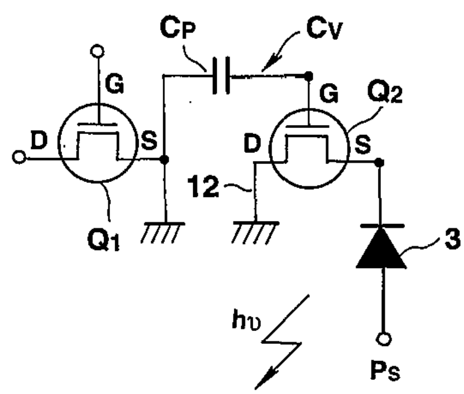


FIG.4

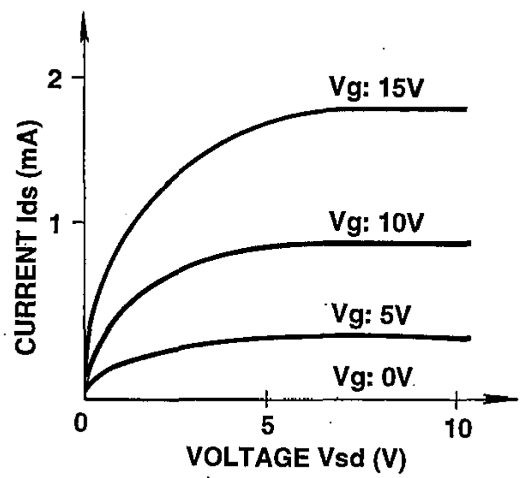

CURRENT Ids (mA)
2
1
Vg: 15V
Vg: 10V
Vg: 5V
Vg: 0V
0
5
10
VOLTAGE Vsd (V)

FIG.5

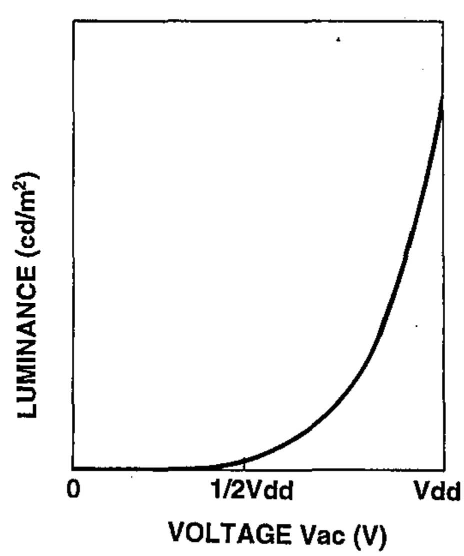

LUMINANCE (cd/m²)
0
1/2Vdd
Vdd
VOLTAGE Vac (V)

FIG.6

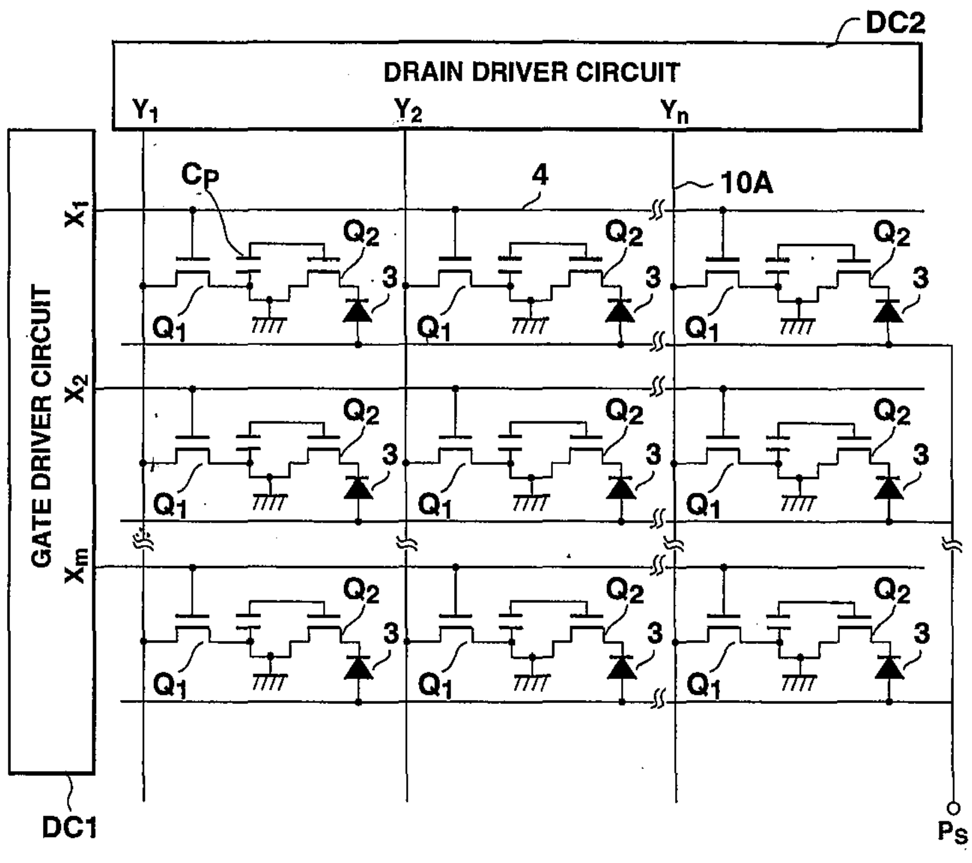
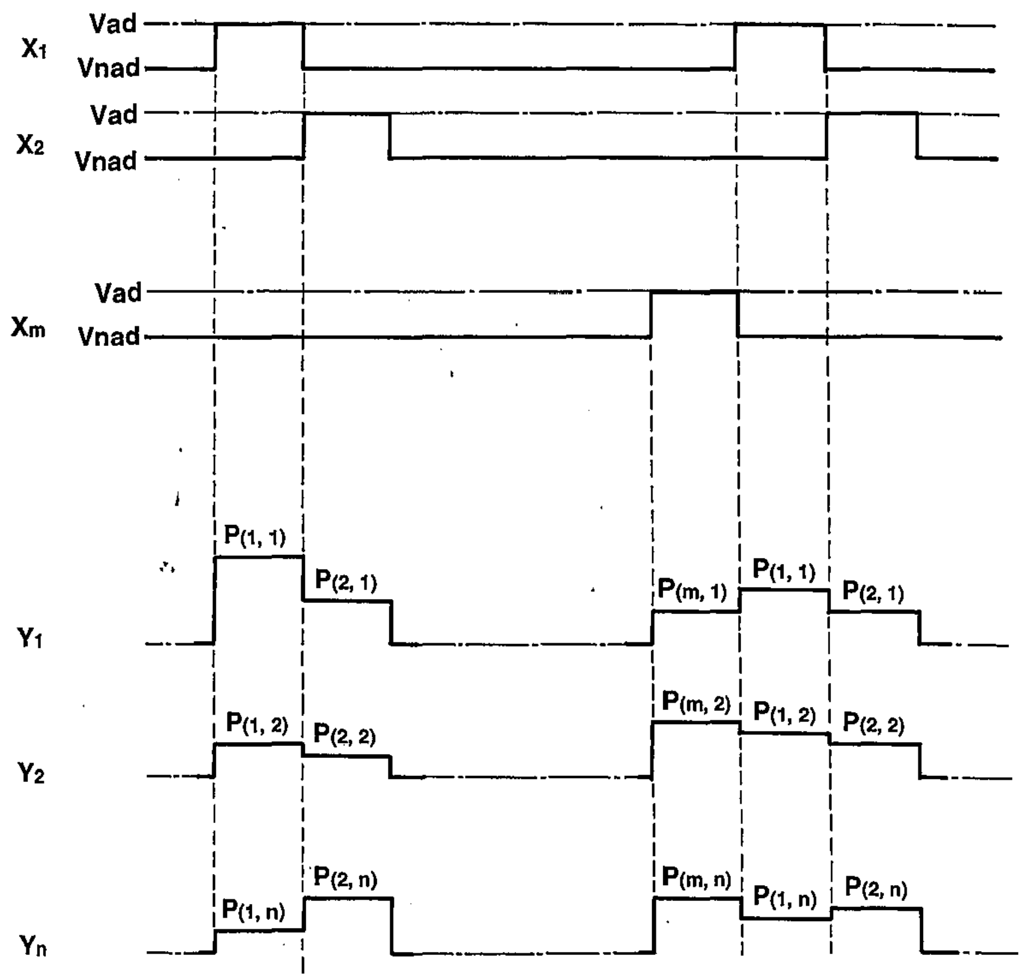

DC2
DRAIN DRIVER CIRCUIT
Y1
Y2
Yn
GATE DRIVER CIRCUIT
X1
X2
Xm
CP
4
10A
Q2
Q1
3
DC1
PS

FIG.7



X1
Vad
Vnad
X2
Vad
Vnad
Xm
Vad
Vnad
Y1
P(1, 1)
P(2, 1)
P(m, 1)
P(1, 1)
P(2, 1)
Y2
P(1, 2)
P(2, 2)
P(m, 2)
P(1, 2)
P(2, 2)
Yn
P(1, n)
P(2, n)
P(m, n)
P(1, n)
P(2, n)

FIG.8

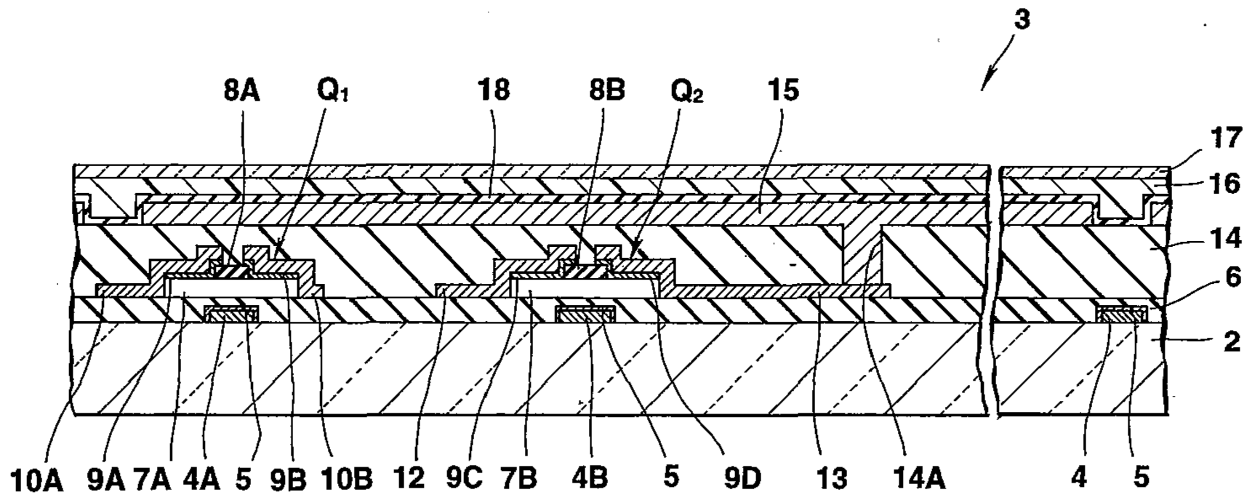

3
8A
Q1
18
8B
Q2
15
17
16
14
6
2
10A
9A
7A
4A
5
9B
10B
12
9C
7B
4B
5
9D
13
14A
4
5

FIG.9

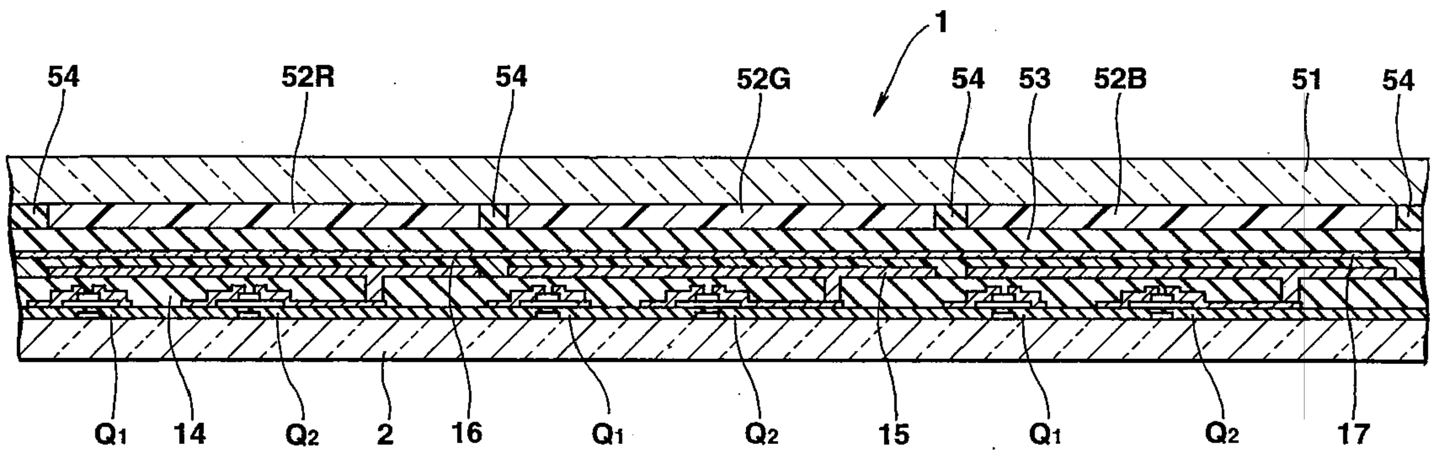


FIG.10

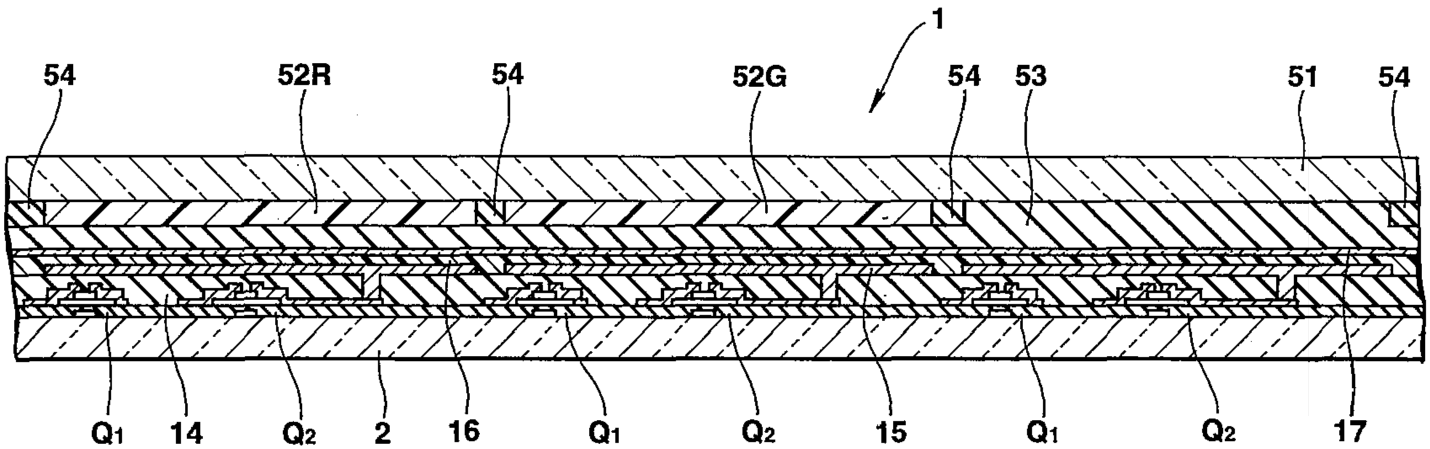


FIG.11

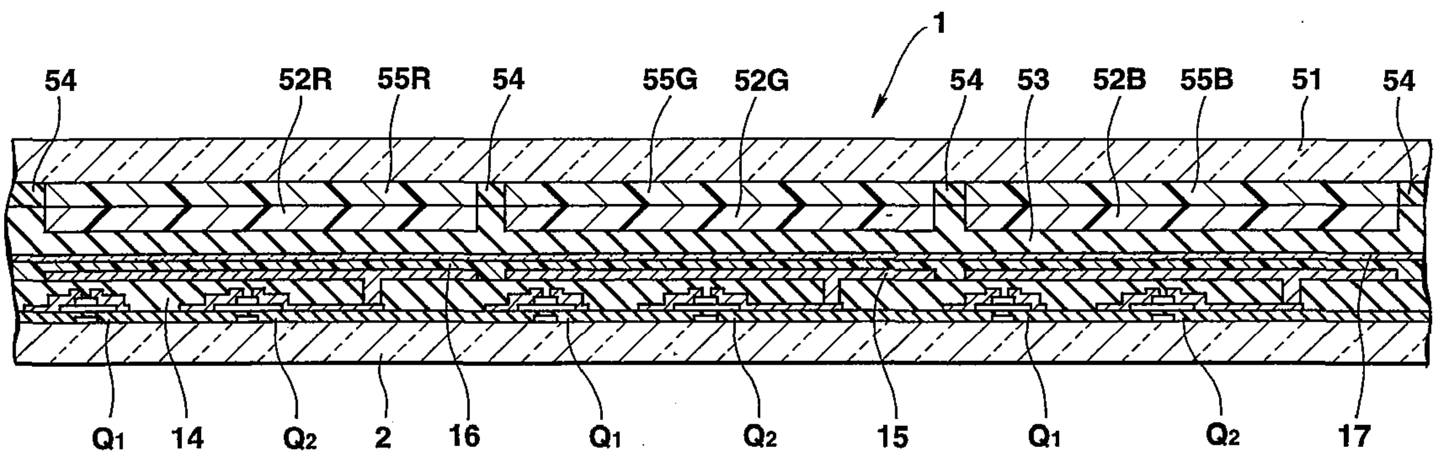

1
54
52R
55R
54
55G
52G
54
53
52B
55B
51
54
Q1
14
Q2
2
16
Q1
Q2
15
Q1
Q2
17

FIG.12

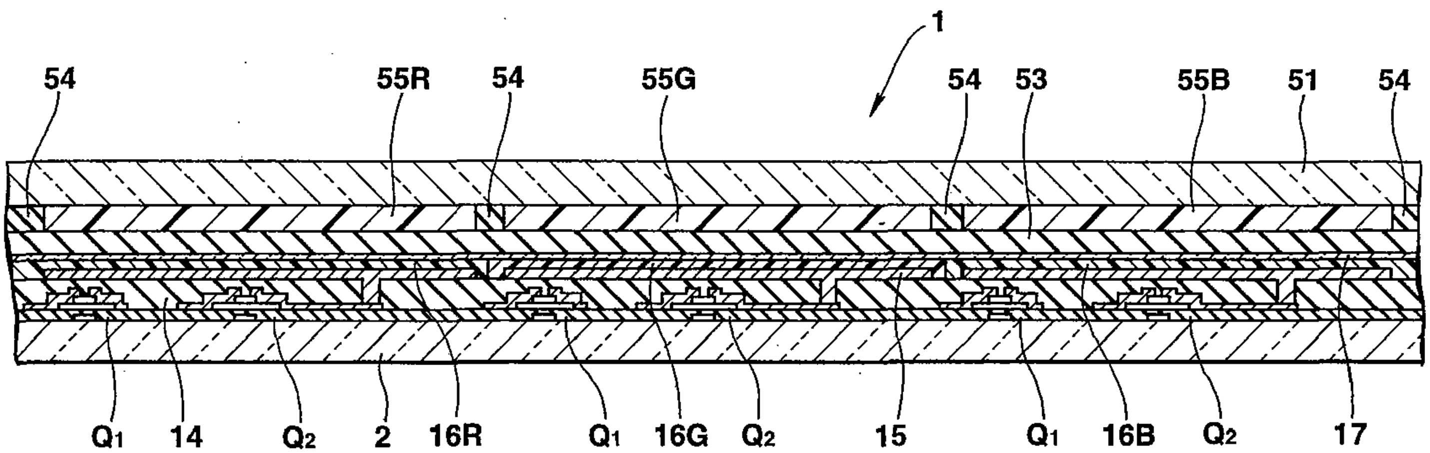

1
54
55R
54
55G
54
53
55B
51
54
Q1
14
Q2
2
16R
Q1
16G
Q2
15
Q1
16B
Q2
17

FIG.13

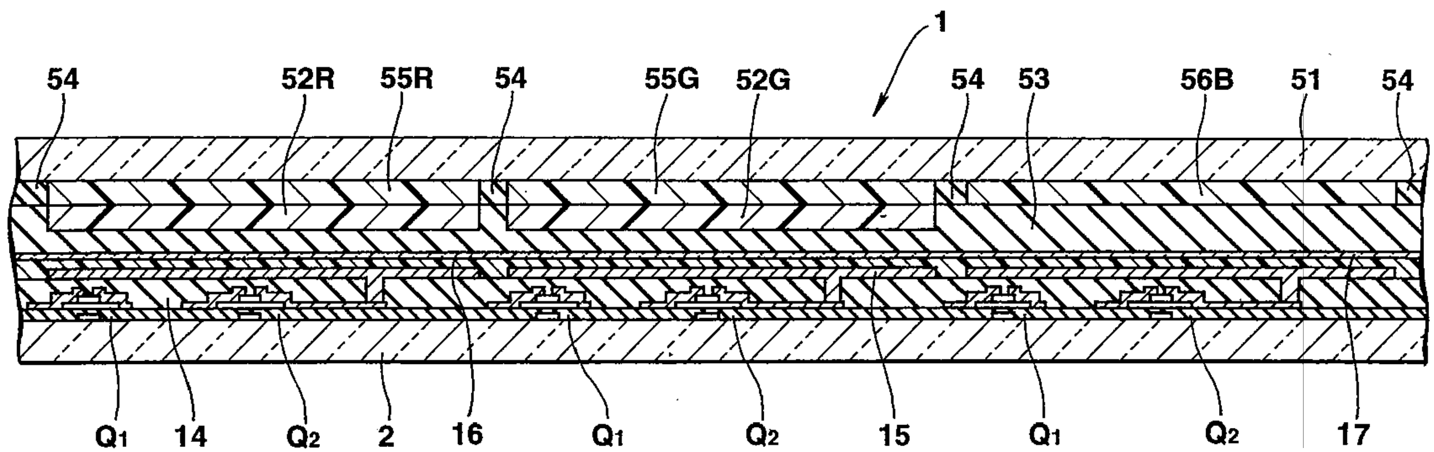


FIG.14

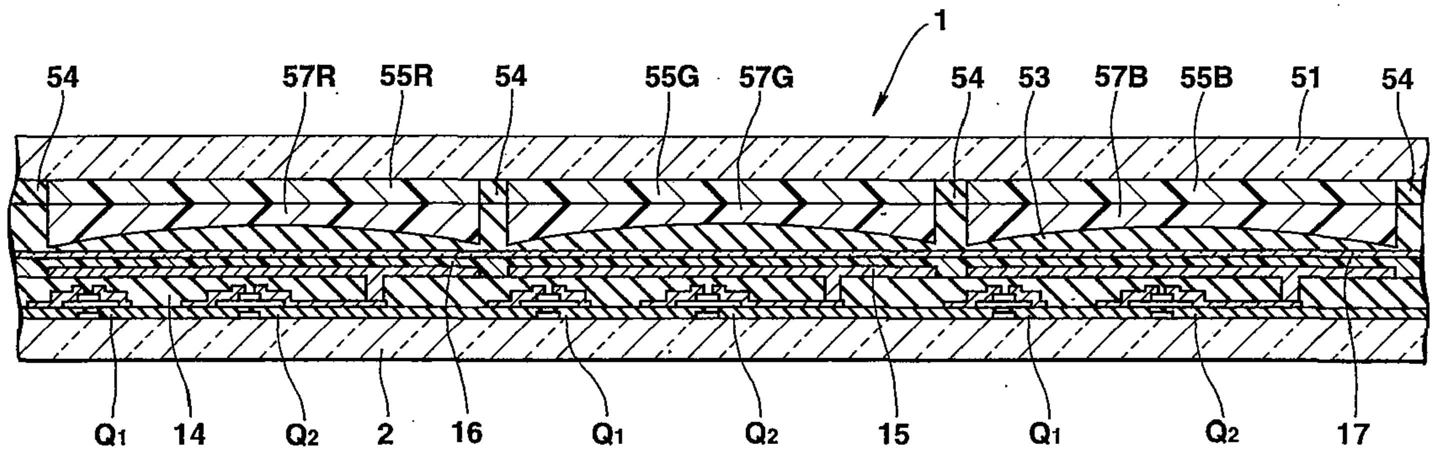

1
54
57R
55R
54
55G
57G
54
53
57B
55B
51
54
Q1
14
Q2
2
16
Q1
Q2
15
Q1
Q2
17

FIG.15

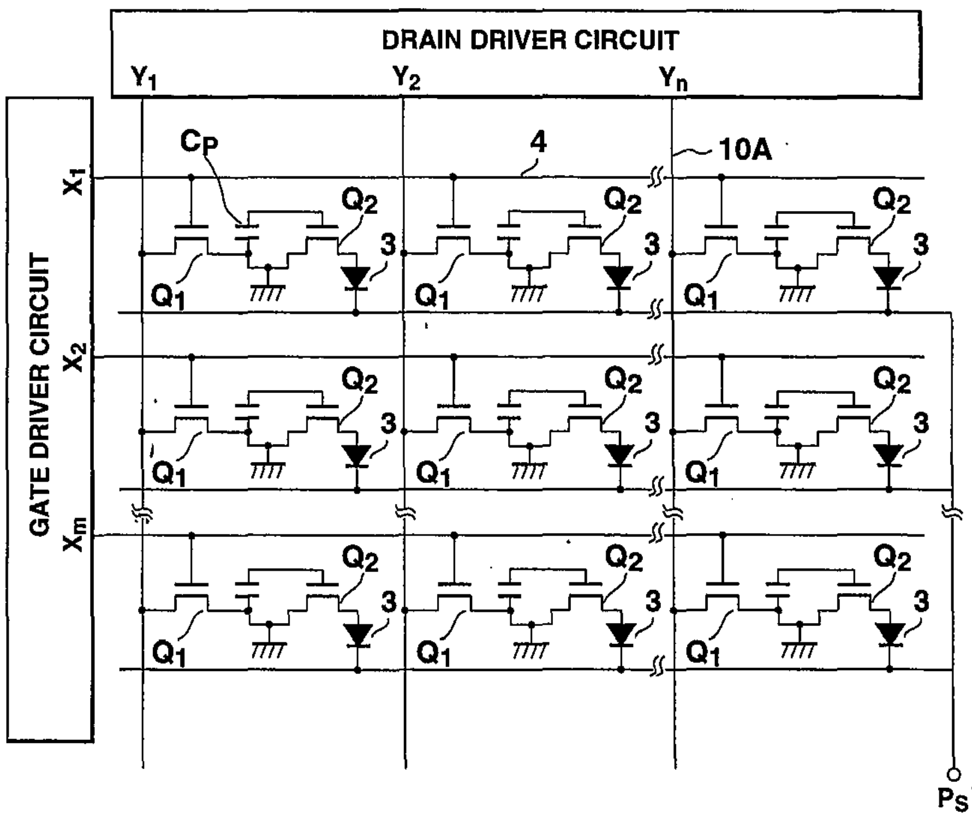

DRAIN DRIVER CIRCUIT
Y1
Y2
Yn
GATE DRIVER CIRCUIT
X1
X2
Xm
CP
4
10A
Q2
Q1
3
PS

FIG.16

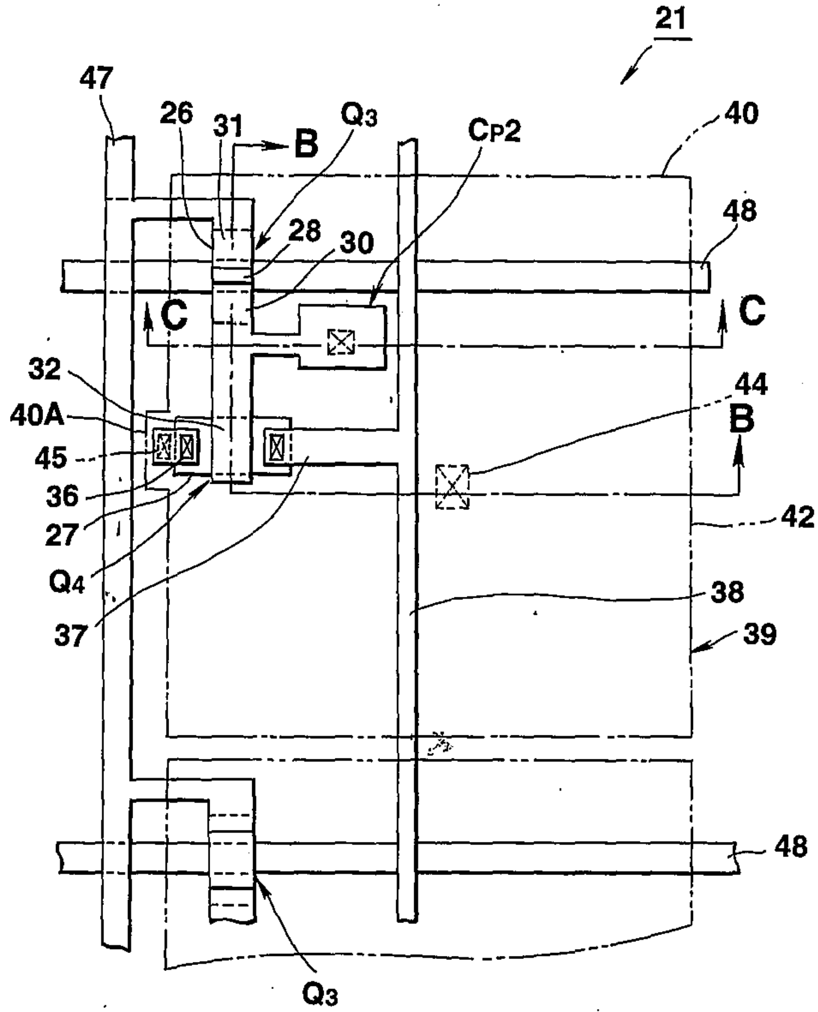

21
47
26
31
B
Q3
CP2
40
48
28
30
C
C
32
44
B
40A
45
36
27
Q4
42
37
38
39
48
Q3

FIG.17

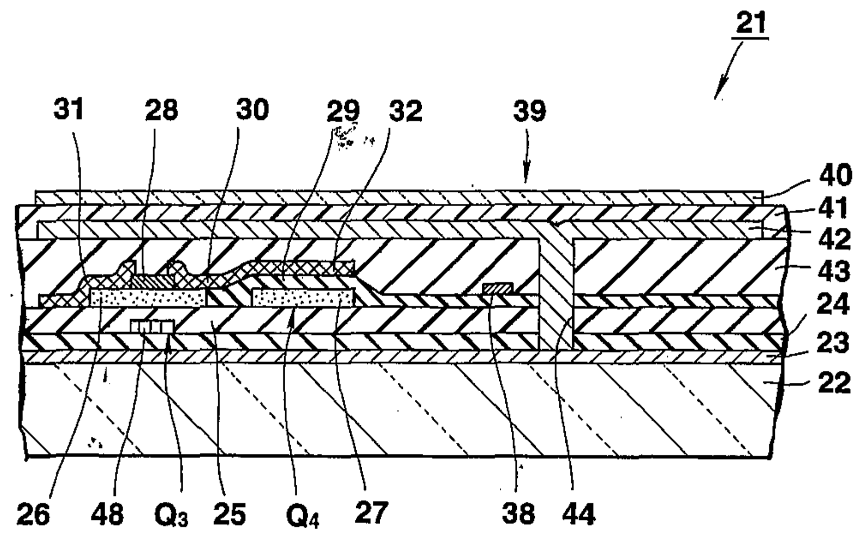


FIG.18

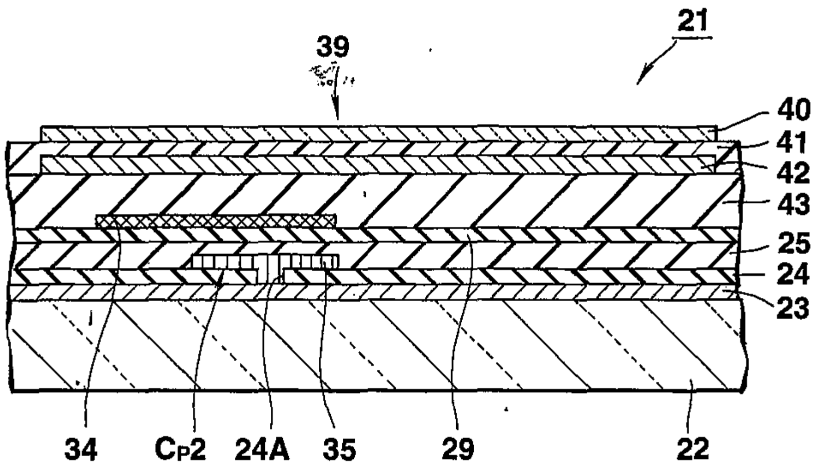
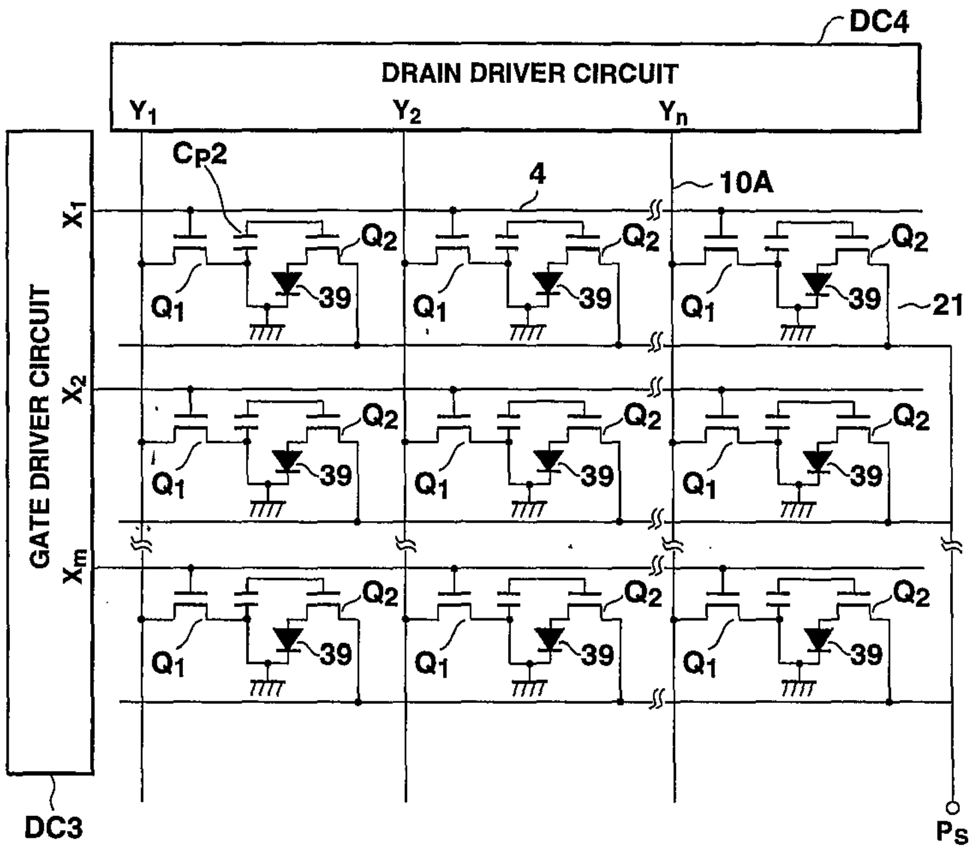


FIG.19



DC4
DRAIN DRIVER CIRCUIT
Y1
Y2
Yn
Cp2
4
10A
X1
Q2
Q1
39
21
GATE DRIVER CIRCUIT
X2
Xm
DC3
Ps

FIG.20

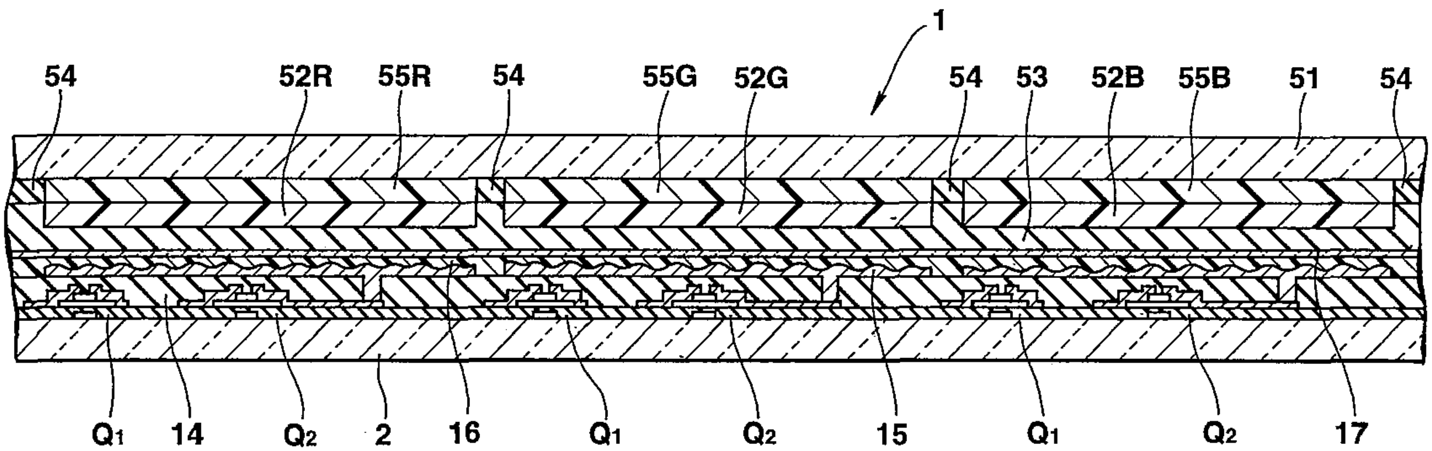

1
54
52R
55R
54
55G
52G
54
53
52B
55B
51
54
Q1
14
Q2
2
16
Q1
Q2
15
Q1
Q2
17

FIG.21

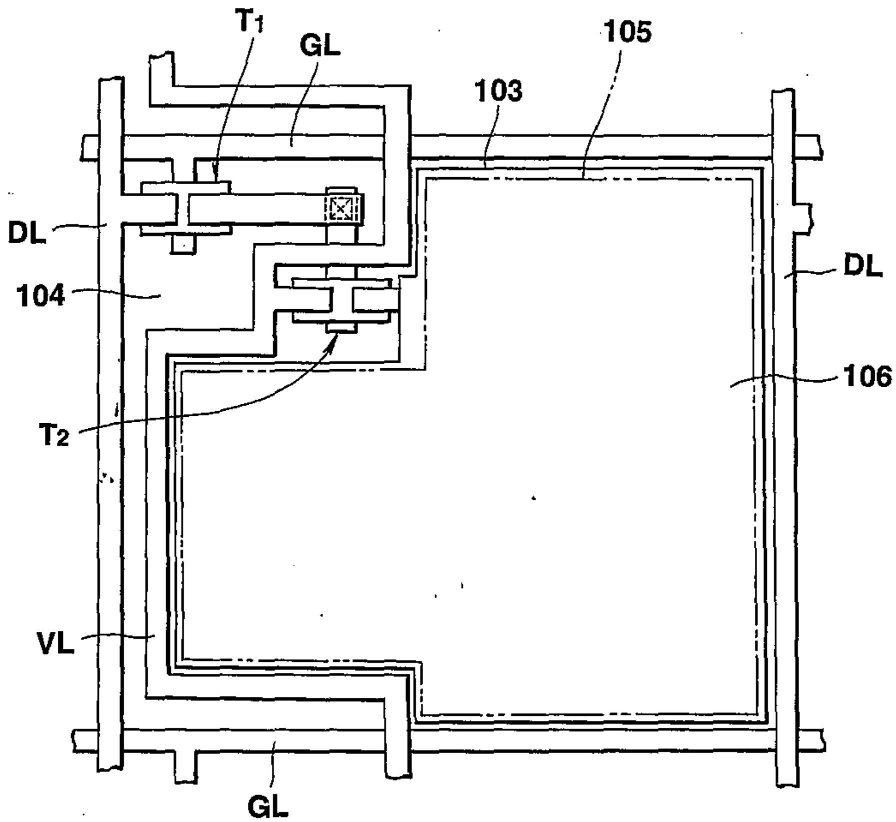


FIG.22

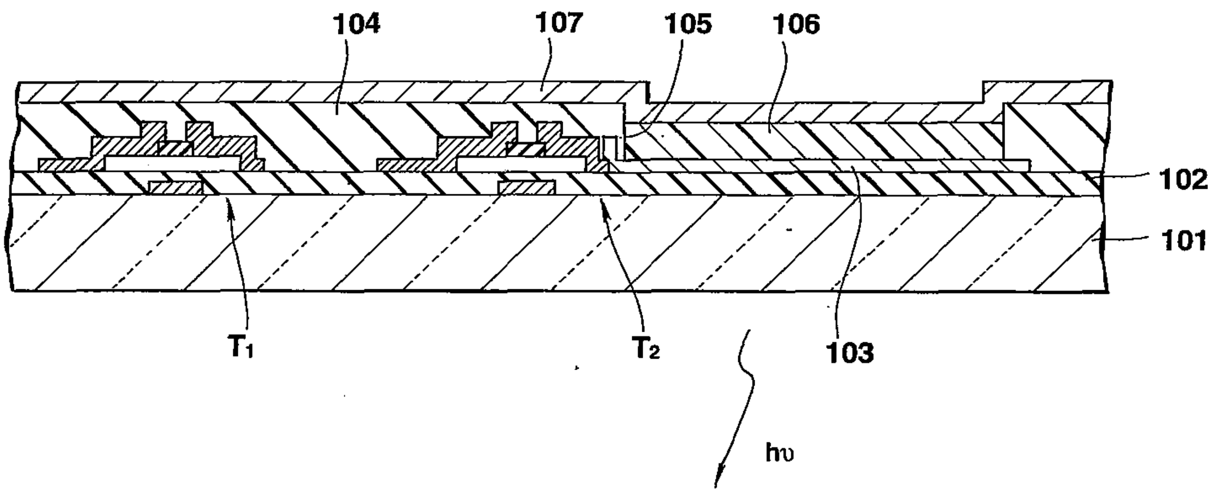


FIG.23

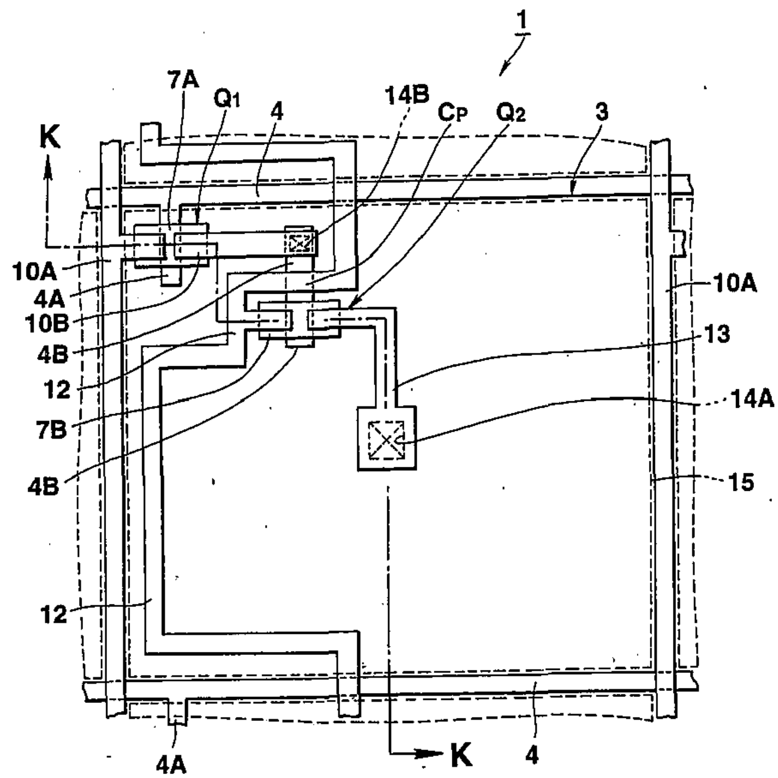


FIG.1

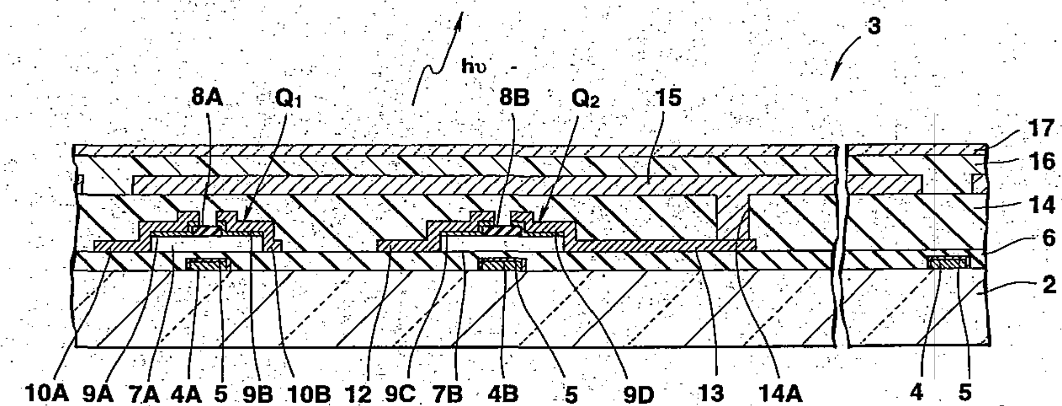

hυ
3
8A
Q1
8B
Q2
15
17
16
14
6
2
10A 9A 7A 4A 5 9B 10B 12 9C 7B 4B 5 9D 13 14A
4 5

FIG.2

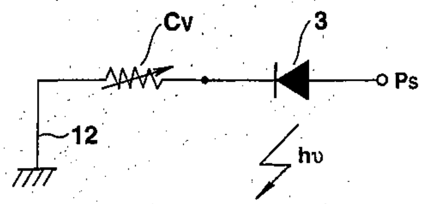


FIG.3

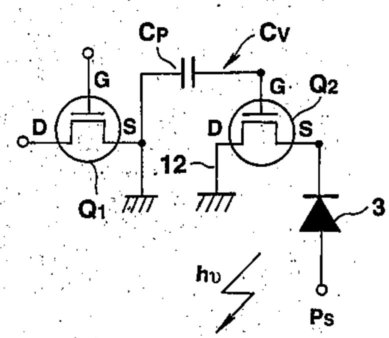


FIG.4

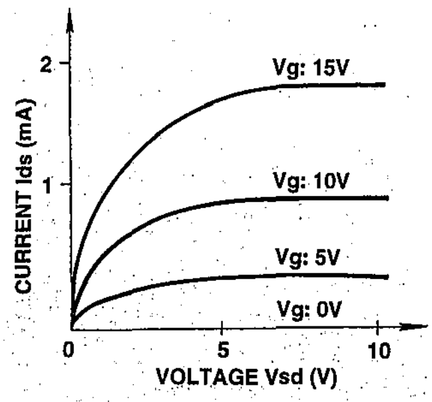

CURRENT Ids (mA)
2
1
Vg: 15V
Vg: 10V
Vg: 5V
Vg: 0V
0
5
10
VOLTAGE Vsd (V)

FIG.5

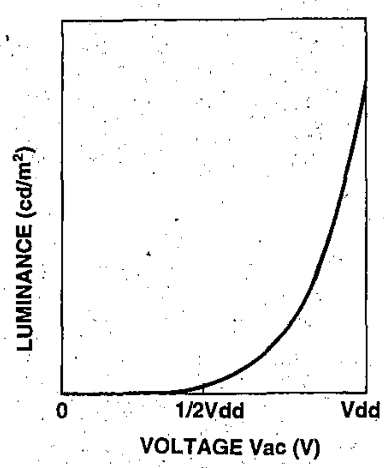

LUMINANCE (cd/m²)
0
1/2Vdd
Vdd
VOLTAGE Vac (V)

FIG.6

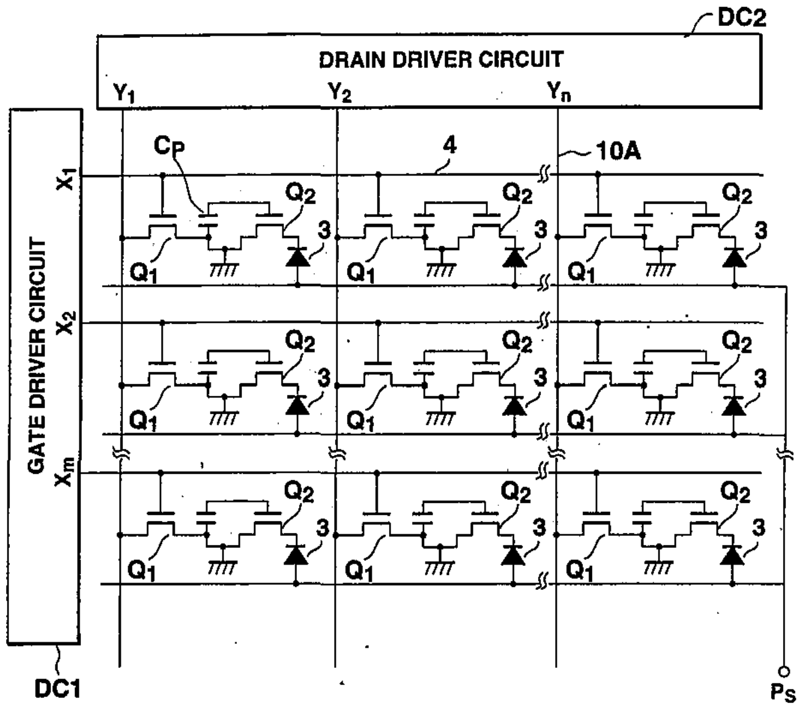

DC2
DRAIN DRIVER CIRCUIT
Y1
Y2
Yn
GATE DRIVER CIRCUIT
X1
X2
Xm
Cp
4
10A
Q2
3
Q1
DC1
Ps

FIG.7

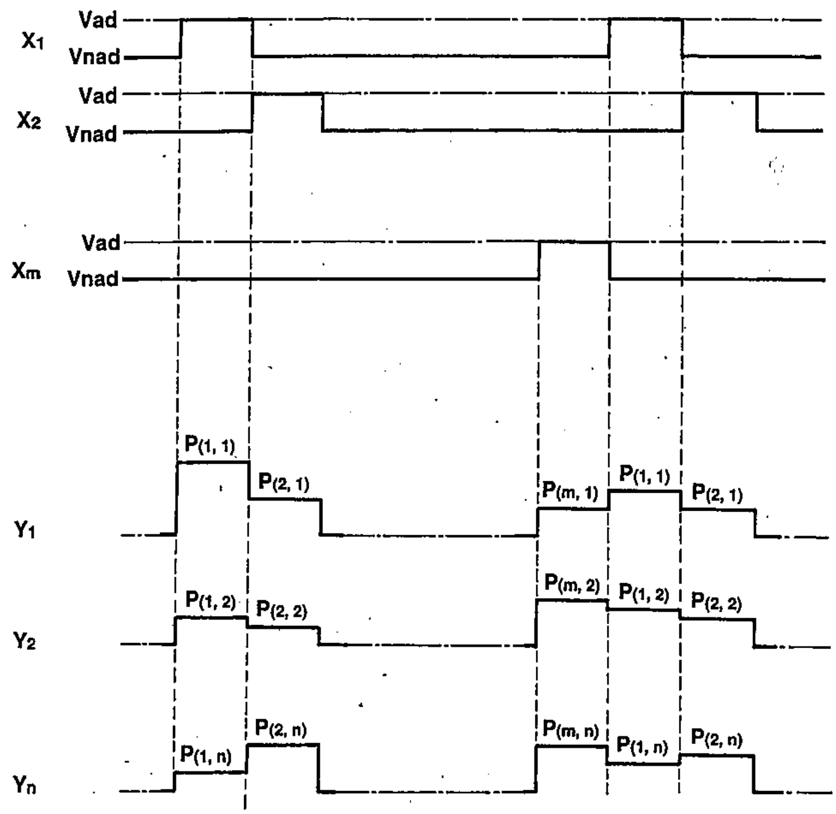

X1
Vad
Vnad
X2
Vad
Vnad
Xm
Vad
Vnad
Y1
P(1, 1)
P(2, 1)
P(m, 1)
P(1, 1)
P(2, 1)
Y2
P(1, 2)
P(2, 2)
P(m, 2)
P(1, 2)
P(2, 2)
Yn
P(1, n)
P(2, n)
P(m, n)
P(1, n)
P(2, n)

FIG.8

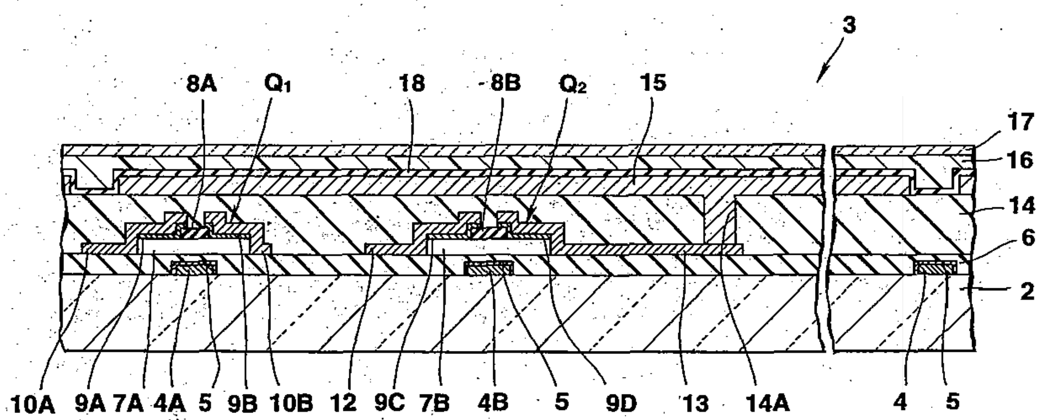

3
8A
Q1
18
8B
Q2
15
17
16
14
6
2
10A
9A
7A
4A
5
9B
10B
12
9C
7B
4B
5
9D
13
14A
4
5

FIG.9

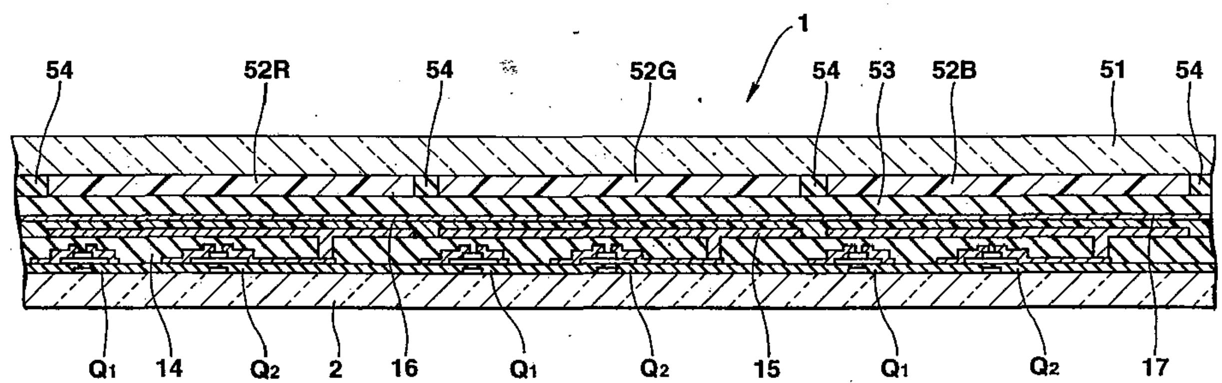


FIG.10

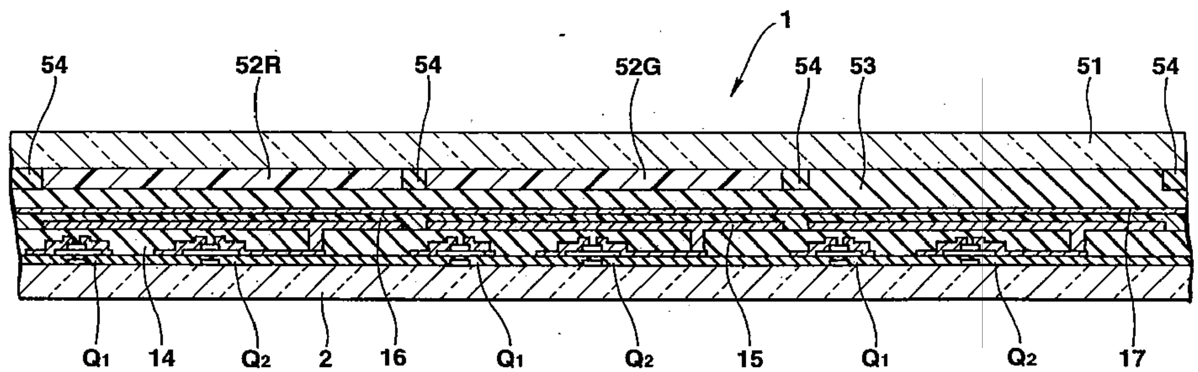


FIG.11

08977917 .111597

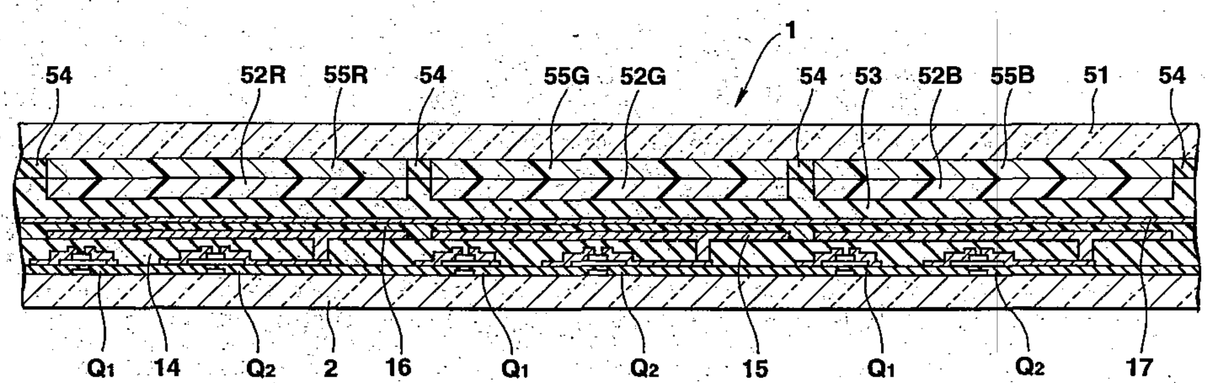


FIG.12

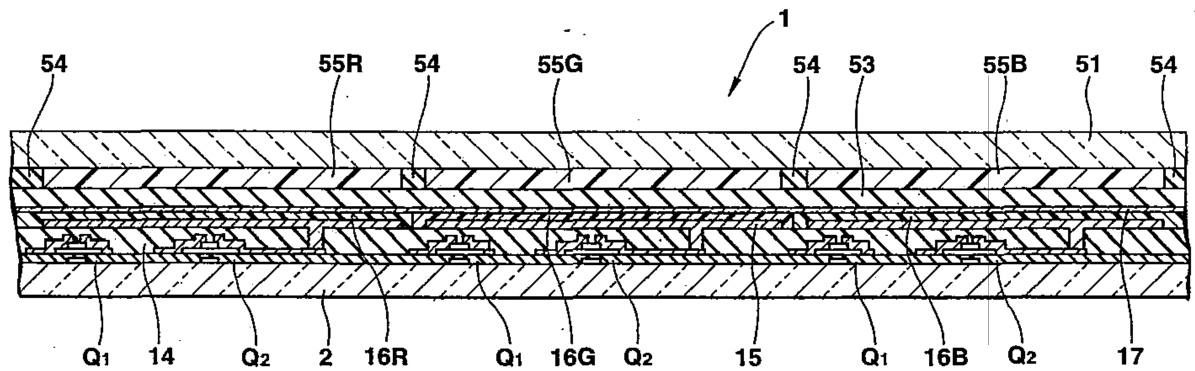

1
54
55R
54
55G
54
53
55B
51
54
Q1
14
Q2
2
16R
Q1
16G
Q2
15
Q1
16B
Q2
17

FIG.13

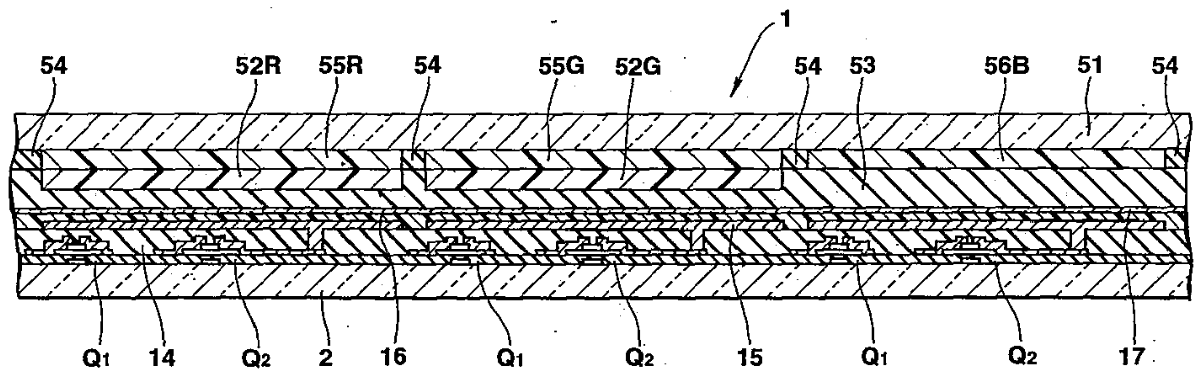


FIG.14

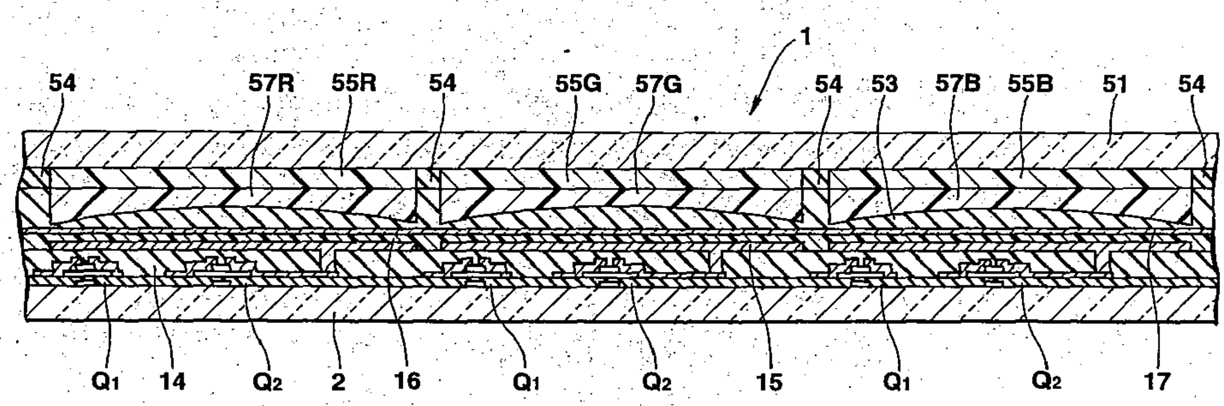

1
54
57R
55R
54
55G
57G
54
53
57B
55B
51
54
Q1
14
Q2
2
16
Q1
Q2
15
Q1
Q2
17

FIG.15

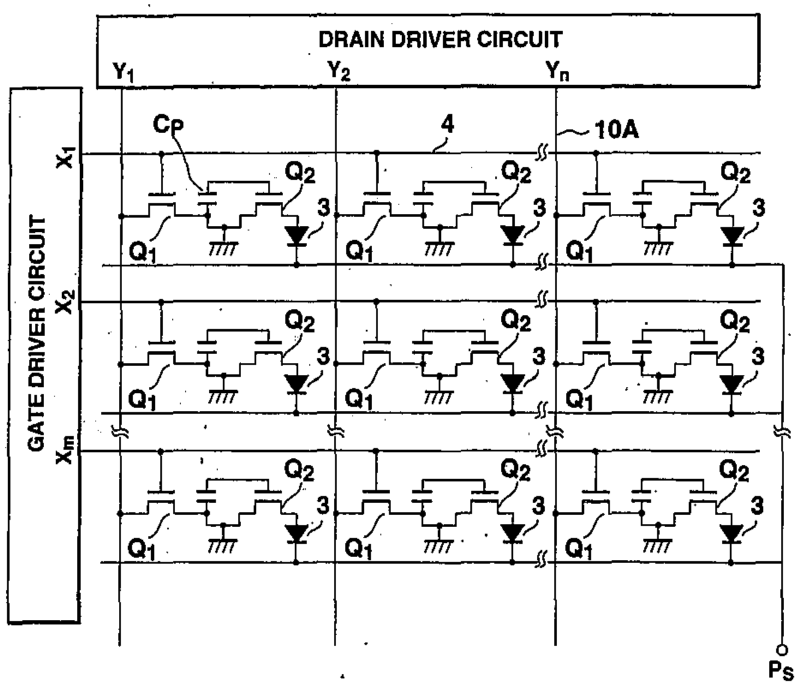

DRAIN DRIVER CIRCUIT
GATE DRIVER CIRCUIT
Y_1
Y_2
Y_n
X_1
X_2
X_m
Cp
4
10A
Q_1
Q_2
3
Ps

FIG.16

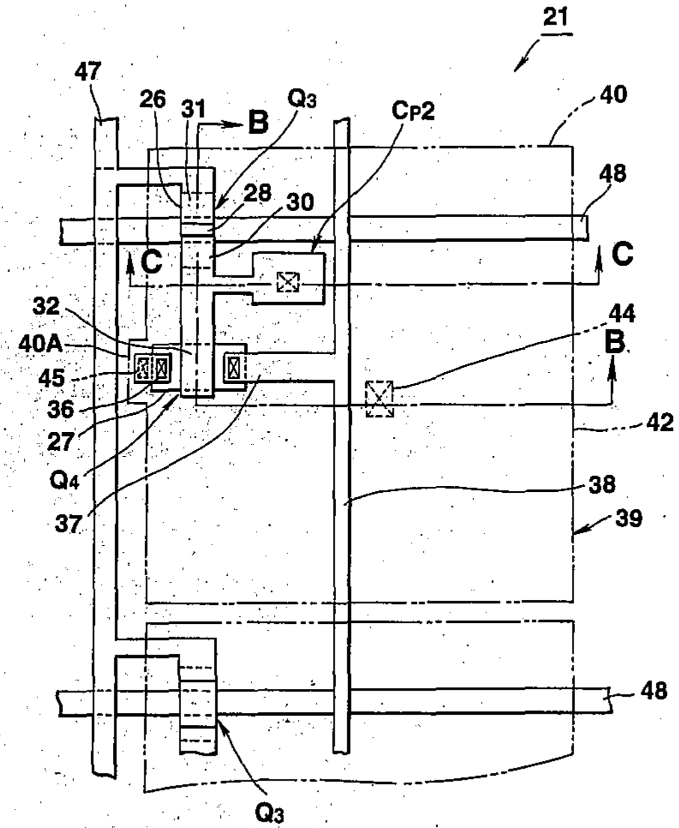

21
47
26
31
B
Q3
CP2
40
48
28
30
C
C
32
40A
45
36
27
Q4
37
44
B
42
38
39
48
Q3

FIG.17

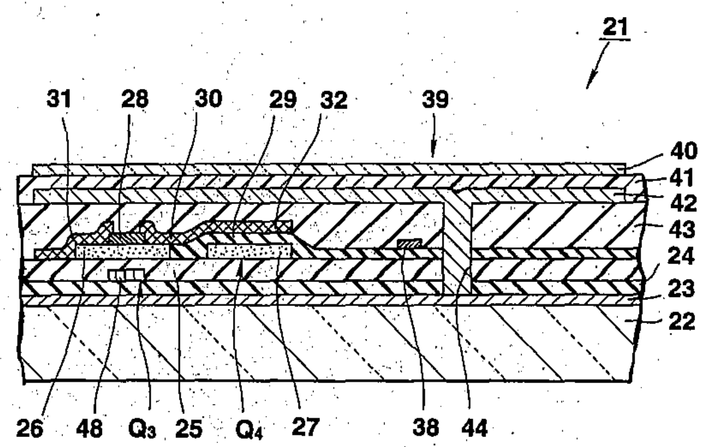


FIG.18

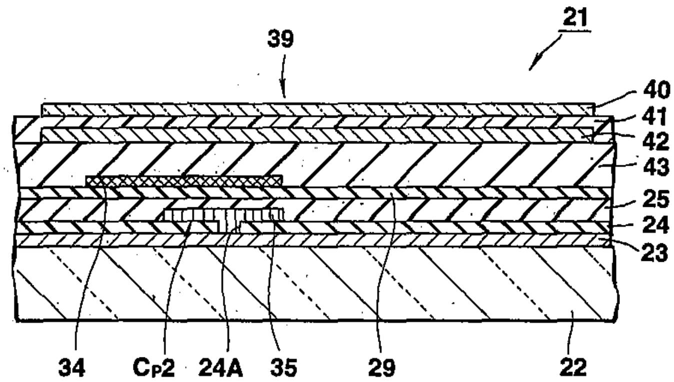


FIG.19

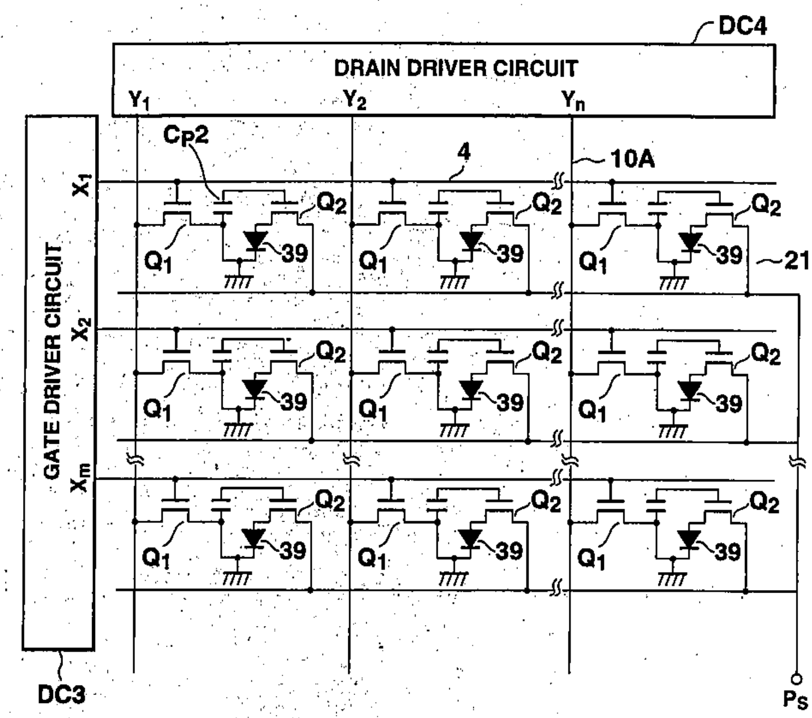

DC4
DRAIN DRIVER CIRCUIT
Y1
Y2
Yn
CP2
4
10A
X1
X2
Xm
GATE DRIVER CIRCUIT
Q1
Q2
39
21
DC3
Ps

FIG.20

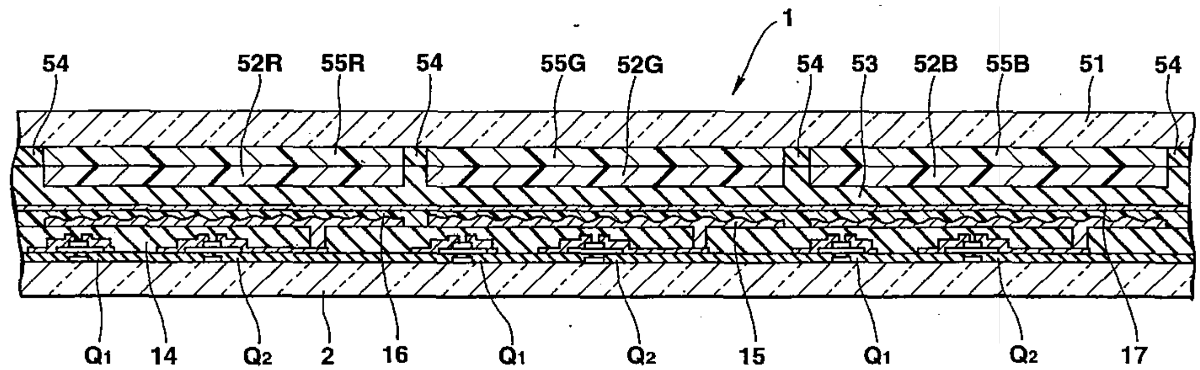

1
54
52R
55R
54
55G
52G
54
53
52B
55B
51
54
Q1
14
Q2
2
16
Q1
Q2
15
Q1
Q2
17

FIG.21

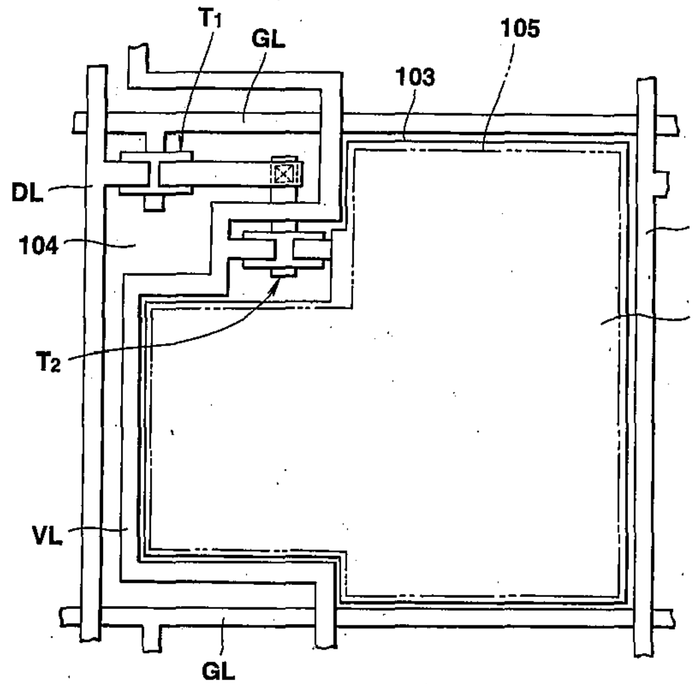


FIG.22

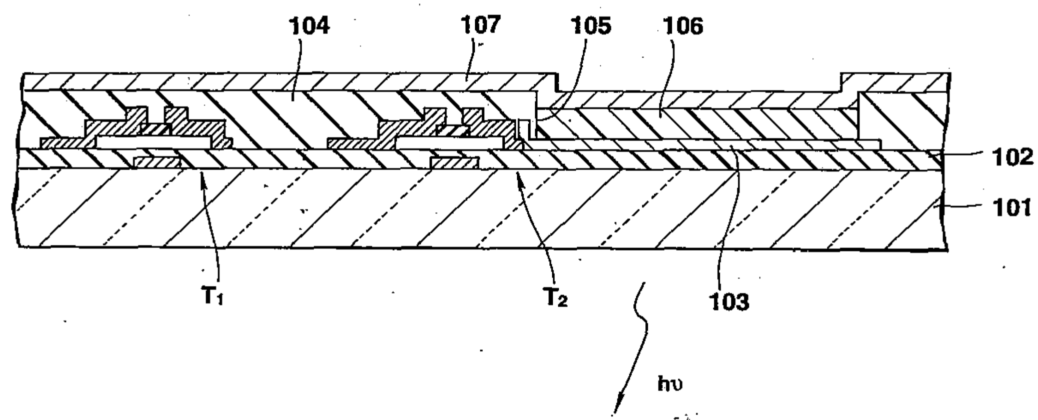


FIG.23

#2

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【発明者】
　【住所又は居所】　東京都青梅市今井３丁目１０番地６
　　カシオ計算機株式会社青梅事業所内
　【氏名】　山田　裕康
【発明者】
　【住所又は居所】　東京都青梅市今井３丁目１０番地６
　　カシオ計算機株式会社青梅事業所内
　【氏名】　白嵜　友之
【特許出願人】
　【識別番号】　000001443
　【住所又は居所】　東京都新宿区西新宿２丁目６番１号
　【氏名又は名称】　カシオ計算機株式会社
　【代表者】　樫尾　和雄
【代理人】
　【識別番号】　100074985
　【弁理士】
　【氏名又は名称】　杉村　次郎
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【書類名】　　明細書

【発明の名称】　表示装置

【特許請求の範囲】

【請求項１】　基板上に設けられ、走査ライン及び信号ラインに接続されたスイッチング素子と、前記スイッチング素子の上方に設けられた第１電極と、前記第１電極上に設けられ、電界に応じて光を発光する電界発光層と、前記電界発光層上に設けられ、前記電界発光層の光を透過する第２電極と、を有する発光素子と、

からなることを特徴とする表示装置。

【請求項２】　前記スイッチング素子は、絶縁膜を介して前記第１電極と接続されていることを特徴とする請求項１記載の表示装置。

【請求項３】　前記スイッチング素子は、前記走査ライン及び前記信号ラインに接続された選択トランジスタと、前記選択トランジスタに接続された駆動トランジスタと、からなることを特徴とする請求項１又は２に記載の表示装置。

【請求項４】　前記選択トランジスタは、前記走査ラインに接続されたドレイン電極と、前記信号ラインに接続されたゲート電極と、半導体層と、を有する薄膜トランジスタであり、前記駆動トランジスタは、前記選択トランジスタのソース電極に接続されたゲート電極と、前記第１電極に接続されたソース電極と、半導体層と、を有する薄膜トランジスタであることを特徴とする請求項３記載の表示装置。

【請求項５】　前記発光素子は、マトリクス状に複数配置され、前記スイッチング素子は、前記発光素子の下方に各々配置されていることを特徴とする請求項１乃至４に記載の表示装置。

【請求項６】　前記第１電極は、絶縁膜を介して前記選択トランジスタ及び前記駆動トランジスタの上方に設けられ、前記絶縁膜に設けられたコンタクトホールを介して前記駆動トランジスタに接続されていることを特徴とする請求項３乃至５のいずれかに記載の表示装置。

【請求項７】　前記第１電極は、前記電界発光層の発光する光と同じ波長域の光に対し反射性を有するカソード電極であり、前記第２電極は、前記電界発光

層の発光する光と同じ波長域の光に対し透過性を有するアノード電極であることを特徴とする請求項１乃至６のいずれかに記載の表示装置。

【請求項８】　前記選択トランジスタは、前記信号ラインからの前記電界発光層の発光輝度データに応じた信号電圧に応じた電圧を前記駆動トランジスタに印加するトランジスタであり、前記駆動トランジスタは、前記発光素子の次の選択期間まで前記発光輝度データに応じた電圧を前記第１電極に印加し続けるトランジスタであることを特徴とする請求項３乃至７のいずれかに記載の表示装置。

【請求項９】　前記選択トランジスタは、消去期間に前記信号ラインから消去電圧が印加され書き込み期間に前記信号ラインから書き込み電圧が印加されることを特徴とする請求項３乃至８のいずれかに記載の表示装置。

【請求項１０】　前記電界発光層は、電界に応じて発光する有機エレクトロルミネッセンス層であることを特徴とする請求項１乃至９のいずれかに記載の表示装置。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】

この発明は、表示装置に関し、さらに詳しくは、エレクトロルミネッセンス（以下、ＥＬという）素子によりドットマトリクス表示パネルを構成するＥＬ表示装置に関する。

【０００２】

【従来の技術】

従来、自発光表示素子である有機ＥＬ素子をドットマトリクス状に配置した表示装置が知られている。この表示装置では、カソード・スキャンライン（金属電極側）をコモンラインとし、ＩＴＯ（indume tin oxide）でなるアノード・スキャンラインをデータラインとし、このデータライン側に正電圧をカソード選択期間内で一斉に印加して、コモンラインとデータラインとが直交する部分の有機ＥＬ素子を線順次駆動して画像を表示している。しかし、このような表示装置にあっては、コモンラインとデータラインとが直交する部分の有機ＥＬ素子を線順次駆動して画像を表示するようになっているため、コモンライン数およびデータラ

イン数が多くなるにしたがって、１画素当たりの選択時間（デューティＨ）が短くなり、表示装置として必要な輝度を得ることができないという問題点がある。このため、１画素当たりの輝度を高めるために有機ＥＬ素子に印加する電圧を高くすると有機ＥＬ層の劣化や非発光部分（ダークスポット）が成長し易くなるなどの問題が発生する。

【０００３】

このような問題に対処した表示装置として、画素内に２つの薄膜トランジスタ（以下、ＴＦＴという）を組み合わせて形成して各画素にメモリ性をもたせたものが提案されている。この２つのＴＦＴのうち、一方は選択トランジスタであり、他方はメモリトランジスタとしての機能を備えている。この表示装置は、ガラス基板上の各画素領域内にこれら２つのＴＦＴが形成され、各画素領域内におけるＴＦＴが形成されていない領域に、順次、透明なアノード電極、有機ＥＬ層、不透明なカソード電極が積層された構成となっている。この表示装置においては、電子と正孔との再結合により発生する励起エネルギーにより有機ＥＬ層が発光する機構になっている。すなわち、電圧印加時に、アノード電極から正孔が、カソード電極から電子が、それぞれ有機ＥＬ層に注入されることになる。ここで、キャリア注入効率は、アノード電極のイオン化ポテンシャル、カソード電極の電子親和力（仕事関数）に依存しており、キャリア注入効率に起因する発光効率を向上するため、カソード電極には低仕事関数の材料が選択されていた。しかしながら、低仕事関数の材料はマグネシウム等の金属からなるため、有機ＥＬ層が発光する光に対し反射性を有しており、有機ＥＬ層は透明なＩＴＯ等のアノード電極側から基板を介して発光するような構造になっている。なお、上記したように、発光する有機ＥＬ層は２つのＴＦＴが形成された領域と平面的に重ならない配置となっており、表示光がＴＦＴへ入射するのを防止するよう配慮されている。この理由は、ＴＦＴへ光が入射すると、ＴＦＴのチャネル領域で不要な光起電力が生じて誤動作を引き起こす問題が発生するからである。

【０００４】

【発明が解決しようとする課題】

しかしながら、上記した表示装置では、各画素において発光を起こす領域が２

つのＴＦＴを除いた領域に限定されるため、画素領域に占める発光領域の割合（開口率）が低いという問題が挙げられていた。また、有機ＥＬ層で発生した光は、ガラス基板やその上に形成されたゲート絶縁膜などにより吸収されて通過するため、ガラス基板から出射される表示光の外部発光効率が低くなる点が指摘されていた。これら２つの問題点によって、表示装置が高精細化するほど開口率が低下して所望の輝度を得ることが困難になるという問題がある。

【０００５】

この発明が解決しようとする課題は、各画素部分の開口率を高くすることにより面発光輝度を確保することができるとともに、高精細化しても消費電力の増加を抑制でき、しかも発光寿命の長い表示装置を得るには、どのような手段を講じればよいかという点にある。

【０００６】

【課題を解決するための手段】

請求項１記載の発明は、基板上に設けられ、走査ライン及び信号ラインに接続されたスイッチング素子と、スイッチング素子の上方に設けられた第１電極、第１電極上に設けられ、電界に応じて光を発光する電界発光層及び前記電界発光層上に設けられ、前記電界発光層の光を透過する第２電極、を有する発光素子と、からなることを特徴としている。

【０００７】

請求項１記載の発明によれば、発光素子の電界発光層が電界に応じて発光する光を、電界発光層を挟んでなる、下方にスイッチング素子が設けられた第１電極と第２電極のうち、第２電極の方から出射させることができるので、スイッチング素子により開口率を低くすることなく、表示光を発光することができる。

【０００８】

請求項２記載の発明は、スイッチング素子は、絶縁膜を介して前記第１電極と接続されていることを特徴としている。

【０００９】

請求項３記載の発明は、スイッチング素子は、前記走査ライン及び前記信号ラインに接続された選択トランジスタと、前記選択トランジスタに接続された駆動

トランジスタと、からなることを特徴としている。

【００１０】

請求項４記載の発明は、選択トランジスタは、前記走査ラインに接続されたドレイン電極と、前記信号ラインに接続されたゲート電極と、半導体層と、を有する薄膜トランジスタであり、前記駆動トランジスタは、前記選択トランジスタのソース電極に接続されたゲート電極と、前記第１電極に接続されたソース電極と、半導体層と、を有する薄膜トランジスタであることを特徴としている。

【００１１】

請求項５記載の発明は、発光素子は、マトリクス状に複数配置され、前記スイッチング素子は、前記発光素子の下方に各々配置されていることを特徴としている。

【００１２】

請求項６記載の発明は、第１電極は、絶縁膜を介して前記選択トランジスタ及び前記駆動トランジスタの上方に設けられ、前記絶縁膜に設けられたコンタクトホールを介して前記駆動トランジスタに接続されていることを特徴としている。

【００１３】

請求項７記載の発明は、第１電極は、電界発光層の発光する光と同じ波長域の光に対し反射性を有するカソード電極であり、第２電極は、電界発光層の発光する光と同じ波長域の光に対し透過性を有するアノード電極であることを特徴としている。

このため、第１電極が、低仕事関数の電極材料を適用することができ、発光効率を向上するとともに、電界発光層の発光する光がスイッチング素子に入射することを抑制できるので、スイッチング素子への光入射による誤動作を防止することができ、良好な輝度表示を行うことができ、さらにスイッチング素子の外光によるちらつきがないので視認性が向上する。また、電界発光層の発光する光を反射し、第２電極側に出射するので表示輝度効率がよい。

【００１４】

請求項８記載の発明は、選択トランジスタは、前記信号ラインからの前記電界発光層の発光輝度データに応じた信号電圧に応じた電圧を前記駆動トランジスタ

に印加するトランジスタであり、前記駆動トランジスタは、前記発光素子の次の選択期間まで前記発光輝度データに応じた電圧を前記第１電極に印加し続けるトランジスタであることを特徴としている。

【００１５】

請求項９記載の発明は、選択トランジスタは、消去期間に前記信号ラインから消去電圧が印加され書き込み期間に前記信号ラインから書き込み電圧が印加されることを特徴としている。

【００１６】

請求項１０記載の発明は、電界発光層は、電界に応じて発光する有機エレクトロルミネッセンス層であることを特徴としている。

【００１７】

【発明の実施の形態】

以下、この発明に係る表示装置の詳細を図面に示す各実施形態に基づいて説明する。

【００１８】

（実施形態１）

まず、図１および図２を用いて本発明に係る表示装置の実施形態１の構成を説明する。図１は本実施形態の表示装置の１画素部分を示す平面図であり、図２は図１のＡ－Ａ断面図である。図中１は表示装置を示している。この表示装置１は、図１および図２に示すように、基体としてのガラス基板２の上に、ｎチャネルの選択トランジスタQ_1と、ｎチャネルの駆動トランジスタとしてメモリトランジスタQ_2と、有機ＥＬ素子３などが形成されて構成されている。

【００１９】

具体的な構成を説明すると、ガラス基板２の上に例えばアルミニウム（Ａｌ）でなるゲートメタル膜がパターニングされて、所定方向に沿って平行かつ等間隔をなす複数のアドレス線４と、このアドレス線４に一体的な、選択トランジスタQ_1のゲート電極４Ａと、メモリトランジスタQ_2のゲート電極４Ｂと、が形成されている。なお、これらゲート電極４Ａ、４Ｂおよびアドレス線４の表面には、陽極酸化膜５が形成されている。また、これらアドレス線４、ゲート電極４Ａ、 ４Ｂおよびガラス基板２の上には、窒化シリコンでなるゲート絶縁膜６が形成されている。さらに、ゲート電極４Ａ、４Ｂの上方のゲート絶縁膜６、ゲート絶縁膜６Ａの上には、アモルファスシリコン（ａ－Ｓｉ）でなる半導体層７Ａ、７Ｂがパターン形成されている。また、それぞれの半導体層７Ａ、７Ｂの中央には、チャネル幅方向に沿って形成されたブロッキング層８Ａ、８Ｂが形成されている。そして、半導体層７Ａの上には、ブロッキング層８Ａ上でソース側とドレイン側に分離されたオーミック層９Ａ、９Ａが、形成されている。他方、半導体層７Ｂの上には、ブロッキング層８Ｂ上でソース側とドレイン側に分離されたオーミック層９Ｂ、９Ｂが、形成されている。さらに、選択トランジスタQ_1においては、ドレイン側のオーミック層９Ａに積層されて接続するデータ線１０Ａと、ソース側のオーミック層９Ａに積層されて接続するソース電極１０Ｂと、が形成されている。このソース電極１０Ｂは、メモリトランジスタQ_2のゲート電極４Ｂに対して、ゲート絶縁膜６に開口したコンタクトホール１１を介して接続されている。メモリトランジスタQ_2においては、ソース側のオーミック層９Ｂに積層されて接続するＧＮＤ線１２と、一端がドレイン側のオーミック層９Ｂに積層されて接続して他端が有機ＥＬ素子３の後記するカソード電極１５に接続するドレイン電極１３が形成されている。このような選択トランジスタQ1とメモリトランジスタQ_2とで電圧制御手段が構成されている。

【００２０】

次に、有機ＥＬ素子３の構成を説明する。まず、上記した選択トランジスタQ_1、メモリトランジスタQ_2およびゲート絶縁膜６の上に、表示装置１の表示領域全域に亙って、層間絶縁膜１４が堆積されている。そして、上記したメモリトランジスタQ_2のドレイン電極１３の端部上の層間絶縁膜１４にコンタクトホール１４Ａが形成されている。なお、メモリトランジスタQ_2のドレイン電極１３の端部は、１画素領域の略中央に位置するように設定されている。そして、層間絶縁膜１４の上に、例えばＭｇＩｎでなるカソード電極１５がパターン形成されている。このカソード電極１５は、１画素領域の大部分を覆うような面積および形状（本実施形態では略正方形）を有している。なお、本実施形態においては、カソード電極１５が、相隣接するデータ線１０Ａ、１０Ａと相隣接するアドレス線

４、４とで囲まれる領域（１画素領域）を略覆うように形成されている。ここで、選択トランジスタQ_1とメモリトランジスタQ_2とは、カソード電極１５で全面的に覆われている。

【００２１】

このように、各画素毎にパターン形成されたカソード電極１５、および層間絶縁膜１４の上に、有機ＥＬ層１６が表示領域全域に亙って形成されている。さらに、有機ＥＬ層１６の上には、透明なＩＴＯ（indume tin oxide）でなるアノード電極１７が表示領域全域に亙って形成されている。なお、図示しないが、アノード電極１７の周縁部には、駆動電源が接続されている。

【００２２】

ここで、本実施形態の表示装置１の作用・効果について説明する。上記した構成でなる本実施形態の表示装置１においては、カソード電極１５が、相隣接するデータ線１０Ａ、１０Ａと相隣接するアドレス線４、４とで囲まれる領域（１画素領域）を略覆うように形成されているため、有機ＥＬ素子３は１画素領域の略全域に亙って発光を行うことができる。このため、本実施形態の表示装置１では、１画素当たりの開口率を飛躍的に高めることができる。また、カソード電極１５が光反射性を有するＭｇＩｎで形成されているため、カソード電極１５とアノード電極１７との間に駆動電圧が印加された場合に、有機ＥＬ層１６で発生した表示光は、下方（ガラス基板２側）に漏れることなくアノード電極１７側に出射されるため、選択トランジスタQ_1およびメモリトランジスタQ_2の半導体層７Ａ、７Ｂへ不要に光が入射するのを防止することができる。このため、各トランジスタの光起電力による誤動作を回避することができる。また、表示光は、透明なアノード電極１７から出射されるため、ガラス基板２などにより光吸収されることがなく、輝度の高い状態で出射される。

【００２３】

次に、本実施形態の表示装置１の駆動原理を説明する。まず、本実施形態の表示素子１の１画素部分を図３および図４に示す等価回路図を用いて説明する。図３に示すように、本実施形態の表示素子の１画素部分のＥＬ表示回路は、有機ＥＬ素子３と電圧制御手段Ｖｃとから構成されている。この電圧制御手段Ｖｃは、

図４に示すように、選択トランジスタQ_1とメモリトランジスタQ_2とから構成されている。有機ＥＬ素子３においては、アノード電極側に一定の駆動電源（Ｖｄｄ）が接続され、そのカソード電極側に電圧制御手段Ｖｃが接続され、電圧制御手段Ｖｃを構成するメモリトランジスタQ_2のソース電極側はＧＮＤ線１２を介して接地されている。

【００２４】

これらの等価回路において、電圧制御手段Ｖｃにより、選択時に入力画像データによる階調データに応じて有機ＥＬ素子３の発光輝度を変化させるように電圧を制御することができる。図４に示したメモリトランジスタQ_2は、ＥＥＰＲＯＭメモリ機能を有するＴＦＴであり、選択トランジスタQ_1のゲート電極４Ａにはアドレス線４が接続されるとともに、そのドレイン側にデータ線１０Ａが接続されている。この選択トランジスタQ_1では、アドレス線４から入力される選択信号によりゲートがＯＮされることによって、データ線１０Ａから入力される入力画像データが、メモリトランジスタQ_2に蓄積される。メモリトランジスタQ_2では、そのゲート電極４Ｂに入力される入力画像データ電圧Ｖａに含まれる階調情報により、ゲート電極４Ｂのメモリ深さ（書き込み／消去によるＯＮ閾値電圧Ｖｔシフト量）で有機ＥＬ素子３の発光輝度を制御する。このため、１フレーム中で、その画素データ書き込み時間以外は、その書き込み情報に応じた出力（発光）をする。

【００２５】

ここで、図５を用いて有機ＥＬ素子３の電気特性の説明をする。図５においては、横軸はアノードーカソード間電圧Ｖａｃを、その縦軸は輝度を設定して、電圧ー輝度特性を示している。この図５に示すように、本実施形態の有機ＥＬ素子３は、アノードーカソード間電圧Ｖａｃが１／２Ｖｄｄ～Ｖｄｄの範囲で制御されることにより、その輝度特性が制御される。

【００２６】

ところで、メモリトランジスタQ_2は、ゲート絶縁膜６Ａに不純物イオンがドープされた窒化シリコン膜でなり、ＥＥＰＲＯＭ機能をもつ。このため、メモリトランジスタQ_2は、有機ＥＬ素子３を駆動するための画素駆動用トランジスタ

とすることができる。

【００２７】

また、選択トランジスタQ_1のソース電極１０Ｂは、メモリトランジスタQ_2のゲート電極４Ｂに接続され、ドレイン側にはデータ線１０Ａより書き込み・消去電圧が印加される。これにより、線順次で各画素領域のメモリトランジスタQ_2にデータを書き込むのに、選択トランジスタQ_1のドレイン側のバイアスが画像データで、選択トランジスタQ_1のゲート電極４Ａがアドレス選択とすれば、表示装置１における選択ライン以外の領域の全画素は、メモリトランジスタQ_2のゲート電極４Ｂのデータに応じた階調で発光し続ける。

【００２８】

次に、図６に示す表示装置１の駆動回路図について説明する。この駆動回路図においては、４画素分の表示回路を示している。同図に示すように、各画素領域は、選択トランジスタQ_1とメモリトランジスタQ_2と有機ＥＬ素子３とにより構成されている。各選択トランジスタQ_1のゲート電極４Ａにはアドレス線４が接続され、各選択トランジスタQ_1のドレイン側にはデータ線１０Ａが接続されている。また、アドレス線４において、選択されたラインには正電位である選択電圧Ｖａｄが、非選択のラインにはグランド電位である非選択電圧Ｖｎａｄが、印加されるよう設定されている。データ線１０Ａには、選択期間に、発光輝度に応じた正電位である書き込み電圧Ｖｒと、グランド電位または負電位である消去電圧Ｖｅと、が印加されるように設定されている。

【００２９】

以下に、本実施形態の表示装置１の動作について説明する。

まず、図６に示すように、第Ｍ列のアドレス線４を選択する場合において説明する。第Ｍ列のアドレス線４には選択時に選択電圧Ｖａｄが印加され、その他の列には非選択電圧Ｖｎａｄが印加される。第Ｍ列に接続された選択トランジスタQ_1には、選択期間の第１フィールドに、まずデータ線１０Ａから消去電圧Ｖｅが印加され、前の選択期間にメモリトランジスタQ_2のゲート絶縁膜６Ａに蓄積されたキャリアの抜き取りを行う。次いで選択期間の第２フィールドに、データ線１０Ａから書き込み電圧Ｖｒを印加する。書き込み電圧Ｖｒに応じて有機ＥＬ

素子３が階調発光を行う。非選択期間中は、書き込み電圧Ｖｒに応じてメモリトランジスタQ_2のゲート絶縁膜６Ａ内に蓄積されたキャリアの帯電により、メモリトランジスタQ_2のドレイン電流は流れ続けるので、１フレーム期間発光し続けることができる。

【００３０】

以上のように、本実施形態の表示装置１においては、アドレス線４が非選択時での有機ＥＬ素子３の発光状態を維持することができるため、高精細化しても有機ＥＬ素子３を高輝度化せずに面発光状態を維持することができる。例えば、従来の線順次方式の表示装置において面輝度１００ｃｄを得ようとした場合、アドレス線の数が４８０本あるとすると、４８０００ｃｄ程度の発光輝度が必要だったものが、本実施形態では選択時に非発光になったとしも約１００ｃｄ程度で良いことになる。

【００３１】

また、アドレス線数が１０００本の場合も従来４８０００ｃｄの発光輝度が必要だったものが、本実施形態では、やはり１００ｃｄ程度で良い。ただし、６０Ｈｚが１フレームとすると、アドレス線が増えると画像データの書き込み／消去時間が足りなくなる。書き込み、消去とも５０μｓでできるとすると、最大アドレス本数はノンインタレース方式で３３３本、インタレース方式で６６７本程度となる。

【００３２】

ちなみに、本実施形態のように、ＳｉＮ膜トラップを用いたメモリトランジスタQ_2の保持時間は非常に長い（通常１年～１０年）ため、画面の変化部分だけ書き換えていく方式であれば、書き込み・消去速度がｍｓｅｃオーダもフリッカレスでＯＡ表示パネルレベルの表示は可能であり、高品位な静止画を表示することができる。したがって、本実施形態の表示装置１は、従来提案されていた線順次駆動方式の有機ＥＬ表示パネルに較べて、高輝度化した有機ＥＬ素子を用いずに面発光状態を維持することができる。このため、高輝度かつ中間階調表示を可能とした表示装置を実現することができ、その入力画像の表現力を向上させることができる。

アドレス線４の本数の増加に伴い、キャリアの電位を高速に変位させるためにＰチャネル電流の影響がない程度に消去電圧Ｖｅを負電位にしても良い。

【００３３】

（実施形態２）

図７～図１１は本発明に係る表示装置の実施形態２を示している。図７は本実施形態の表示装置の１画素部を示す平面図であり、図８は図７のＢ－Ｂ断面図、図９は図７のＣ－Ｃ断面図である。また、図１０は等価回路図、図１１は本実施形態におけるアドレス線に出力されるアドレスデータ信号と電圧制御手段の電圧値を示すタイミングチャートである。

【００３４】

以下、本実施形態の表示装置の構成を説明する。図中２１は、表示装置を示している。本実施形態の表示装置２１では、図８および図９に示すように、ガラス基板２２上に例えばＡｌ、ＩＴＯなどでなる接地電極２３が表示領域全域に形成されている。この接地電極２３上の全面には、例えばシリコン酸化膜でなる下地絶縁膜２４が形成されている。そして、この下地絶縁膜２４の上には、複数のアドレス線X_1～Xnが互いに所定間隔を隔てて平行に形成されている。また、アドレス線X_1～Xnおよび下地絶縁膜２４の上には、第１ゲート絶縁膜２５が形成されている。さらに、第１ゲート絶縁膜２５の上には、図７および図８に示すように、例えばアモルファスシリコンでなる、第１半導体層２６と第２半導体層２７とがパターン形成されている。ここで、第１半導体層２６は、上記したアドレス線Ｘがゲート電極としての機能を果たすようになっている。

【００３５】

さらに、第１半導体層２６の上には、ゲート長方向の中央をゲート幅方向に渡ってブロッキング層２８がパターン形成されている。そして、第２半導体層２７の上面および側壁を覆うように、第２ゲート絶縁膜２９が形成されている。なお、ブロッキング層２８および第２ゲート絶縁膜２９は、ＣＶＤ法にて成膜された、例えば窒化シリコンで形成されている。そして、第１半導体層２６のゲート幅方向の両側には、ソース電極３０およびドレイン電極３１が第１半導体層２６に接続するように形成されている。このように、上記したアドレス線Ｘと、第１ゲ

ート絶縁膜２５と、第１半導体層２６と、ソース・ドレイン電極３０、３１と、で選択トランジスタとしての第１薄膜トランジスタQ_3が構成されている。なお、この第１薄膜トランジスタQ_3の入力インピーダンスは、大きくなるように設定されている。そして、図７に示すように、ドレイン電極３１はデータ線Ｙ（Y_j）と一体的にパターン形成されている。また、ソース電極３０は、第２半導体層２７の中央上方を第２ゲート絶縁膜２９を介して横切るゲート電極３２と一体的にパターン形成されている。加えて、このソース電極３０およびゲート電極３２は、図９に示すように、容量３３を構成する容量上部電極３４とも一体的にパターン形成されている。ところで、容量３４は、上記した容量上部電極３４と、この容量上部電極３４の下に形成された第２ゲート絶縁膜２９と、第１ゲート絶縁膜２５と、容量下部電極３５と、から構成されている。なお、容量下部電極３５は、下地絶縁膜２４に開口したコンタクトホール２４Ａを介して接地電極２３と接続されている。

【００３６】

また、第２半導体層２７のゲート電極３２の両側方には、第２半導体層２７に接続されたソース電極３６およびドレイン電極３７が形成されている。このように、第２半導体層２７と、第２ゲート絶縁膜２９と、ゲート電極３２と、ソース電極３６およびドレイン電極３７と、でメモリ用トランジスタとしての第２薄膜トランジスタQ_4が構成されている。なお、ドレイン電極３７は、図７に示すように、データ線Ｙに平行に形成された電源線３８に一体的に形成されている。また、ソース電極３６は、後記する有機ＥＬ素子３９を構成するＥＬ上部電極４０と一体的にパターン形成されている。上記したように、第１薄膜トランジスタQ_3と第２薄膜トランジスタQ_4と容量３３とを接続・構成することにより、電圧制御手段が構成されている。

【００３７】

有機ＥＬ素子３９は、図８および図９に示すように、例えばＩＴＯでなる透明なアノード電極としてのＥＬ上部電極４０と、このＥＬ上部電極４１の下に形成された有機ＥＬ層４１と、この有機ＥＬ層４１の下に形成された、例えばＭｇＩｎなどの遮光性をもつカソード電極としてのＥＬ下部電極４２と、で構成されて

いる。この有機ＥＬ素子３９は、第１薄膜トランジスタQ_3と第２薄膜トランジスタQ_4の上を覆いかつ表示領域全域に亙って形成された層間絶縁膜４３の上に、形成されている。ＥＬ下部電極４２は、層間絶縁膜４３、第２ゲート絶縁膜２９、第１ゲート絶縁膜２５および下地絶縁膜２４に開口したコンタクトホール４４を介して、接地電極２３に接続されている。このＥＬ下部電極４２は、図７に二点鎖線で示す領域においてＥＬ上部電極突出部４０Ａを除く領域を覆うように形成されている。すなわち、ＥＬ下部電極４２は、矩形の電極であり、第１薄膜トランジスタQ_3、第２薄膜トランジスタQ_4、容量３３などを確実に覆う形状・面積を有し、１画素の占有面積の大部分を占めるように形成されている。さらに、有機ＥＬ層４１は、表示領域全域に亙って一枚の層をなすように形成されている。また、ＥＬ上部電極４０は、図７の二点鎖線が示す領域に亙って形成されている。このＥＬ上部電極４０の突出部４０Ａは、同図に示すようにコンタクトホール４５を介して、第２薄膜トランジスタQ_4のソース電極３６と接続されている。以上、本実施形態の表示装置２１の構成を説明した。

【００３８】

図１０は、本実施形態の表示装置２１の１画素部分の等価回路図を示している。また、図１１は、アドレス線X_iに選択信号が出力された場合の容量３３の端子電圧を示すタイミングチャートである。以下、図１０および図１１を用いて、本実施形態の表示装置２１を発光させるための駆動方法を説明する。

【００３９】

まず、図示しないデータドライバを駆動させてデータ線Y_jに電圧が設定された時点で、アドレス線Ｘｉに選択信号を出力して選択を行う。この場合、選択信号は図１１に示すように、アドレス線Ｘの本数がＮとすると、１フレーム期間Ｔ中の１走査期間はＴ／Ｎになり、１走査期間の前半にグランド電位を印加し、次いで後半にしきい値Ｖｔｈを越える書き込み電圧Ｖｒを印加する。このとき、図１０に示した第１薄膜トランジスタQ_3はオンの状態となり、消去及び容量３３の端子電圧量として書き込まれる。そして、容量３３の端子電圧Ｖｃの電位状態に応じて、第２薄膜トランジスタQ_4が当該画素部分の有機ＥＬ層４１に印加する電界を制御する。本実施形態では、選択が解除された後でも、図１１に示すよ

うに容量３３に電位（Ｖｃ）が保持されるため、第２薄膜トランジスタQ_4は次回の選択時まで、保持された電位Ｖｃにより、電源線３８からの負電位である電位$-V_{DD}$を表示電圧に制御して有機ＥＬ層４１へ流し続ける。この間、第２薄膜トランジスタQ_4は電源線３８から電流を供給される。このような動作を繰り返すことで、表示装置２１は発光状態を持続させることができるため、コントラストを飛躍的に向上することが可能となる。また、薄膜トランジスタを用いて有機ＥＬ層４１へ流す電流を精密に制御できるため、階調表示が容易となり、例えば画素部分をＲＧＢで整列させれば、フルカラー表示も実現可能となる。

【００４０】

本実施形態においては、第１および第２薄膜トランジスタQ_3、Q_4がＭＯＳ型トランジスタであるが、これらがバイポーラトランジスタであっても、第１のトランジスタにおいては選択信号電圧がベースに印加された場合、１選択信号線あたりに多数の第１のトランジスタが接続されていても、それぞれの第１のトランジスタの入力インピーダンスが大きく設定されていることにより、アドレス線を流れる電流量を小さく抑える作用がある。このため、有機ＥＬ素子３９に要する電流量を小さくすることができ、電源の寿命を長くすることができる。また、第２のトランジスタにデータ信号電圧が印加された場合も、このトランジスタの入力インピーダンスが大きく設定されているため、容量３３に蓄積された電圧の減衰を低く抑えることができ、データ信号電圧の保持時間を長くすることが可能となる。

【００４１】

本実施形態の表示装置２１は、上記したようにＥＬ下部電極４２の面積が、１画素の占有領域の面積に近い面積であるため画素の発光効率や開口率を飛躍的に高くできる。また、ＥＬ下部電極４２は、遮光性をもつ電極であるため、このＥＬ下部電極４２の下方に存在する第１薄膜トランジスタQ_3や第２薄膜トランジスタQ_4に表示光を出射させることがなく、両トランジスタのチャネル領域に起電力を生じさせる光が入射することを防止できる。このため、表示特性が安定な駆動を行うことができる。さらに、本実施形態においては、各画素部分の開口率を向上して輝度を確保できるため、各有機ＥＬ素子３９に印加する電圧を高くし

て高輝度化を図る必要がなく、有機ＥＬ層４１に過剰の電圧を印加する必要がなくなり、有機ＥＬ層４１の劣化を抑制することができる。

【００４２】

以上、実施形態１および実施形態２について説明したが、本発明はこれらに限定されるものではなく、構成の要旨に付随する各種の変更が可能である。例えば、上記した実施形態１では、メモリトランジスタQ_2として、不純物がドープされた窒化シリコン膜でなるゲート絶縁膜を備えたＭＯＳトランジスタを適用したが、ドープしていないゲート絶縁膜のトランジスタを適用することも可能である。また、上記した実施形態では、カソード電極１５をＭｇＩｎで形成したが、光が透過できない他のカソード材料を用いても勿論よい。さらに、上記した実施形態１および実施形態２においては、基体としてガラス基板２を用いたが、不透明な基板を適用したり、合成樹脂からなる基板を適用しても勿論よい。さらにまた、上記した実施形態１では、半導体層をアモルファスシリコンで形成したが、多結晶シリコンを用いて形成してもよい。また、上記した実施形態１では、アノード電極１７から表示光が出射される構成としたが、アノード電極１７の前方にカラーフィルタを適宜配置する構成としても勿論良い。実施形態２においても、カラーフィルタを備える構成としても勿論よい。さらに、上記した実施形態１および実施形態２においては、ＥＬ層を有機ＥＬ材料で形成したが、無機ＥＬ材料を用いた構成としても勿論よい。又アノード電極上に透明絶縁膜を形成してもよい。

【００４３】

【発明の効果】

以上の説明から明らかなように、この発明によれば、選択トランジスタと駆動トランジスタでなる電圧制御手段を反射性電極が覆う構成としたため、トランジスタに光入射がなく、光起電力に起因する誤動作を防止することができる。また、カソード電極を画素領域を略覆うように形成し、アノード電極側から光を出射するので画素における開口率を大幅に向上させることができる。このため、各画素部分の輝度を確保できるため、各発光素子を高輝度化する必要がなく、電界発光層に過剰の電圧を印加する必要がなくなり、電界発光層の劣化を抑制する効果

を奏する。

【図面の簡単な説明】

【図１】

本発明に係る表示装置の実施形態１を示す平面図。

【図２】

図１のＡ－Ａ断面図。

【図３】

実施形態１のＥＬ表示回路を示す等価回路図。

【図４】

実施形態１のＥＬ表示回路の具体例を示す等価回路図。

【図５】

実施形態１の有機ＥＬ素子の電気特性を示すグラフ。

【図６】

実施形態１の表示装置の駆動回路図。

【図７】

本発明に係る表示装置の実施形態２を示す平面図。

【図８】

図７のＢ－Ｂ断面図。

【図９】

図７のＣ－Ｃ断面図。

【図１０】

実施形態２のＥＬ表示回路を示す等価回路図。

【図１１】

実施形態２のタイミングチャート。

【符号の説明】

１　表示装置

２　ガラス基板

３　有機ＥＬ素子

４　アドレス線

４Ａ、４Ｂ　ゲート電極

６　ゲート絶縁膜

６Ａ　ゲート絶縁膜

７Ａ、７Ｂ　半導体層

１０Ａ　データ線

１０Ｂ　ソース電極

１２　ＧＮＤ線

１３　ドレイン電極

１５　カソード電極

１６　有機ＥＬ層

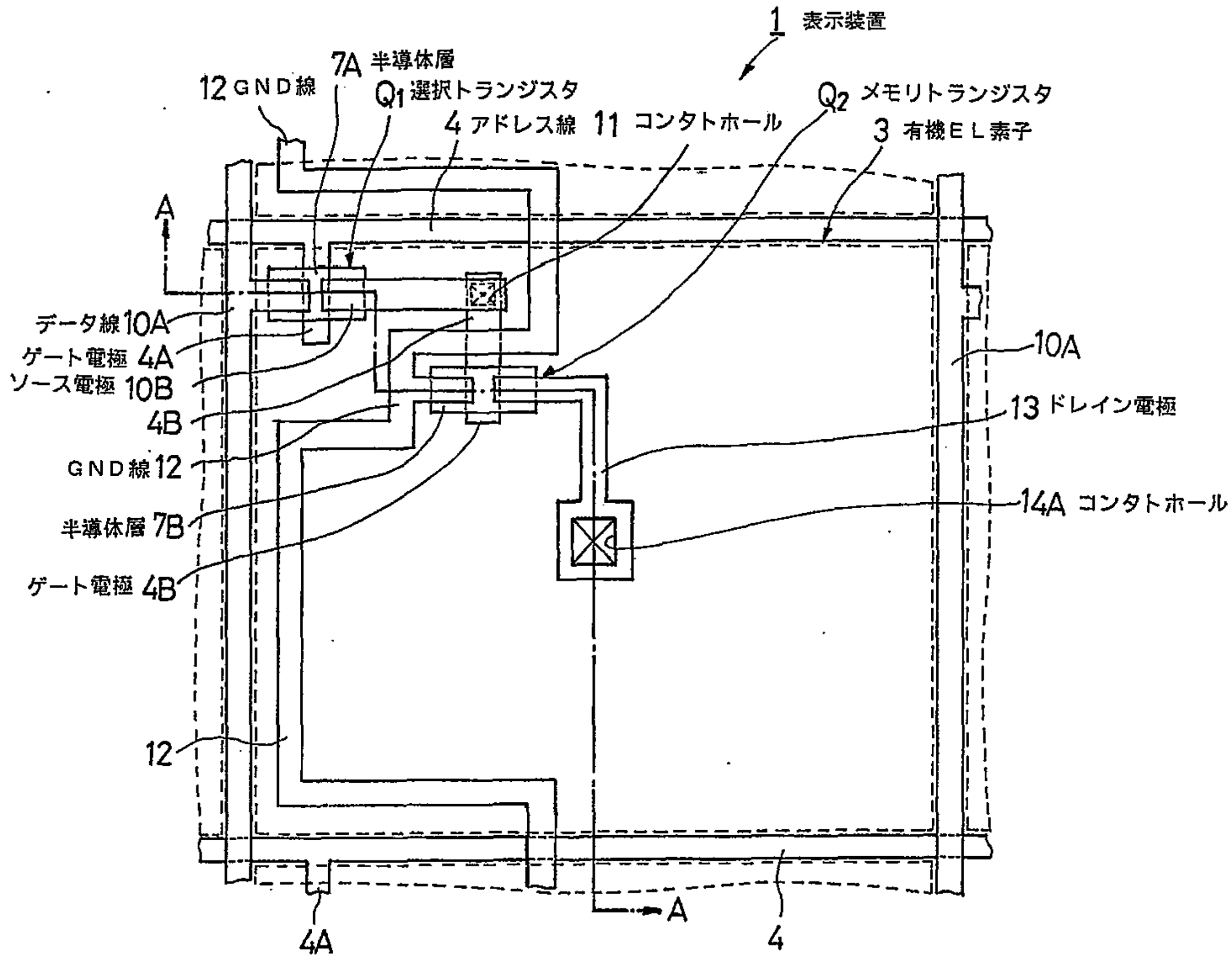
１７　アノード電極

Q_1　選択トランジスタ

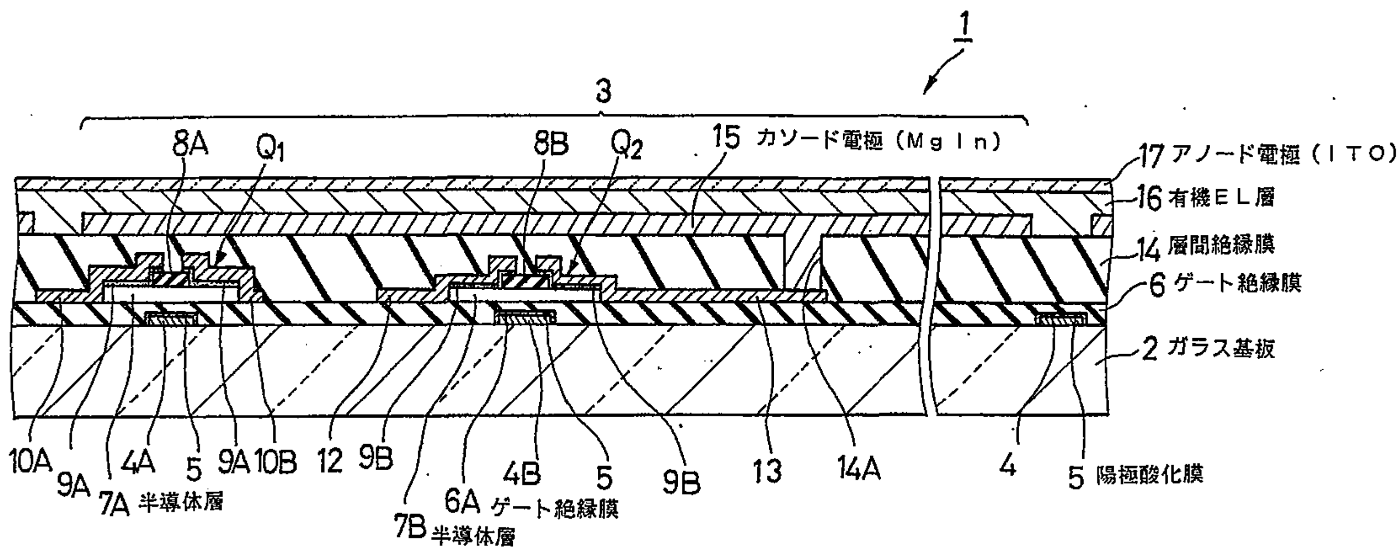
Q_2　メモリトランジスタ

【書類名】 図面

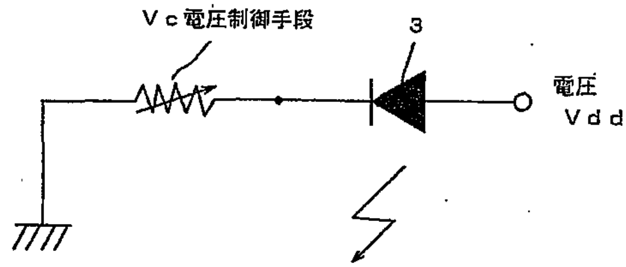
【図1】


1 表示装置
7A 半導体層
12 GND線
Q1 選択トランジスタ
4 アドレス線
11 コンタクトホール
Q2 メモリトランジスタ
3 有機ＥＬ素子
A
データ線 10A
ゲート電極 4A
ソース電極 10B
4B
GND線 12
半導体層 7B
ゲート電極 4B
12
4A
A
4
10A
13 ドレイン電極
14A コンタクトホール

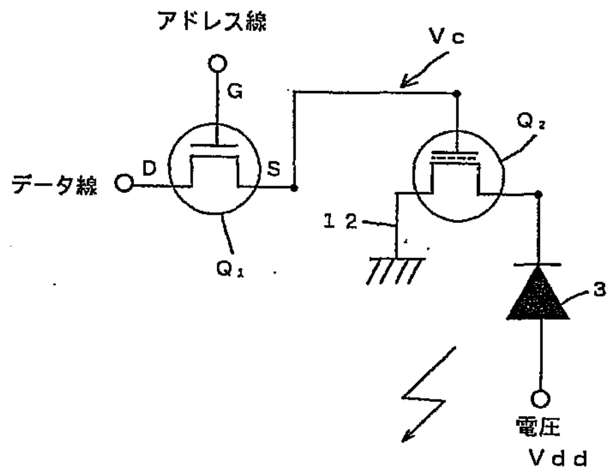
【図2】


1
3
8A
Q1
8B
Q2
15 カソード電極（Mg In）
17 アノード電極（ITO）
16 有機EL層
14 層間絶縁膜
6 ゲート絶縁膜
2 ガラス基板
10A
9A
7A 半導体層
4A
5
9A
10B
12
9B
7B 半導体層
6A ゲート絶縁膜
4B
5
9B
13
14A
4
5 陽極酸化膜

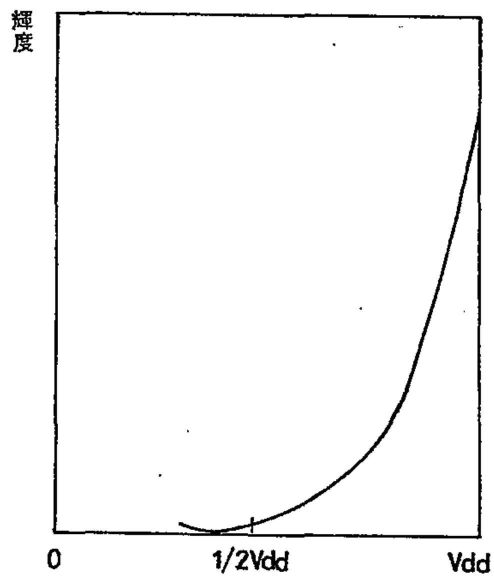
【図３】



【図４】

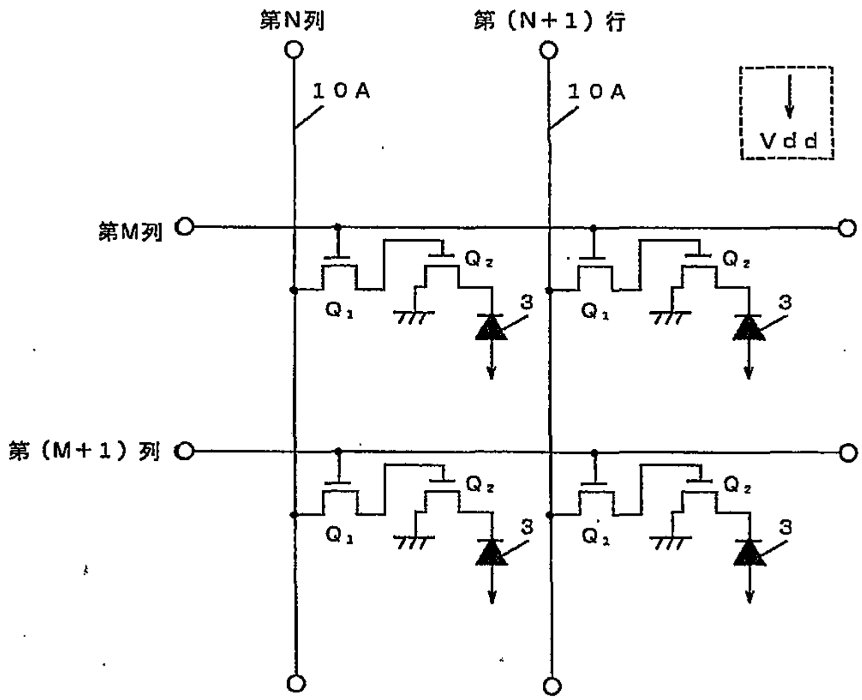


【図５】

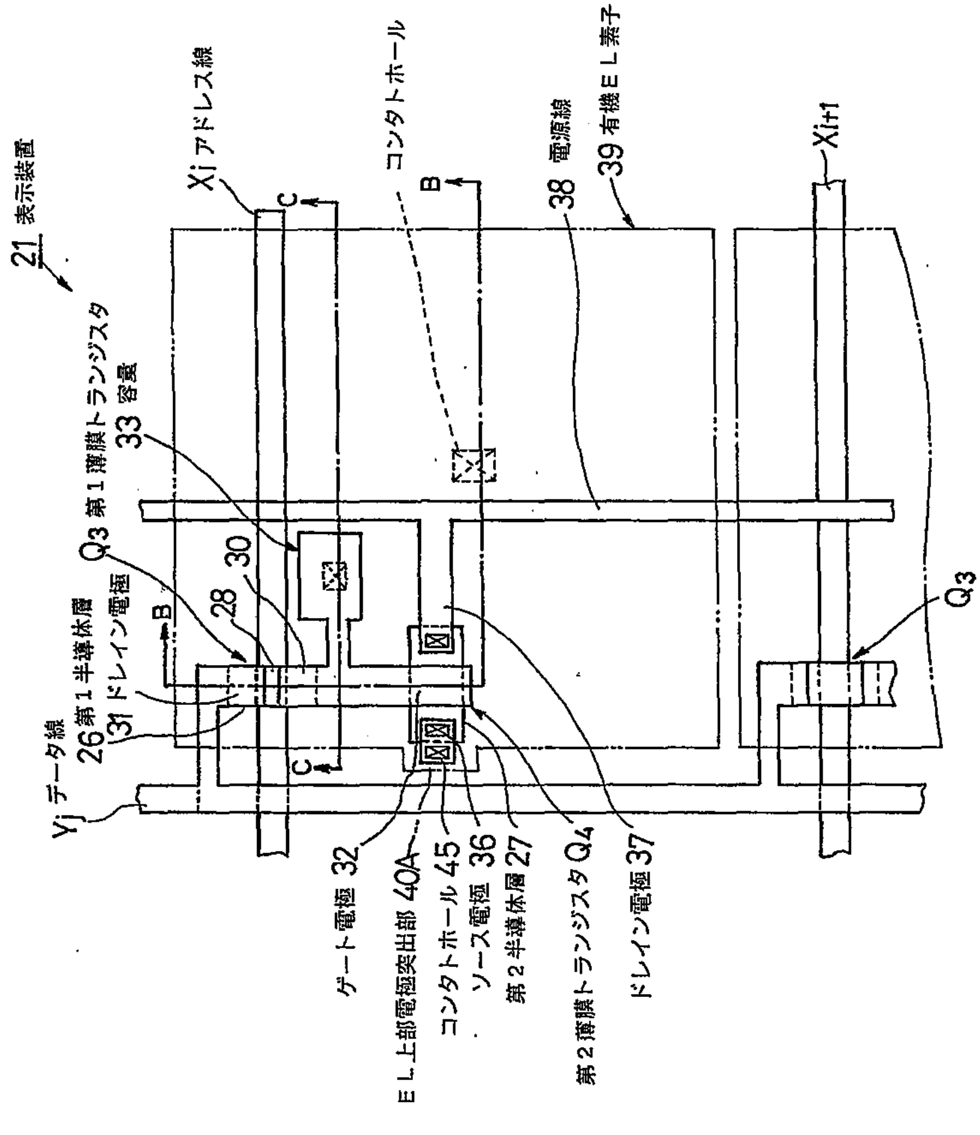


アノード・カソード間電圧
有機ＥＬダイオード特性

【図６】



【図７】


21 表示装置
Q3 第１薄膜トランジスタ
33 容量
Xi アドレス線
コンタクトホール
38 電源線
39 有機ＥＬ素子
Xi+1
30
28
B
C
Q3
26 第１半導体層
31 ドレイン電極
Yj データ線
32 ゲート電極
40A ＥＬ上部電極突出部
45 コンタクトホール
36 ソース電極
27 第２半導体層
Q4 第２薄膜トランジスタ
37 ドレイン電極

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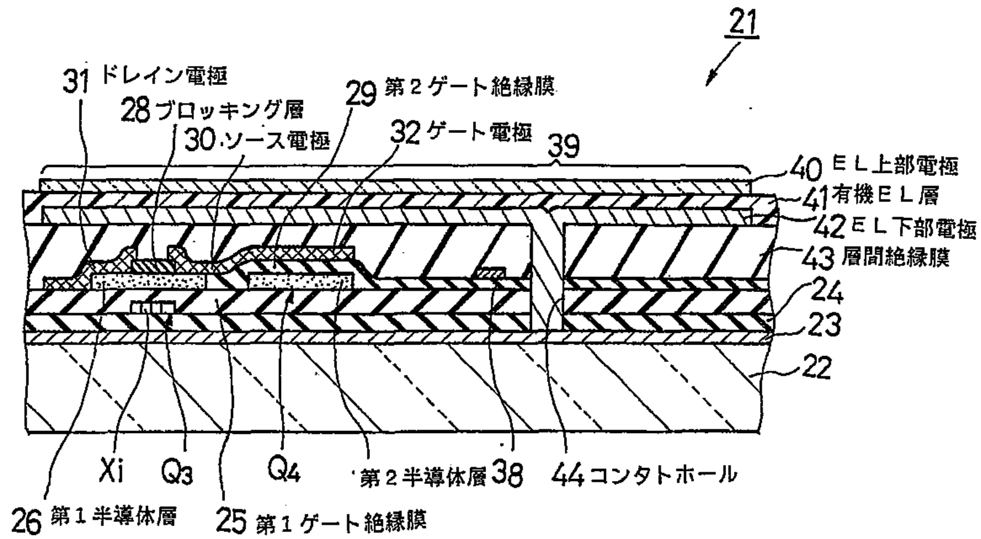
【図8】



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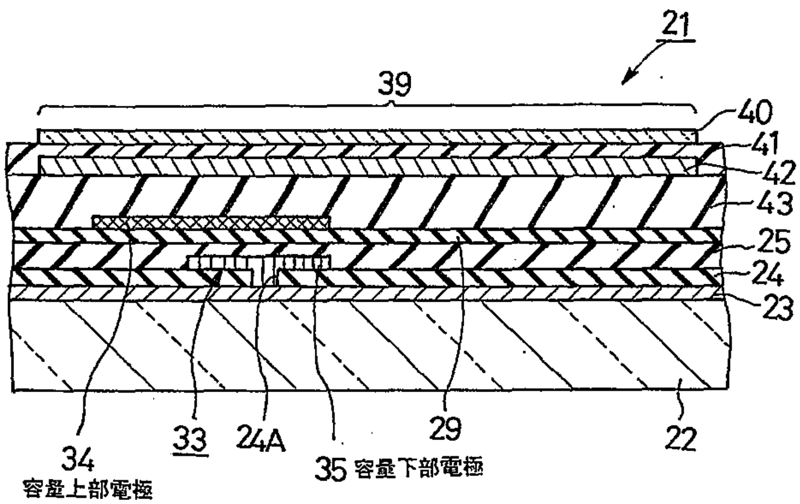
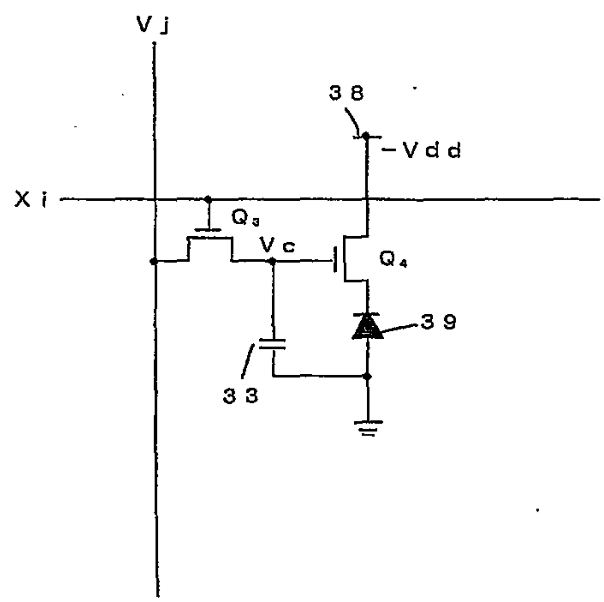
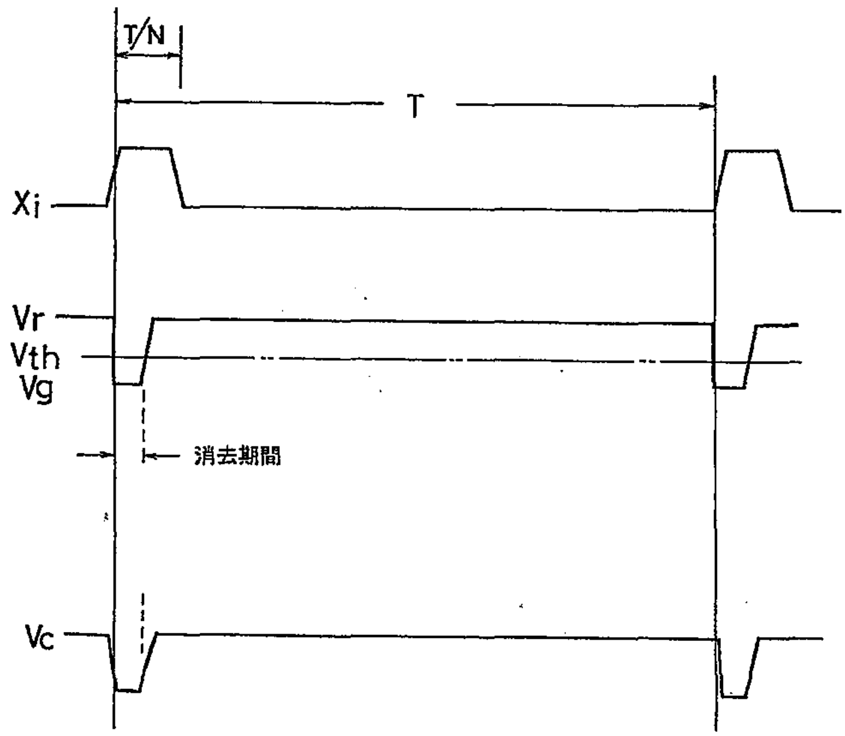
【図９】


21
39
40
41
42
43
25
24
23
34
容量上部電極
33
24A
35 容量下部電極
29
22

【図１０】


Vj
38
-Vdd
Xi
Q3
Vc
Q4
39
33

【図１１】



【書類名】　　　要約書

【要約】

【課題】　画素部分の開口率が高く、発光寿命の長い表示装置を提供する。

【解決手段】　ガラス基板２上の各画素領域内に、それぞれ、選択トランジスタQ_1とメモリトランジスタQ_2とが形成され、これらトランジスタの上にカソード電極１５を画素領域を略覆うように形成する。カソード電極１５の上には、順次有機ＥＬ層１６、アノード電極１７を形成する。メモリトランジスタQ_2のゲート絶縁膜を不純物イオンがドープされた窒化シリコン膜で形成することにより、ＥＥＰＲＯＭ機能をもつ薄膜トランジスタとする。このような構成としたことにより、メモリトランジスタQ_2で有機ＥＬ素子３の駆動を１フレーム期間維持させることが可能となる。このため、各画素での高輝度化を図ることなく、面輝度を確保できるため、有機ＥＬ層１６に過剰な電圧を印加しなくてもよく、有機ＥＬ層１６の劣化を抑制することができる。

【選択図】　　図２

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【訂正書類】　特許願

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【特許出願人】
【識別番号】　000001443
【住所又は居所】　東京都新宿区西新宿２丁目６番１号
【氏名又は名称】　カシオ計算機株式会社
【代理人】　申請人
【識別番号】　100074985
【住所又は居所】　東京都港区西新橋１丁目１３番４号　ＴＳビル３階　杉村次郎特許事務所
【氏名又は名称】　杉村　次郎

出　願　人　履　歴　情　報

識別番号　〔０００００１４４３〕

１．変更年月日　１９９０年　８月１０日
　　［変更理由］　新規登録
　　住　所　東京都新宿区西新宿２丁目６番１号
　　氏　名　カシオ計算機株式会社

日 本 国 特 許 庁
PATENT OFFICE
JAPANESE GOVERNMENT

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This is to certify that the annexed is a true copy of the following application as filed with this Office.

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Applicant (s): カシオ計算機株式会社

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特許庁長官
Commissioner,
Patent Office

荒井寿光

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【発明者】
　【住所又は居所】　東京都青梅市今井３丁目１０番地６
　　カシオ計算機株式会社青梅事業所内
　【氏名】　河村　義裕
【発明者】
　【住所又は居所】　東京都青梅市今井３丁目１０番地６
　　カシオ計算機株式会社青梅事業所内
　【氏名】　白寄　友之
【特許出願人】
　【識別番号】　000001443
　【住所又は居所】　東京都新宿区西新宿２丁目６番１号
　【氏名又は名称】　カシオ計算機株式会社
　【代表者】　樫尾　和雄
【代理人】
　【識別番号】　100074985
　【弁理士】
　【氏名又は名称】　杉村　次郎
【手数料の表示】
　【予納台帳番号】　023180
　【納付金額】　21,000円
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【書類名】　明細書
【発明の名称】　ＥＬ素子
【特許請求の範囲】

【請求項１】　発光層の前面に透明電極が形成され、かつ該発光層の背面に当該発光層を挟んで前記透明電極に対向して複数の発光領域を形成する背面電極が形成されると共に、前記発光領域うち所定の発光領域の発光層で発生した光の波長変換を行って変換光を透過させる色変換層が前記所定の発光領域に位置する前記透明電極の前方に対応するように配置され、当該色変換層の前方に前記変換光の透過波長域を制限する色フィルタ層が前記色変換層に対応するように配置されていることを特徴とするＥＬ素子。

【請求項２】　前記発光領域に対応する色変換層は複数種類あることを特徴とする請求項１記載のＥＬ素子。

【請求項３】　前記色変換層は、前記発光領域の発光層から入射する光の波長を長波長側へ変換させることを特徴とする請求項１または請求項２に記載のＥＬ素子。

【請求項４】　前記発光層で発光する光は青色光であり、前記色変換層は青色光を赤色光に変換する第１変換層と青色光を緑色光に変換する第２変換層との２種類が存在すると共に、前記色変換層が配置されない前記発光領域が存在し、前記第１変換層に対応するように特定波長域の赤色光のみを透過させる第１色フィルタ層が配置され、前記第２変換層に対応するように特定波長域の緑色光のみを透過させる第２色フィルタ層が配置され、前記色変換層が対応して配置されない前記発光領域の前方には特定波長域の青色光のみを透過させる第３フィルタ層が配置されていることを特徴とする請求項２または請求項３に記載のＥＬ素子。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】

この発明は、ＥＬ素子に関し、さらに詳しくは、効率のよいカラー表示を行うＥＬ素子に関する。

【０００２】

【従来の技術】

従来、ＥＬ素子には有機材料からなる有機ＥＬ素子があり、図１７に示すような構成のものが知られている。このＥＬ素子は、透明なガラス基板１の後面に赤（Ｒ）、緑（Ｇ）、青（Ｂ）のカラーフィルタ２Ｒ、２Ｇ、２Ｂが配置され、保護膜３を介して複数の前面電極４が所定方向に平行に配置され、前面電極４に対して有機発光層５を介して直交する背面電極６が複数設けられた構成となっている。この有機発光層５は、Ｒ、Ｇ、Ｂの蛍光材料がランダムかつ均一に分散されており、電界の印加により白色光を発生するように設定されている。また、前面電極４と背面電極６とが交差するドット部分とカラーフィルタ２Ｒ、２Ｇ、２Ｂのそれぞれとが対応するような配置となっている。すなわち、前面電極４と背面電極６との間に電界を印加すると、両電極が交差するドット部分の有機発光層５でキャリアの再結合に起因して発光が起こるが、この光が対応するカラーフィルタに入射するように位置設定されている。

【０００３】

【発明が解決しようとする課題】

上記した従来の有機ＥＬ素子では、Ｒ、Ｇ、Ｂの各カラーフィルタを用いてカラー表示を行うため、必然的に有機発光層５の発光色を白色にしなければならないが、有機材料の白色蛍光体では、Ｒ蛍光材料とＧ蛍光材料とが混合されているので、無輻射の遷移を生じる確立が高くなるため、良好な変換効率を得ることが困難であるという問題があった。また、白色光をカラーフィルタに通してＲ、Ｇ、Ｂ光を生じさせる手法では、原理的にＲ、Ｇ、Ｂの各カラーフィルタでは、それぞれ白色光の波長域のうちＲ、Ｇ、Ｂの波長域を除く波長域の成分を概ね吸収してしまうので、有機発光層５での発光輝度に対しカラーフィルタから出射される表示光の輝度がかなり低くなってしまっていた。このような理由から、図１７に示した有機ＥＬ素子では、エネルギー効率の高い表示を実現することは極めて困難であった。

この発明が解決しようとする課題は、エネルギー効率が良好でかつ色純度の高い表示を可能にする有機ＥＬ素子を得るにはどのような手段を講じればよいかという点にある。

【０００４】

【課題を解決するための手段】

請求項１記載の発明は、発光層の前面に透明電極が形成され、かつ該発光層の背面に当該発光層を挟んで前記透明電極に対向して複数の発光領域を形成する背面電極が形成されると共に、前記発光領域のうち所定の発光領域の発光層で発生した光の波長変換を行って変換光を透過させる色変換層が前記所定の発光領域に位置する前記透明電極の前方に対応するように配置され、当該色変換層の前方に前記変換光の透過波長域を制限する色フィルタ層が前記色変換層に対応するように配置されていることを特徴としている。

【０００５】

請求項１記載の発明においては、発光層の発光領域から発生した光の波長を色変換層で効率的に変換して色変換を行うことができる。また、色フィルタ層が色変換層の前方に配置されているため、色変換された光の色純度を高める作用を奏することができる。このため、エネルギー効率が高く、色純度の高いＥＬ素子を実現することができる。

【０００６】

請求項２記載の発明は、前記発光領域に対応する色変換層は複数の色の種類に応じて複数あることを特徴としている。請求項３記載の発明は、前記色変換層が、前記発光領域の発光層から入射する光の波長を長波長側へ変換させることを特徴としている。請求項４記載の発明は、前記発光層で発光する光は青色光であり、前記色変換層は青色光を赤色光に変換する第１変換層と青色光を緑色光に変換する第２変換層との２種類が存在すると共に、前記色変換層が配置されない前記発光領域が存在し、前記第１変換層に対応するように特定波長域の赤色光のみを透過させる第１色フィルタ層が配置され、前記第２変換層に対応するように特定波長域の緑色光のみを透過させる第２色フィルタ層が配置され、前記色変換層が対応して配置されない前記発光領域の前方には特定波長域の青色光のみを透過させる第３フィルタ層が配置されていることを特徴としている。

【０００７】

請求項２～４に記載された発明によれば、多色表示が可能でエネルギー効率の

高い表示を行えるＥＬ素子の実現が可能となる。

【０００８】

【発明の実施の形態】

以下、この発明に係る有機ＥＬ素子の詳細を図面に示す各実施形態に基づいて説明する。

（実施形態１）

図１は、本発明に係る有機ＥＬ素子の実施形態を示す断面図である。本実施形態は、有機発光層の発光領域がマトリクス状に配置された有機ＥＬ素子に本発明を適用したものである。発光領域は、赤色に発光する赤色発光部と、緑色に発光する緑色発光部と、青色に発光する青色発光部と、が所定の配列で隣接して配置され、この３色のドット部分で画素が構成されている。このため、本実施形態の有機ＥＬ素子は、多色表示パネルとして用いることができるものである。

【０００９】

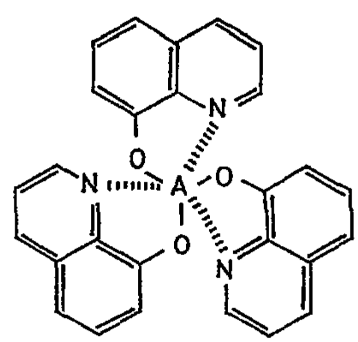
以下、図１を用いて有機ＥＬ素子１１の構成を説明する。まず、透明なガラス基板１２の背面に、第１色フィルタ層としての赤色フィルタ層１３と、第２色フィルタ層としての緑色フィルタ層１４と、が所定の配列で形成されている。なお、これら赤色フィルタ層１３と緑色フィルタ１４とは、後記する発光領域と対応するように設定されている。赤色フィルタ層１３は、赤色波長域の光を含む光を入射すると、赤色波長域の光の透過しそれ以外の波長域の光を吸収する層であり、緑色フィルタ層１４は、緑色波長域の光を含む光を入射すると、緑色波長域の光の透過しそれ以外の波長域の光を吸収する層である。赤色フィルタ層１３の背面には、青色の波長域の光を吸収し、より長波長域の赤色の波長域の光を発光するフォトルミネッセンス層としての青・赤色変換層１５が対応するように接合して形成されている。また、緑色フィルタ層１４の背面には、青色の波長域の光を吸収し、より長波長域の緑色の波長域の光を発光するフォトルミネッセンス層としての青・緑色変換層１６が対応するように接合して形成されている。そして、これら色フィルタ層や色変換層が形成されたガラス基板１２の背面を覆うように保護膜１７が平坦に形成されている。

【００１０】

さらに、保護膜１７の背面には、所定方向に沿ってＩＴＯでなる、複数の透明電極１８が互いに平行に形成されている。なお、この透明電極１８は、所定の列をなす青・赤色変換層１５、青・緑色変換層１６などと平面的に重なるように設定されている。さらに、保護膜１７および透明電極１８を覆うように、有機発光層１９が背面側に形成されている。この有機発光層１９は、電界が印加されることにより青色光が発生するような有機エレクトロルミネッセンス材料が用いられている。この有機発生層１９の背面には、透明電極１８と交差（直交）するように複数の背面電極２０が形成されている。有機発光層１９、背面電極２０側から順にトリス（８－ヒドロキシキノリン）アルミニウム（以下、Ａｌｑ３）からなる電子輸送層と、4,4′－ビス（2,2－ジフェニルビニレン）ビフェニル（以下、ＤＰＶＢｉ）９６ｗｔ％と4,4′－ビス（２－カルバゾールビニレン）ビフェニル（以下、ＢＣｚＶＢｉ）４ｗｔ％とからなる発光層と、N,N′－ジ（α－ナフチル）－N,N′－ジフェニル－1,1′－ビフェニル－4,4′－ジアミン（以下、α－ＮＰＤ）からなる正孔輸送層と、から構成されている。

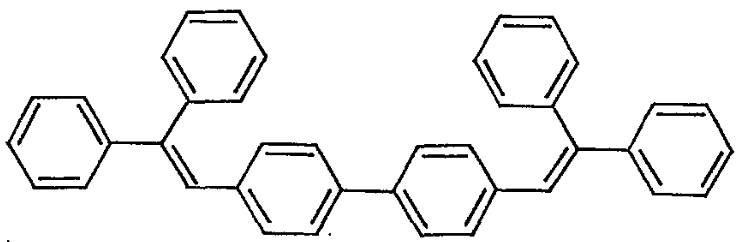
以下にＡｌｑ３、ＤＰＶＢｉ、ＢＣｚＶＢｉ、α－ＮＰＤの構造式を示す。

【化１】



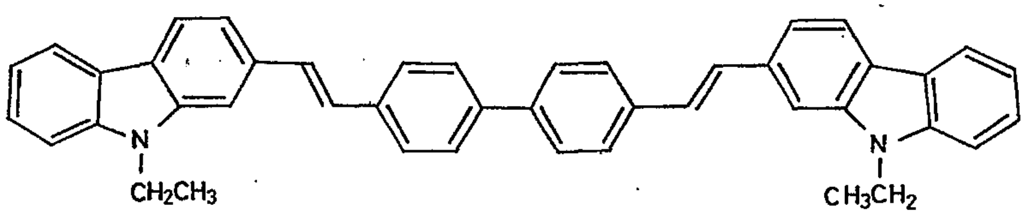
Ａｌｑ３

【化2】



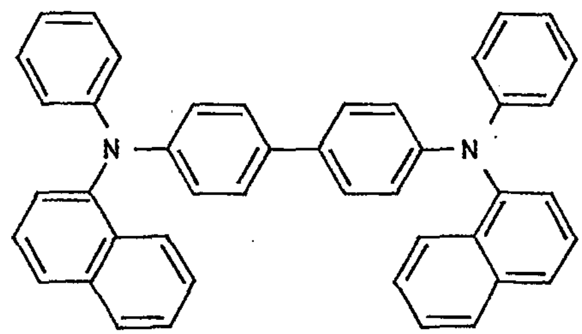
ＤＰＶＢｉ

【化3】



ＢＣｚＶＢｉ

【化４】



α－ＮＰＤ

なお、本実施形態では、背面電極２０を光反射性を有しかつ有機発光層１９にキャリアを注入し易い性質をもつメタル材料（例えば、ＭｇＩｎ、ＡｌＬｉなど）で形成した。これら背面電極２０と透明電極１８との交差部分の有機発光層１９は、電界が印加されると発光する発光領域となる。上記した青・赤色変換層１５や青・緑色変換層１６は、発光領域と対応する配置となるように設定されている。上記した本実施形態の有機ＥＬ素子１１では、発光領域と青・赤色変換層１５とが平面的に重なる部分と、発光領域と青・緑色変換層１６とが平面的に重なる部分と、発光領域に対して色変換層が重ならない部分と、の３つのドット部分が形成されている。すなわち、発光領域と青・赤色変換層１５とが平面的に重なる部分では、赤色の発光表示を行うことができ、発光領域と青・緑色変換層１６とが平面的に重なる部分では、緑色の発光表示を行うことができ、発光領域に対して色変換層が重ならない部分では青色の発光表示を行うことができる。このため、これら３つのドット部分の発光を制御することにより、自発光多色表示を行うことが可能となる。

【００１１】

次に、上記した有機ＥＬ素子１１の作用・動作について説明する。

まず、青・赤色変換層１５に対応する発光領域で発光が起こるように透明電極

１８と背面電極２０とが選択された場合は、有機発光層１９の発光領域に電界が印加されることにより、青色光がその発光領域で発生する。この青色光は、透明電極１８および保護膜１７を透過して青・赤色変換層１５に入射する。この青色光は、青・赤色変換層１５に吸収され、新たに青・赤色変換層１５では赤色光を発生させる。この赤色光は、赤色フィルタ層１３を透過することにより、赤色の色純度が高められる。この赤色光は、ガラス基板１２を透過して表示光として前方に出射される。赤色フィルタ層１３は、特定の赤色波長域のみを透過し、その他の波長域の光を吸収するが、赤色フィルタ層１３に入射される光は、主に赤色の波長域を主体とした光なので、赤色フィルタ層１３の光吸収は少なく、表示光の輝度は高いものとなる。

【００１２】

また、青・緑色変換層１６に対応する発光領域で発光が起こるように透明電極１８と背面電極２０とが選択された場合は、有機発光層１９の発光領域に電界が印加されることにより、青色光がその発光領域で発生する。この青色光は、透明電極１８および保護膜１７を透過して青・緑色変換層１６に入射する。この青色光は、青・緑色変換層１６に吸収され、新たに青・緑色変換層１６では緑色光を発生させる。この緑色光は、緑色フィルタ層１４を透過することにより、緑色の色純度が高められる。この緑色光は、ガラス基板１２を透過して表示光として前方に出射される。緑色フィルタ層１４は、特定の緑色波長域のみを透過し、その他の波長域の光を吸収するが、緑色フィルタ層１４に入射される光は、主に緑色の波長域を主体とした光なので、緑色フィルタ層１４の光吸収は少なく、表示光の輝度は高いものとなる。

【００１３】

さらに、色変換層が対応して配置されない部分の発光領域で発光が起こるように透明電極１８と背面電極２０とが選択された場合は、有機発光層１９の発光領域に電界が印加されることにより、青色光がその発光領域で発生する。この青色光は、透明電極１８、保護膜１７およびガラス基板１２を透過して前方に表示光として出射される。なお、各ドット部分において、青色光が背面電極２０側に向けて出射しても背面電極２０自体に光反射性があるため、青色光を前方に向けて

反射させることができ、光の利用効率を高めることができる。

【００１４】

本実施形態では、上記した３つのドット部分の色表示を制御することにより、加法混色を行うことができ、多色表示またはフルカラー表示を行うことが可能となる。特に、本実施形態では、有機発光層１９の発光色が青色であるため、従来の白色発光を利用したＲＧＢ発光システムに比較してエネルギー効率を大幅に高めることができる。また、本実施形態においては、赤色表示ドット部分に赤色フィルタ層１３を、緑色表示ドット部分に緑色フィルタ層１４を、配置したことにより、仮に青色発光の輝度を高くした結果、各色変換層を透過する青色光が発生した場合にも赤色フィルタ層１３や緑色フィルタ層１４が配置されているため、これらのフィルタで青色光を吸収させることができる。このため、これらの部分では表示を見る観察者側に青色光が視認されることがなく、色純度の高い表示が可能となる。

【００１５】

（実施形態２）

図２は、本発明に係る有機ＥＬ素子の実施形態２を示す断面図である。本実施形態の有機ＥＬ素子１１の構成は、有機ＥＬ素子１１の色変換層が対応して配置されないドット部分の発光領域に対応するように、ガラス基板１２の背面に青色の波長域の光を透過し、他の可視光波長域の光を吸収する青色フィルタ層２１を形成したものであり、他の構成は上記実施形態１と同様である。

【００１６】

本実施形態においては、有機発光層１９で発光した青色光を青色フィルタ層２１を透過させることにより、表示光としての青色の色純度をより高めることが可能となる。他の作用・動作は上記実施形態１と同様である。

【００１７】

（実施形態３）

図３は、本発明に係る有機ＥＬ素子の実施形態３を示す断面図である。本実施形態は、ガラス基板１２の背面に、赤色フィルタ層１３、緑色フィルタ層１４、青色フィルタ層２１が配置・形成され、ガラス基板１２およびこれらフィルタ層

を覆うように第１保護膜１７Ａが平坦に形成され、さらにこの第１保護膜１７Ａの背面に青・赤色変換層１５および青・緑色変換層１６が配置・形成されこれらを覆うように第２保護膜１７Ｂが形成されている。さらに、第２保護膜１７Ｂの背面には、上記実施形態１および実施形態２と同様に透明電極１８、有機発光層１９、および背面電極２０が形成されている。

【００１８】

本実施形態においては、色フィルタ層を覆う第１保護膜１７Ａと色変換層を覆う第２保護膜１７Ｂを形成することにより、各色フィルタ層の透過特性を互いに均一にさせるために色フィルタ層の厚さをそれぞれ最適値に設定することにより発生する凸凹を補償することができ、またフィルタ層とガラス基板１２との段差を第１保護膜１７Ａで平坦化でき、色変換層と第１保護膜１７Ａとの段差を第２保護膜１７Ｂで平坦化できるため、素子全体としての平坦化を達成することができる。また、平坦化を達成することにより、色変換層の寸法精度を向上できるという利点がある。なお、他の作用・動作は、上記した実施形態１および実施形態２と同様である。

【００１９】

（実施形態４）

図４は、本発明に係る有機ＥＬ素子の実施形態４を示す断面図である。本実施形態では、同図に示すように、ガラス基板１２の前面に赤色フィルタ層１３、緑色フィルタ層１４、青色フィルタ層２１が配置され、ガラス基板１２の前面およびこれらのフィルタ層を覆うように第１保護膜１７Ａが平坦に形成されている。また、ガラス基板１２の背面には、赤色フィルタ層１３に対応するように配置された青・赤色変換層１５と、緑色フィルタ層１４に対応するように配置された青・緑色変換層１６と、が形成され、ガラス基板１２の背面およびこれら光変換層を覆うように第２保護膜１７Ｂが平坦に形成されている。そして、この第２保護膜１７Ｂの背面には、上記した実施形態１～３と同様の構成で透明電極１８、有機発光層１９、および背面電極２０が形成されている。

【００２０】

本実施形態では、１枚のガラス基板１２の表背面にフィルタ層や色変換層を形

成するため、これらの形成プロセスを簡略化することができる。

【００２１】

（実施形態５）

図５は、本発明に係る有機ＥＬ素子の実施形態５を示す断面図である。本実施形態では、ガラス基板１２の前面に青・赤色変換層１５と青・緑色変換層１６とが所定の配置になるように形成され、ガラス基板１２およびこれら色変換層の上に平坦な第２保護膜１７Ｂが形成されている。この第２保護膜１７Ｂの上には、赤色フィルタ層１３、緑色フィルタ層１４、および青色フィルタ層２１がそれぞれ所定の位置に配置され、これらフィルタ層および第２保護膜１７Ｂの上に平坦な第１保護膜１７Ａが形成されている。一方、ガラス基板１２の背面には、上記した実施形態１～４と同様の構成で透明電極１８、有機発光層１９、および背面電極２０が形成されている。

【００２２】

（実施形態６）

図６は、本発明に係る有機ＥＬ素子の実施形態６を示す断面図である。本実施形態の有機ＥＬ素子１１は、同図に示すようにガラス基板１２の前面側に作成されている。まず、ガラス基板１２の前面には、所定方向に向けて平行をなす複数の背面電極２０がパターン形成されている。また、ガラス基板１２および背面電極２０の上には、有機発光層１９が形成されている。有機発光層１９の上には、背面電極２０と交差（直交）するように複数の透明電極１８が形成されている。さらに、有機発光層１９および透明電極１８の上には、第１保護膜２２Ａが平坦に形成されている。そして、背面電極２０と透明電極１８とが交差する部分（発光領域）にそれぞれ対応するように、青・赤色変換層１５と、青・緑色変換層１６と、が所定位置に配置されている。第１保護膜２２Ａおよびこれら色変換層の上には、第２保護膜２２Ｂが平坦に形成されている。さらに、第２保護膜２２Ｂの上には、青・赤色変換層１５に対応するように赤色フィルタ層１３が、青・緑色変換層１６に対応するように緑色フィルタ層１６が、また色変換層が配置されていない発光領域に対応するように青色フィルタ層２１が、形成されている。そして、第２保護膜２２Ｂおよびこれらフィルタ層の上には、第３保護膜２２Ｃが

平坦に形成されている。

【００２３】

なお、上記した本実施形態では、ガラス基板１２を用いたが、電気絶縁性を有する基板であれば合成樹脂を用いてもよい。

【００２４】

本実施形態では、ガラス基板１２を基にして、順次薄膜を積層するプロセスを繰り返すことにより有機ＥＬ素子１１を製造することができる。なお、上記した第１保護膜２２Ａ、第２保護膜２２Ｂ、第３保護膜２２Ｃは、いずれかを省略してもよい。本実施形態によれば、発光した光をガラス基板１２を透過させずに表示光として用いることができるため、ガラス内での光損失および屈折による視認性の悪化などの問題を解消することができる。なお、他の作用・動作は、上記した実施形態１と同様である。

【００２５】

（実施形態７）

図７は、本発明に係る有機ＥＬ素子の実施形態７を示す断面図である。本実施形態は、上記した実施形態２のガラス基板１２の前面に、例えば紫外光等の励起光の入射を防止する励起光吸収フィルタ層２３を配置した構成をもつ。なお、他の構成は、上記実施形態２と同様である。

【００２６】

本実施形態においては、励起光フィルタ層２３を素子の最前部に配置したことにより、有機発光層１９に励起光が入射して、有機発光層１９の励起、発光が生ずるのを抑制することができる。このような励起、発光を抑制することにより、有機ＥＬ素子１１のコントラストを向上させることができる。また、励起光の入射を防止することにより、色変換層や有機発光層１９などの劣化を防止することもできる。なお、他の作用・動作ならびに効果は、上記した実施形態２と同様であるので説明を省略する。

【００２７】

（実施形態８）

図８は、本発明に係る有機ＥＬ素子の実施形態８を示す断面図である。本実施

形態の有機ＥＬ素子の構成を同図を用いて説明する。本実施形態においては、第１ガラス基板２４と第２ガラス基板２５との２枚用いた構成である。まず、第１ガラス基板２４の前面には、青・赤色変換層１５と、青・緑色変換層１６と、が所定の位置に配置されるように形成されている。また、青・赤色変換層１５の上には、赤色フィルタ層１３が形成されてる。さらに、青・緑色変換層１６の上には、緑色フィルタ層１４が形成されている。他方、第２ガラス基板２５の背面には、所定方向に沿ってそれぞれ平行をなす複数の透明電極１８が形成されている。第２ガラス基板２５およびこれら透明電極１８の背面側には、有機発光層１９が形成されている。さらに、有機発光層１９の背面には、この有機発光層１９を挟んで透明電極１８と交差（直交）する複数の背面電極２０が形成されている。そして、第１ガラス基板２４の背面と、第２ガラス基板２５の前面と、が対向し、かつ、有機発光層１９の発光領域と、色変換層などが対応するように設定されている。

【００２８】

本実施形態においては、第１ガラス基板２４と第２ガラス基板２５とを重ね合わせる際に、液晶表示装置の製造プロセスで用いられるパネル張り合わせ技術を用いることができる。これにより、本実施形態では、第１ガラス基板２４と第２ガラス基板２５とを、数μｍ程度の精度で重ね合わせることができる。

【００２９】

（変形例１）

なお、図９は本実施形態８の変形例１であり、第１ガラス基板２４の前面の色変換層が配置されていない、発光領域に対応する位置に青色フィルタ層２１を配置した構成であり、他の構成は本実施形態８と同様である。

【００３０】

（変形例２）

図１０は変形例２を示す断面図である。この変形例２は、変形例１の色変換層とフィルタ層とをそれぞれ保護膜で覆うようにした構成である。すなわち、第１ガラス基板２４の上に、青・赤色変換層１５、青・緑色変換層１６を所定の位置に配置させた後、これらの色変換層を覆うように、平坦な第１保護膜２６が形成

されている。この第１保護膜２６の上には、赤色フィルタ層１３、緑色フィルタ層１４および青色フィルタ層２１が適宜配置され、これらフィルタ層の上に第２保護膜２７が平坦に形成されている。この変形例２における他の構成、すなわち第２ガラス基板２５側の構成は、本実施形態８と同様である。

【００３１】

（変形例３）

図１１は、本実施形態８の変形例３を示している。この変形例３においては、本実施形態８の第１ガラス基板２４の前面側にフィルタ層を設け、背面側に色変換層を設けた構成であり、背面側が第１保護膜２６で覆われ、前面側が第２保護膜２７で覆われている。

【００３２】

（変形例４）

図１２は、本実施形態８の変形例４を示している。この変形例４においては、本実施形態８の第１ガラス基板２４の背面側に色変換層や色フィルタ層を設けたものであり、第２ガラス基板２５と第１ガラス基板２４側とを対向させた構成である。すなわち、第１ガラス基板２４の背面に、赤色フィルタ層１３、緑色フィルタ層１４、青色フィルタ層２１が配置され、これらが第２保護膜２７で覆われている。また、第２保護膜２７の背面に、青・赤色変換層１５、青・緑色変換層１６が適宜配置され、これら変換層が第１保護膜２６で覆われている。

【００３３】

（変形例５）

図１３は、本実施形態８の変形例５を示す断面図である。この変形例５は、上記変形例４の第１ガラス基板２４の前面に励起光吸収フィルタ層２３を配置した構成である。本実施形態においては、励起光フィルタ層２３を素子の最前部に配置したことにより、有機発光層１９に励起光（例えば紫外光）が入射して、有機発光層１９の励起、発光が生ずるのを抑制することができる。このような励起、発光を抑制することにより、有機ＥＬ素子１１のコントラストを向上させることができる。また、紫外光の入射を防止することにより、色変換層や有機発光層１９などの劣化を防止することもできる。

【００３４】

（変形例６）

図１４および図１５は、本実施形態８の変形例６を示している。この変形例６における第１ガラス基板２４側の構成は上記変形例４と同様であるが、これに対向する第２ガラス基板２５側の構成が異なっている。すなわち、第２ガラス基板２５の前面に、所定方向に沿って複数の背面電極２０が形成され、第２ガラス基板２５および背面電極２０を覆うように有機発光層１９が形成されている。また、有機発光層１９の前面には、有機発光層１９を挟んで背面電極２０と交差する複数の透明電極１８が形成されている。このような構成の第１ガラス基板２４側と第２ガラス基板２５側とを対向させた状態で支持するには、図１５に示すように第１ガラス基板２４側と第２ガラス基板２５側との周縁部にシール材２８を介在させて支持している。このような接合方法は、液晶表示装置の製造プロセスを用いることで可能である。このようにシール材２８を用いて接合することにより、各電極や有機発光層１９を外気から遮蔽することができるため、素子の劣化を抑制することが可能となる。シール材２８で囲まれた内部には、窒素ガスや希ガス或いはシリコーンオイルを封入してもよい。

【００３５】

（実施形態９）

図１６は、本発明に係る有機ＥＬ素子の実施形態９を示す断面図である。本実施形態では、フィルタ層として、ある波長を境としてそれより短波長光は吸収し、長波長光を透過させる短波長遮断型の光学的ローパスフィルタを用いている。本実施形態の有機ＥＬ素子１１の構成は、上記した実施形態１における赤色フィルタ層１３および緑色フィルタ層１４をローパスフィルタ層２９で置き換えたものである。このローパスフィルタ層２９は、隣接するドット部分の青・赤色変換層１５および青・緑色変換層１６に共に重なるように、ガラス基板１２の背面に形成されている。なお、本実施形態における他の構成は、上記した実施形態１と同様である。

【００３６】

本実施形態では、各色変換層の前方（観察者側）に設けたローパスフィルタ層

２９が青の波長帯のみ吸収し、赤や緑のより長波長側の光を透過するように設定されている。このローパスフィルタ層２９を設けた理由は、高輝度表示において青色の抜けを防止し、色純度を向上することであり、このような構成では赤色（Ｒ）、緑色（Ｇ）の共通層によりこれを実現することができる。なお、青・緑色変換層１６が高輝度な青色光を透過させなければ、青・赤色変換層１５のみと対応するローパスフィルタ層２９を設けてもよい。一般に、光学的ローパスフィルタは、バンドパスフィルタに比べ吸収端の設計が容易であり、また透過波長域の透過率を向上させることも容易であるという利点がある。

【００３７】

以上、実施形態１～９を説明したが、本発明はこれらに限定されるものではなく、構成の要旨に付随する各種の変更が可能である。例えば、上記各実施形態では、有機発光層１９として青色光を発生させる有機ＥＬ材料を用いたが、これに限定されず適宜変更することが可能である。また、保護膜も適宜省略することが可能である。

【００３８】

【発明の効果】

以上の説明から明らかなように、この発明によれば、エネルギー効率が良好でかつ色純度の高い表示を可能にするＥＬ素子を実現できるという効果を奏する。

【図面の簡単な説明】

【図１】

本発明に係る有機ＥＬ素子の実施形態１を示す断面図。

【図２】

本発明に係る有機ＥＬ素子の実施形態２を示す断面図。

【図３】

本発明に係る有機ＥＬ素子の実施形態３を示す断面図。

【図４】

本発明に係る有機ＥＬ素子の実施形態４を示す断面図。

【図５】

本発明に係る有機ＥＬ素子の実施形態５を示す断面図。

【図６】

本発明に係る有機ＥＬ素子の実施形態６を示す断面図。

【図７】

本発明に係る有機ＥＬ素子の実施形態７を示す断面図。

【図８】

本発明に係る有機ＥＬ素子の実施形態８を示す断面図。

【図９】

実施形態８の変形例１を示す断面図。

【図１０】

実施形態８の変形例２を示す断面図。

【図１１】

実施形態８の変形例３を示す断面図。

【図１２】

実施形態８の変形例４を示す断面図。

【図１３】

実施形態８の変形例５を示す断面図。

【図１４】

実施形態８の変形例６を示す断面図。

【図１５】

実施形態８の変形例６を示す断面図。

【図１６】

本発明に係る有機ＥＬ素子の実施形態９を示す断面図。

【図１７】

従来例を示す断面図。

【符号の説明】

１１　有機ＥＬ素子

１２　ガラス基板

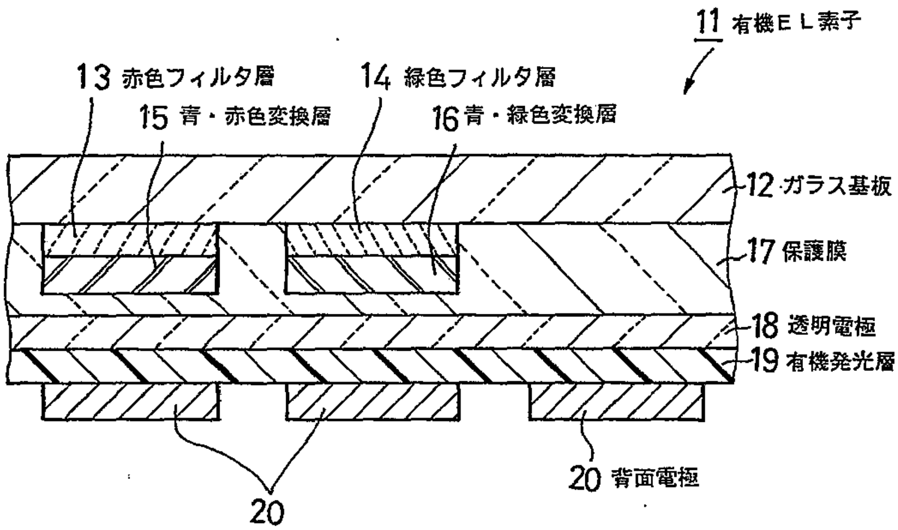
１３　赤色フィルタ層

１４　緑色フィルタ層

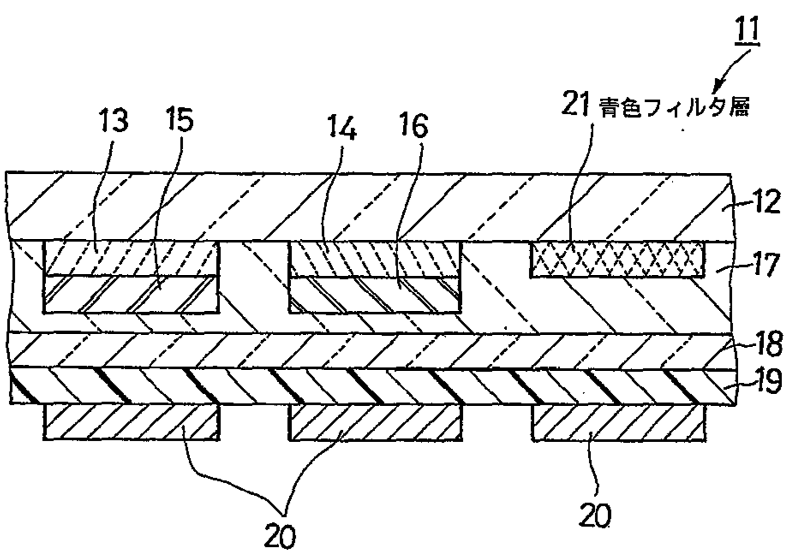
１５　青・赤色変換層
１６　青・緑色変換層
１８　透明電極
１９　有機発光層
２０　背面電極
２１　青色フィルタ層

【書類名】　図面

【図１】


11 有機ＥＬ素子
13 赤色フィルタ層
14 緑色フィルタ層
15 青・赤色変換層
16 青・緑色変換層
12 ガラス基板
17 保護膜
18 透明電極
19 有機発光層
20 背面電極
20

【図２】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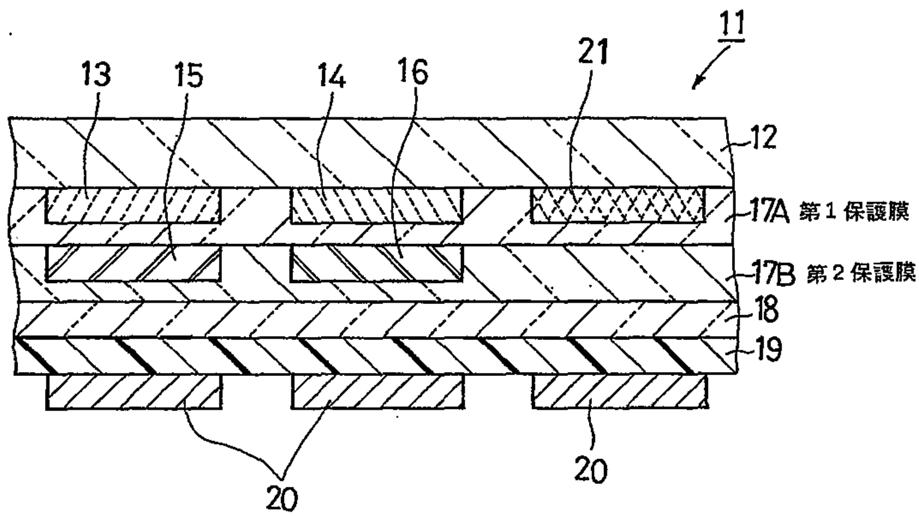
【図３】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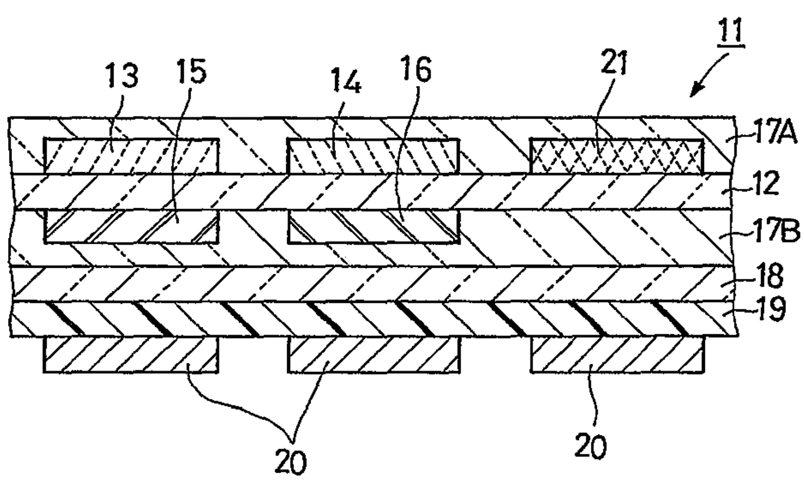
【図４】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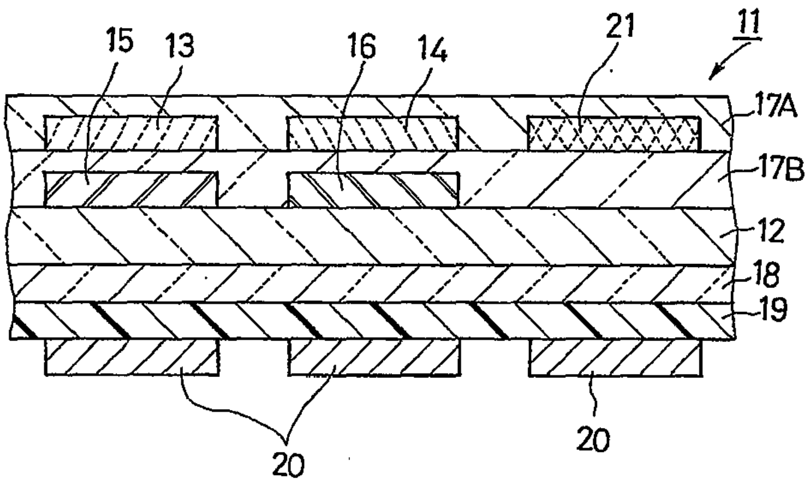
【図５】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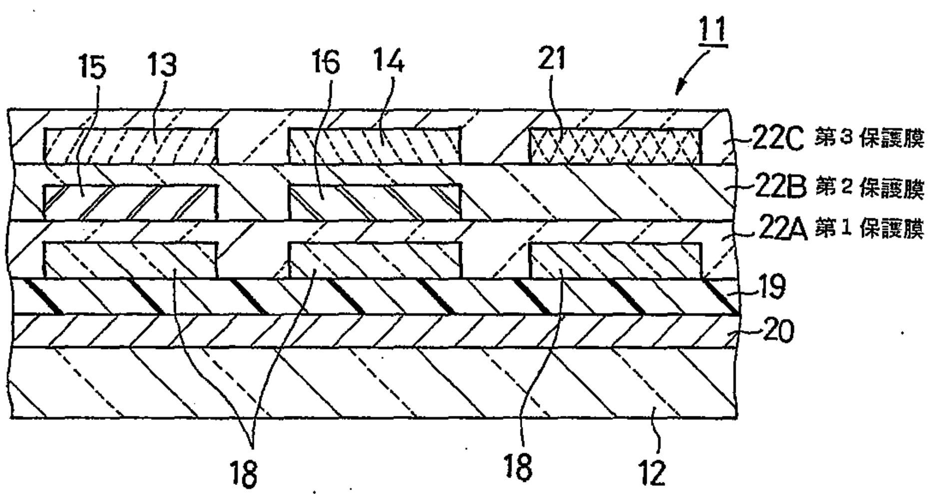
【図６】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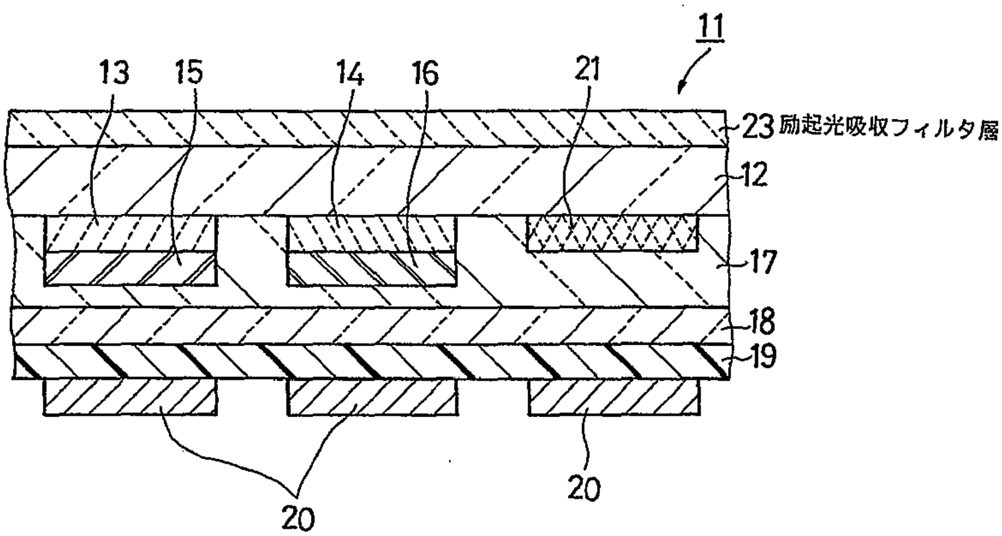
【図７】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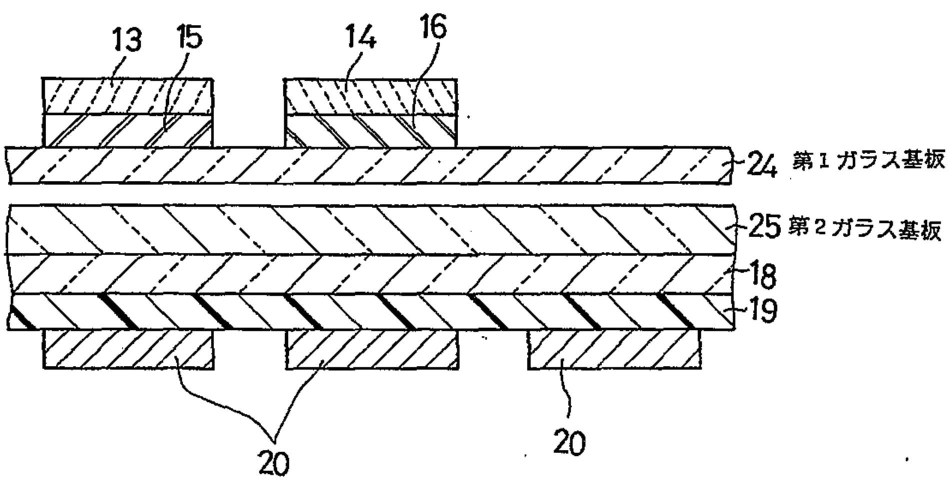
【図８】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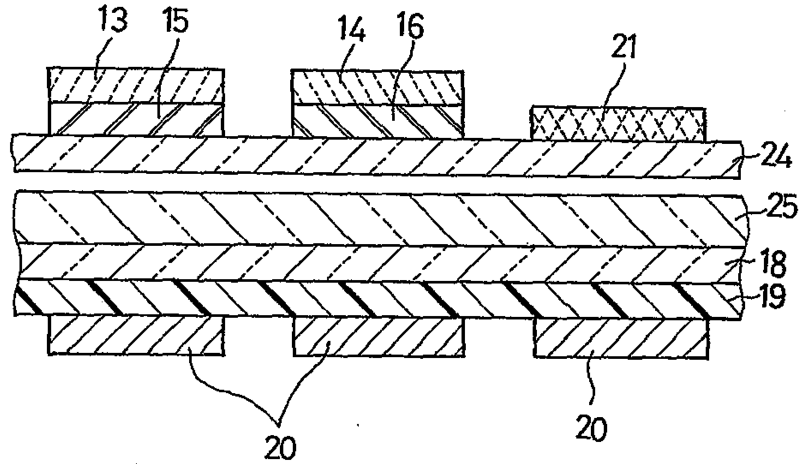
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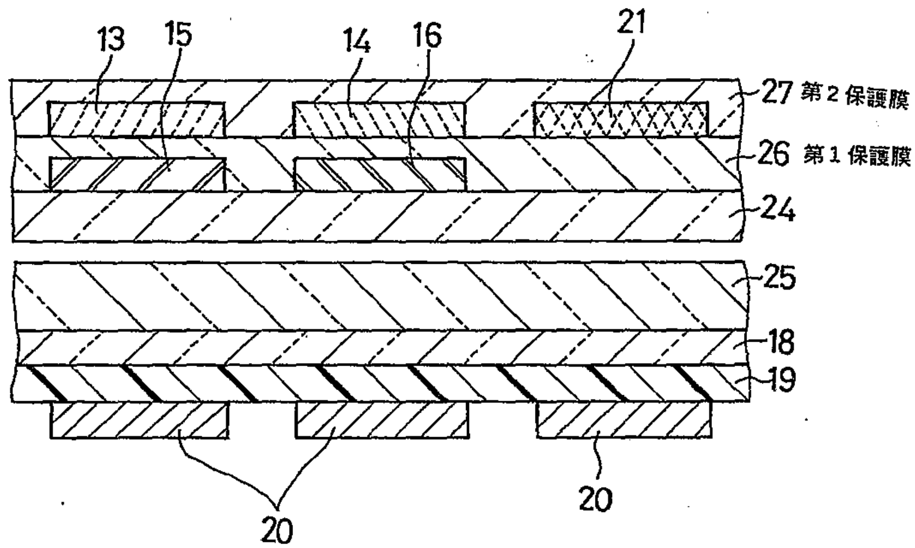
【図１０】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26 第１保護膜
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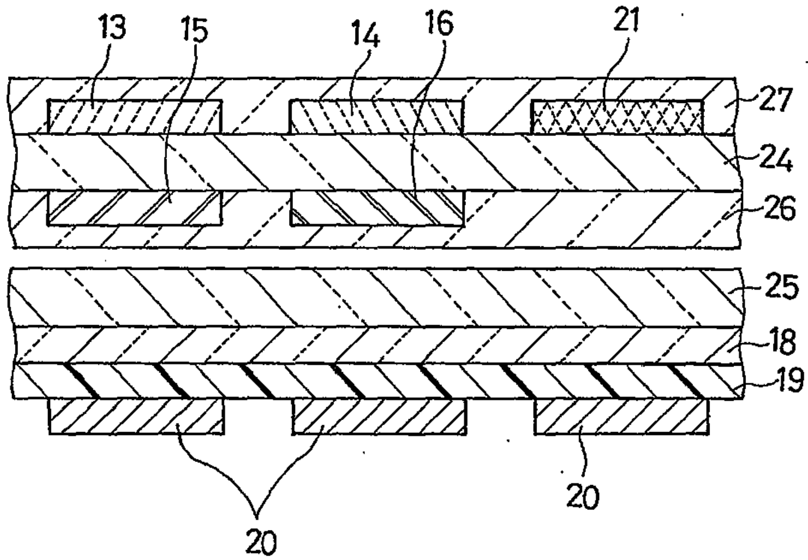
【図１１】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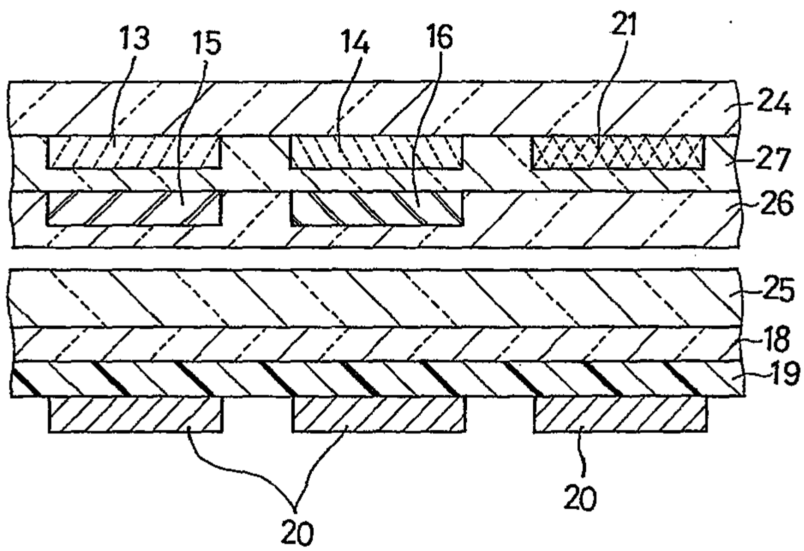
【図１２】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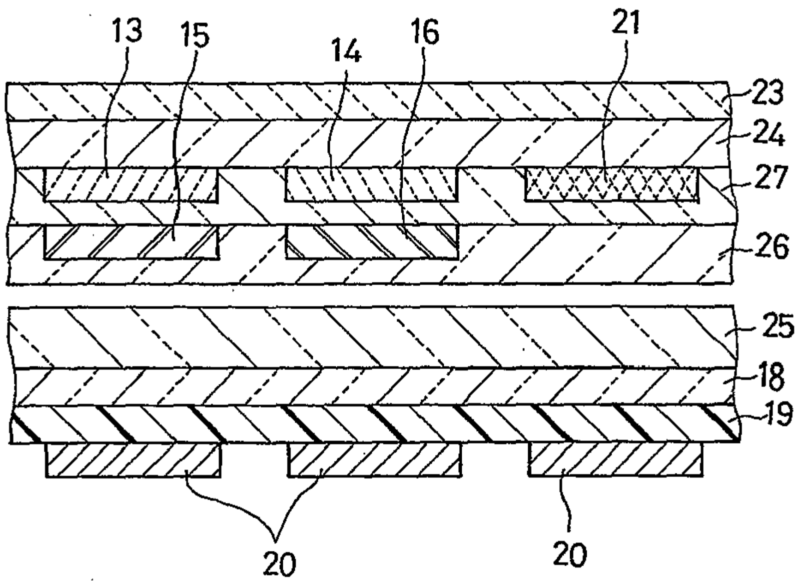
【図１３】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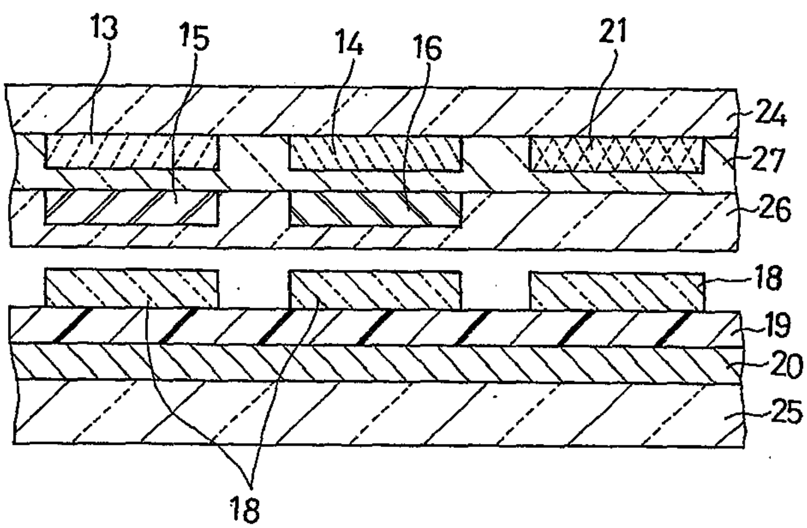
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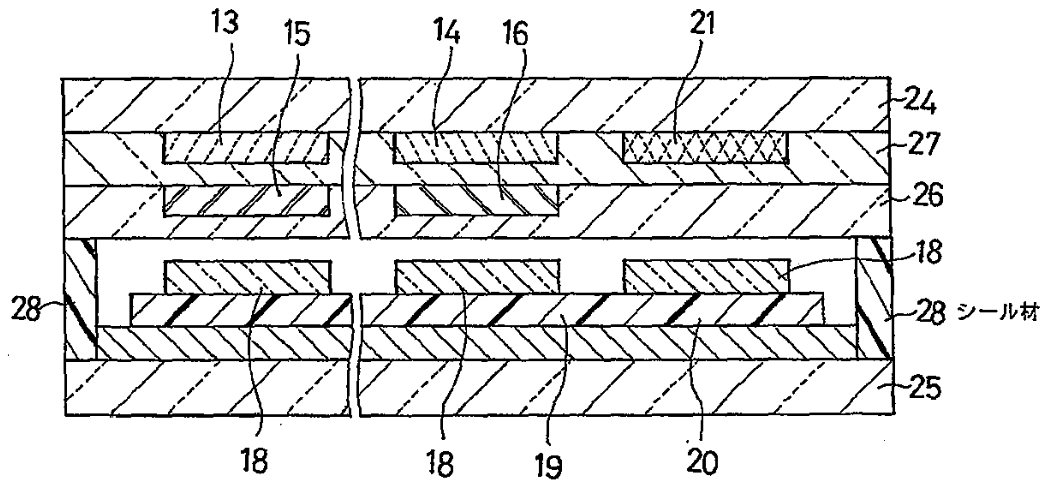
【図１５】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28 シール材
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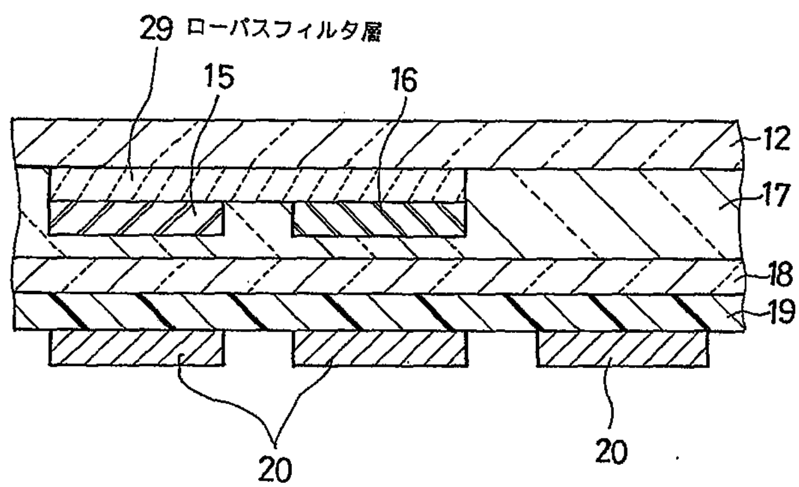
【図１６】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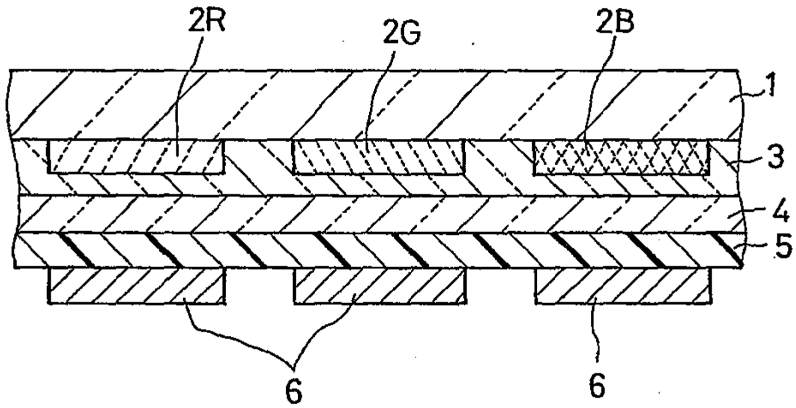
【図１７】



【書類名】　　　要約書

【要約】

【課題】　色発光のエネルギー効率が良好で、かつ色純度の高い表示が行える有機ＥＬ素子を提供する。

【解決手段】　ガラス基板１２の背面に、赤色表示部分に赤色フィルタ層１３を、緑色表示部分に緑色フィルタ層１４を配置し、赤色フィルタ層１３には青・赤色変換層１５を積層し、緑色フィルタ層１４には青・緑色変換層１６を積層して形成する。なお、青色表示部分には色フィルタ層や色変換層は配置しない。そして、そして、これらの表示部分に発光領域が対応するように、青色発光を行う有機発光層１９の前面に透明電極１８を所定方向に沿って形成すると共に、背面に背面電極２０を透明電極１８に交差するように形成する。このような構成とすることにより、発光領域で発生した青色光は、色変換層で赤色や緑色の光に変換され、色変換層が対応して配置されていない発光領域では、そのまま青色光が表示光として発生する。

【選択図】　　図１

【書類名】　職権訂正データ
【訂正書類】　特許願

<認定情報・付加情報>
【特許出願人】
【識別番号】　000001443
【住所又は居所】　東京都新宿区西新宿２丁目６番１号
【氏名又は名称】　カシオ計算機株式会社
【代理人】　申請人
【識別番号】　100074985
【住所又は居所】　東京都港区西新橋１丁目１３番４号　ＴＳビル３階　杉村次郎特許事務所
【氏名又は名称】　杉村　次郎

出　願　人　履　歴　情　報

識別番号　　　　〔０００００１４４３〕

１．変更年月日　　１９９０年　８月１０日
　［変更理由］　新規登録
　　　住　所　　東京都新宿区西新宿２丁目６番１号
　　　氏　名　　カシオ計算機株式会社

Receipt

MAR 18 1998

Attorney Docket No. : 970719/LH

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF MAILING

I hereby certify this correspondence is being deposited with the United States Postal Service as First Class mail in an envelope addressed to: Assistant Commissioner for Patents, Washington, D.C. 20231 on the date noted below.

Attorney: Leonard Holtz
Dated: March 16, 1998

In the event that this Paper is late filed, and the necessary petition for extension of time is not filed concurrently herewith, please consider this as a Petition for the requisite extension of time, and to the extent not tendered by check attached hereto, authorization to charge the extension fee, or any other fee required in connection with this Paper, to Account No. 06-1378.

Applicant(s) : Hiroyasu YAMADA et al

Serial No. : 08/976,217

Filed : 21 Nov 1997

Art Unit : 2773

REQUEST FOR CORRECTED FILING RECEIPT

Assistant Commissioner for Patents

ATTN: APPLICATIONS BRANCH

Sir:

Please issue a corrected Filing Receipt correcting the error(s) indicated in red on the accompanying copy. Please also correct the Patent Office records.

The error is due to: __X__ Patent Office Error (No fee required)

______ Applicant's Error (Check for $25.00 attached)

Frishauf, Holtz, Goodman, Langer & Chick, P.C.
767 Third Avenue - 25th Fl.
New York, N.Y. 10017-2023
Tel(212)319-4900
Fax(212)319-5101
LH/pob

Respectfully submitted,

Leonard Holtz
Reg.No. 22,974

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GROUP 2600

PTO-103X
(Rev. 8-95)

FILING RECEIPT

UNITED STATES DEPARTMENT OF COMMERCE
Patent and Trademark Office
ASSISTANT SECRETARY AND COMMISSIONER
OF PATENTS AND TRADEMARKS
Washington, D.C. 20231

APPLICATION NUMBER	FILING DATE	GRP ART UNIT	FIL FEE REC'D	ATTORNEY DOCKET NO.	DRWGS	TOT CL	IND CL
08/976,217	11/21/97	2773	$790.00	970719/LH	21	17	2

FRISHAUF HOLTZ GOODMAN LANGER & CHICK
767 THIRD AVENUE 25TH FLOOR
NEW YORK NY 10017

Receipt is acknowledged of this nonprovisional Patent Application. It will be considered in its order and you will be notified as to the results of the examination. Be sure to provide the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION when inquiring about this application. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. If an error is noted on this Filing Receipt, please write to the Application Processing Division's Customer Correction Branch within 10 days of receipt. Please provide a copy of the Filing Receipt with the changes noted thereon.

Applicant(s)

HIROYASU YAMADA, TOKYO, JAPAN; TOMOYUKI SHIRASAKI, TOKYO, JAPAN; YOSHIHIRO KAWAMURA, TOKYO, JAPAN.

FOREIGN APPLICATIONS-	JAPAN	~~33138/1996~~ 331388/1996	~~00/00/00~~ 11/28/96
	JAPAN	331389/1996	11/28/96

TITLE
DISPLAY APPARATUS

PRELIMINARY CLASS: 345

(see reverse)

UNITED STATE [E]PARTMENT OF COMMERCE
Patent and Trademark Office
Address: COMMISSIONER OF PATENTS AND TRADEMARKS
Washington, D.C. 20231

5-1

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR		ATTORNEY DOCKET NO.
08/976,217	11/21/97	YAMADA	H	970719/LH

LM12/0831

FRISHAUF HOLTZ GOODMAN LANGER & CHICK
767 THIRD AVENUE 25TH FLOOR
NEW YORK NY 10017

EXAMINER	
KOVALICK, V	
ART UNIT	PAPER NUMBER
2778	4

DATE MAILED: 08/31/99

Please find below and/or attached an Office communication concerning this application or proceeding.

Commissioner of Patents and Trademarks

Office Action Summary	Application No. 08/976,217	Applicant(s) Hiroyasu Yamada	
	Examiner Vincent E. Kovalick	Group Art Unit 2778	

☒ Responsive to communication(s) filed on *Nov 21, 1997*.

☐ 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. 11; 453 O.G. 213.

A shortened statutory period for response to this action is set to expire *3* month(s), or thirty days, whichever is longer, from the mailing date of this communication. Failure to respond within the period for response will cause the application to become abandoned. (35 U.S.C. § 133). Extensions of time may be obtained under the provisions of 37 CFR 1.136(a).

Disposition of Claims

☒ Claim(s) *1-17* is/are pending in the application.

Of the above, claim(s) ______ is/are withdrawn from consideration.

☐ Claim(s) ______ is/are allowed.

☒ Claim(s) *1-10, 12-14, 16, and 17* is/are rejected.

☒ Claim(s) *11 and 15* is/are objected to.

☐ Claims ______ are subject to restriction or election requirement.

Application Papers

☒ See the attached Notice of Draftsperson's Patent Drawing Review, PTO-948.

☐ The drawing(s) filed on ______ is/are objected to by the Examiner.

☐ The proposed drawing correction, filed on ______ is ☐approved ☐disapproved.

☐ 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

☒ 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.

☐ received in Application No. (Series Code/Serial Number) ______.

☐ received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

*Certified copies not received: ______.

☐ Acknowledgement is made of a claim for domestic priority under 35 U.S.C. § 119(e).

Attachment(s)

☒ Notice of References Cited, PTO-892

☐ Information Disclosure Statement(s), PTO-1449, Paper No(s). ______

☐ Interview Summary, PTO-413

☒ Notice of Draftsperson's Patent Drawing Review, PTO-948

☐ Notice of Informal Patent Application, PTO-152

--- SEE OFFICE ACTION ON THE FOLLOWING PAGES ---

DETAILED ACTION

Claim Rejections - 35 USC § 102

1. 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 --
>
> (e) the invention was described in a patent granted on an application for patent by another filed in the United States before the invention thereof by the applicant for patent, or on an international application by another who has fulfilled the requirements of paragraphs (1), (2), and (4) of section 371© of this title before the invention thereof by the applicant for patent.

2. Claims 1-2 and 6 are rejected under 35 U.S.C. 102(e) as being anticipated by Tang et al. (U. S. Patent No. 5,684,365).

Relative to claims 1-2 and 6, Tang et al. **teaches** (col. 1, lines 16-19) an electroluminescent (EL) display panel employing thin-film-transistors (TFT) as active-matrix addressing elements, and organic electroluminescent thin films as the emissive medium. Tang et al. **teaches** (col. 4, lines 29-41 and sheet 4 of 5, Fig. 8) the active elements (TFT) being disposed over the top surface of a substrate, the active elements in turn being driven by an externally supplied signal (sheet 1 of 5, Fig. 2). Tang et al. further **teaches** (col. 4, lines 51-54) a dielectric passivation (insulation) layer being deposited over at least the source of an active element, and preferable over the entire surface of the device, with the insulation layer having at least one contact hole (sheet 4 of 5, Fig. 8). Still further, Tang et al. **teaches** (col. 4, lines 47-50) an anode (electrode) layer formed on an insulation film, and connected to said active elements through said contact hole. Typically (col. 10, lines 15-20), the anode material is transparent and the cathode material opaque so that light is transmitted through the anode material. However, in an alternative embodiment, light is emitted through the cathode rather than the anode. In this case the cathode must be light transmissive and the **anode may be opaque** (shielding visible light). Still further, Tang et al. **teaches** (col. 4, lines 55-59, col. 7, lines 42-45 and sheet 4 of 5, Fig. 8) an organic electroluminescent layer being positioned directly on the top surface of the anode layer and subsequently, a cathode layer is deposited directly on the top surface of the organic electroluminescent layer.

Claim Rejections - 35 USC § 103

3. 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.

4. Claims 5, 7-9 and 17 are rejected under 35 U.S.C. 103(a) as being unpatentable over Tang et al. as applied to claim 1 hereinabove, and further in view of Stewart (U. S. Patent No. 5,302,966).

Regarding claims 5, 7-9 and 17, Stewart **teaches** (col. 1, lines 54-58; col. 2, lines 49-58 and sheet 2 of 7, Fig. 2) a plurality of pixels arranged in rows and columns. The active matrix circuit at a pixel comprises a first transistor (selection transistor) having its gate connected to a select line, its source connected to a data line and its drain connected to the gate of a second transistor (drive transistor). The source of the second transistor is also connected to the data line and its drain connected to one electrode of an EL cell. A capacitor is connected between the gate of the second transistor and the source of a reference potential.

It would have been obvious to a person of ordinary skill at the time of the invention to incorporate the limitation as taught by Stewart in the device of Tang et al. in that Tang (col. 1, lines 1-20) teaches an electroluminescent display panel employing thin-film-transistors as active-matrix addressing elements, and organic electroluminescent thin films as the emissive medium.

5. Claim 3 is rejected under 35 U.S.C. 103(a) as being unpatentable over Tang et al. as applied to claim 1 hereinabove, and further in view of Nakamura et al. (U.S. Patent No. 5,427,858).

Regarding claim 3, Nakamura et al. **teaches** (col. 10, lines 35-50) an organic electroluminescence device wherein electrode material can be selected from electrically conductive metals such as gold, silver, copper, aluminum, indium, **magnesium** etc.

It would have been obvious to a person of ordinary skill in the art at the time of the invention, that one electrode could be formed of a conductive material containing magnesium in that cathode electrodes are normally formed of a metal such as magnesium whose work function is low, as pointed out in the disclosure of the instant invention (page 3, lines 3-5).

6. Claim 4 is rejected in that at least one first electrode having a rough surface which is in contact with the electroluminescent layer is an design/ manufacturing choice.

It would have been obvious to a person of ordinary skill in the art at the time of the invention that specifying an electrode having a rough surface to be in contact with the electroluminescent layer is in common practice and well known in the art.

7. Claims 10 and 12-14 are rejected under 35 U.S.C. 103(a) as being unpatentable over Tang et al. as applied to claim 1 hereinabove, and further in view of Eida et al. (U.S. Patent No. 5,909,081).

Relative to claims 10 and 12-14, Eida et al. **teaches** (col. 6, lines 20-23 and col. 23, 48-53) a fluorescent layer may convert the light emitted from an organic EL device into light of a wave length longer than that of the light emitted from the organic EL device. Eida et al. further . **teaches** (col. 6, lines 41-49, and sheet 2 of 6, Figs. 4 and 5) the structure as shown in Fig. 4, the fluorescent layers which emit rays of fluorescent light of different colors are separately disposed on the same plane to obtain emitted light of the three primary colors(RGB). In this case, the plate thickness of the transparent inorganic oxide substrate is preferable in a range of from 1um to 200 um. Further, as shown in Fig. 5, a color filter may be arranged on each of the fluorescent layers to control the fluorescent colors and thereby to promote the color purity.

It would have been obvious to a person of ordinary skill in the art at the time of the invention to incorporate in the device as taught by Tang et al. the features as taught by Eida et al. in order to optemize a multi-color light emission apparratus suitable for use in multi-color or full color flat panel displays.

8. Claim 16 is rejected under 35 U.S.C. 103(a) as being unpatentable over Tang et al. taken with Stewart as applied to claims 1-2, 5-9 and 17 in item 4 hereinabove, and further in view of Kishita et al. (U. S. Patent No. 5,847,516).

Relative to claims 16, Kishita et al. **teaches** (col 1, lines 12-13 and 18-25, and sheet 4 of 11, Fig. 4) a circuit for driving an electroluminescent display device wherein EL elements in the display are arranged in a matrix and a scan side driver IC and data side driver IC are respectively provided on a scan side and data side of the display elements. Accordingly, drive voltage pulses having a differing polarity with each positive and negative field are applied to the EL elements by the respective driver ICs and the EL elements emit light.

It would have been obvious to a person of ordinary skill in the art at the time of the invention to incorporate in the device as taught by Tang et al. taken with Stewart, the limitation as taught by Kishita et al. in that scan and data line drive circuits are an essential element in matrix type display devices such as those taught by Tang et al. and Stewart, and the incorporation to said drive circuits in matrix type display devices is understood.

Allowable Subject Matter

9. Claims 11 and 15 are objected to as being dependent upon a rejected base claim, but would be allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims.

Relative to claim 11, the prior art of record **does not teach** a display apparatus wherein at least one wavelength conversion layer has a concave surface facing at least one second electrode.

Regarding claim 15, the prior art of record **does not teach** a display apparatus wherein an electroluminescent layer has a thickness whose value falls in a rage of wavelength of light which the electroluminescent layer emits.

Conclusion

10. The prior art made of record and not relied upon is considered pertinent to applicant's disclosure.

U. S. Patent No.	5,828,181	Okuda
U. S. Patent No.	5,640,067	Yamauchi et al.
U. S. Patent No.	5,302,468	Nimiki et al.

Responses

11. Responses to this action should be mailed to: Commissioner of Patents and Trademarks Washington, D.C. 20231. If applicant desires to fax a response, (703) 308-9051 may be used for formal communications or (703) 308-6606 for informal or draft communications. NOTE: a Request for Continuation (Rule 609 or 62) cannot be faxed.

Please label "PROPOSED" or "DRAFT" for informal facsimile communications. For after final responses, please label "AFTER FINAL" or "EXPEDITED PROCEDURE" on the document.

Hand-delivered responses should be brought to Crystal Part II, 2121 Crystal Drive, Arlington, VA., Sixth Floor (Receptionist)

Inquires

12. Any inquiry concerning this communication or earlier communications from the examiner should be directed to Vincent E. Kovalick whose telephone number is (703) 306-3020. The examiner can normally be reached on Monday-Thursday from 9:00 a.m. to 4:00 p.m.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Bipin Shalwala, can be reached on (703) 305-4938.

13. Any inquiry of a general nature or relating to the status of this application or proceeding should be directed to the Group receptionist whose telephone number is (703) 305-3900.

Vincent E Kovalick

Vincent E. Kovalick

BIPIN SHALWALA
SUPERVISORY PATENT EXAMINER
TECHNOLOGY CENTER 2700

Notice of References Cited

Application No.	Applicant(s)	
08/976,217	Hiroyasu Yamada	
Examiner	**Group Art Unit**	
Vincent E. Kovalick	2778	Page 1 of 1

U.S. PATENT DOCUMENTS

	DOCUMENT NO.	DATE	NAME	CLASS	SUBCLASS
A	5,909,081	06/01/99	Eida et al.	313	504
B	5,684,365	11/04/97	Tang et al.	345	76
C	5,427,858	06/27/95	Nakamura et al.	428	421
D	5,302,966	04/12/94	Stewart	315	169.3
E	5,847,516	12/08/98	Kishita et al.	315	169.3
F	5,828,181	10/27/98	Okuda	345	76
G	6,640,067	06/17/97	Yamauchi et al.	313	504
H	5,302,468	04/12/94	Nimike et al.	313	500
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United States Patent [19]

Eida et al.

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[45] **Date of Patent: Jun. 1, 1999**

[54] **MULTI-COLOR LIGHT EMISSION APPARATUS WITH ORGANIC ELECTROLUMINESCENT DEVICE**

[75] Inventors: **Mitsuru Eida; Masahide Matsuura; Hiroshi Tokailin**, all of Sodegaura, Japan

[73] Assignee: **Idemitsu Kosan Co., Ltd.**, Tokyo, Japan

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PCT Pub. Date: **Aug. 15, 1996**

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Feb. 14, 1995	[JP]	Japan	7-049089
Oct. 24, 1995	[JP]	Japan	7-299111

[51] **Int. Cl.**[6] **H05B 33/04**; H05B 33/14

[52] **U.S. Cl.** **313/504**; 313/506; 313/512; 345/76; 315/169.3; 428/917

[58] **Field of Search** 313/504, 501, 313/506, 509, 512; 428/917; 345/76, 36, 45; 315/169.3; 257/40

[56] **References Cited**

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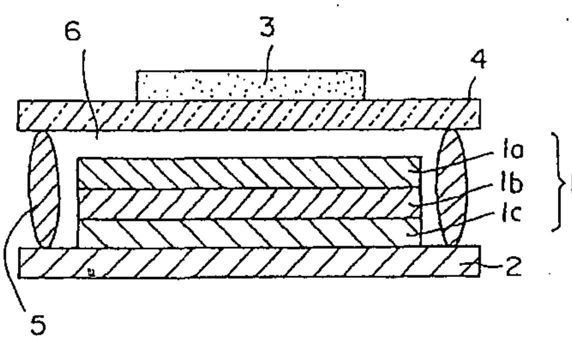
Primary Examiner—Sandra O'Shea
Assistant Examiner—Michael Day
Attorney, Agent, or Firm—Oblon, Spivak, McClelland, Maier & Neustadt, P.C.

[57] **ABSTRACT**

This invention provides a multi-color light emission apparatus wherein a transparent inorganic oxide substrate (4) is disposed between an organic EL device (1) and a fluorescent layer (3) in such a manner as to arrange the fluorescent layer (3) with a gap with the organic EL device (1), and the organic EL device (1) is sealed by sealing means (5) between the transparent inorganic oxide substrate (4) and a support substrate (2). The invention provides also a multi-color light emission apparatus wherein a transparent insulating inorganic oxide layer (12) having a thickness of 0.01 to 200 μm is interposed between the fluorescent layer (3) and the organic EL device (1). In this way, light emission life and angle-of-view characteristics can be improved.

10 Claims, 6 Drawing Sheets



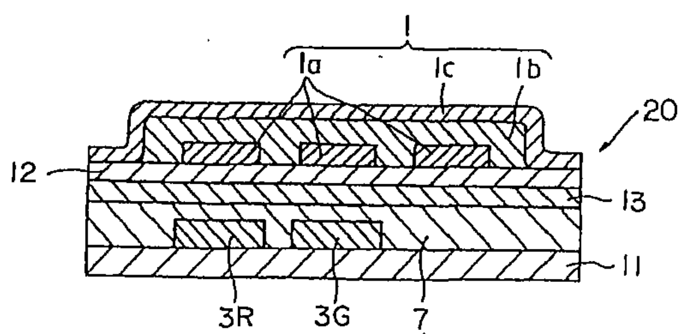


Fig. 1

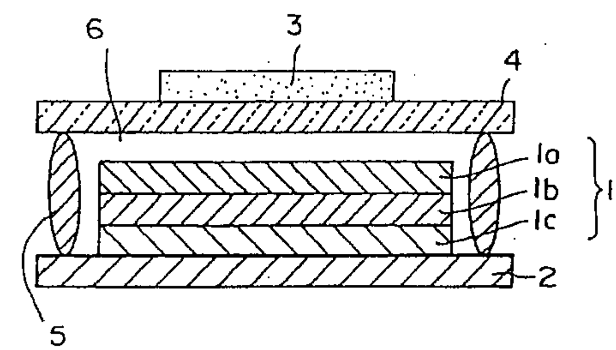


Fig. 2

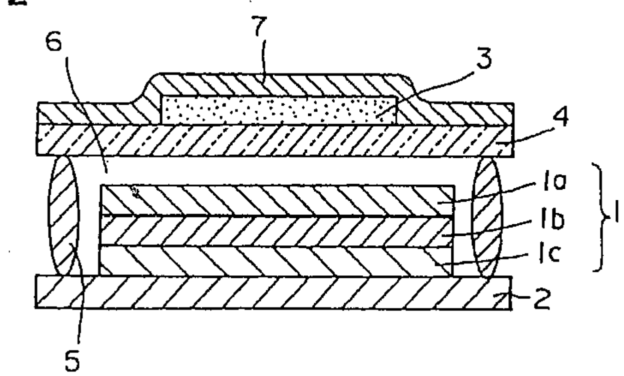


Fig. 3

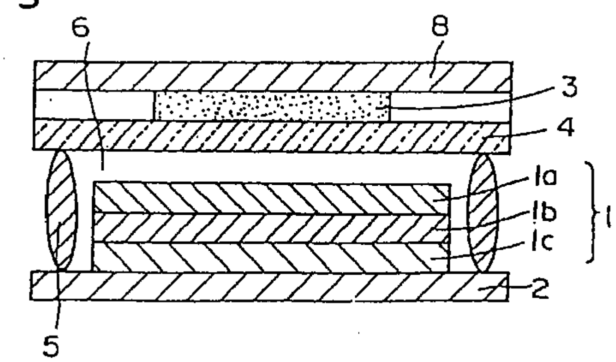


Fig. 4

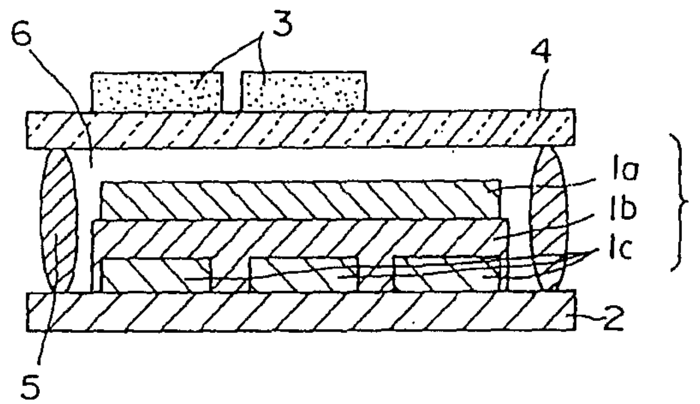


Fig. 5

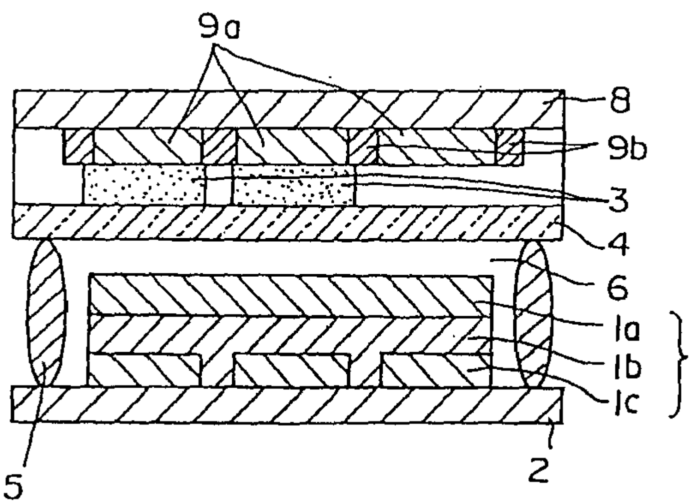


Fig. 6

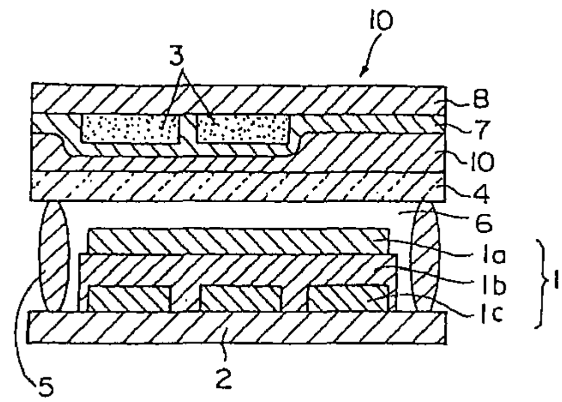


Fig. 7

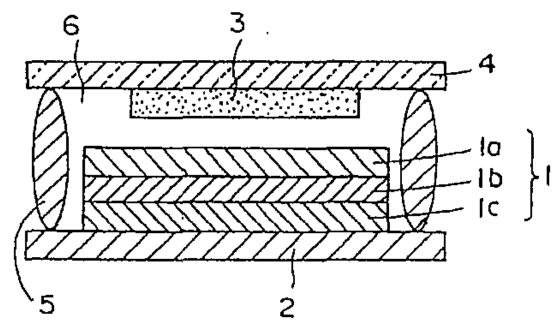


Fig. 8

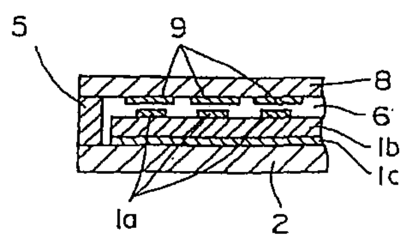


Fig. 9

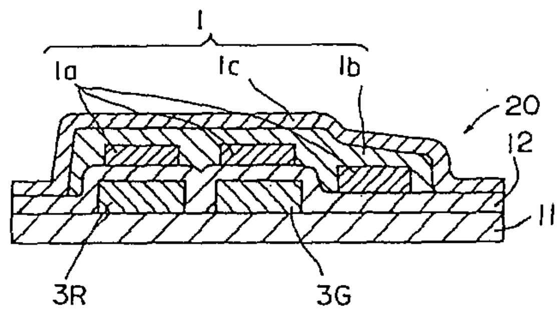


Fig. 10

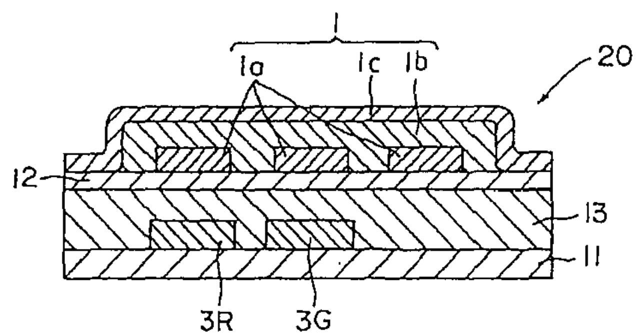


Fig. 11

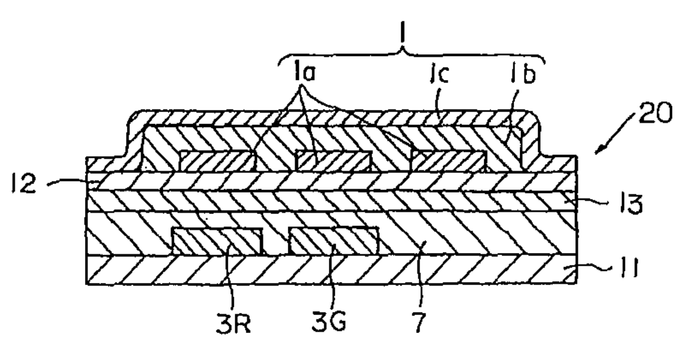


Fig. 12

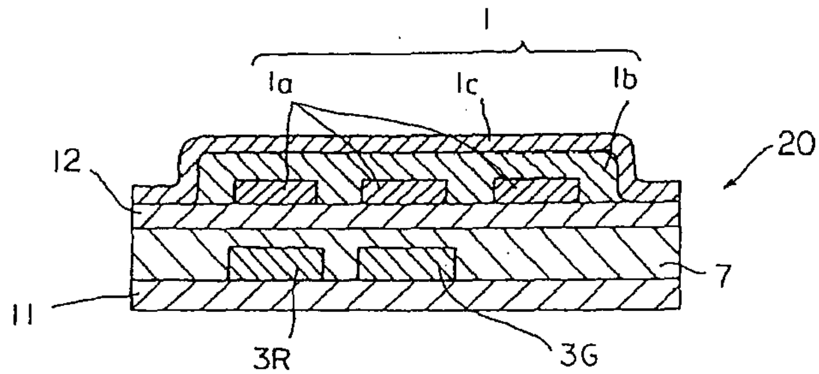


Fig. 13

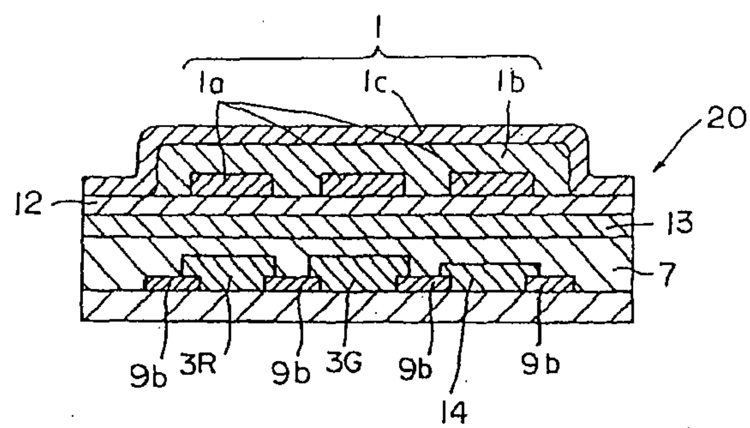


Fig. 14

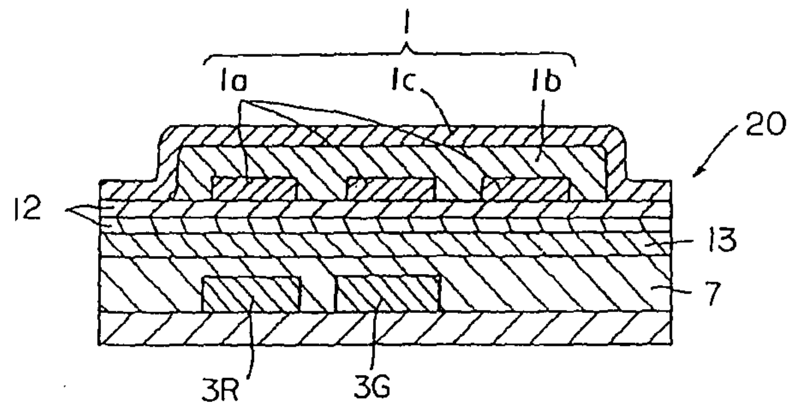
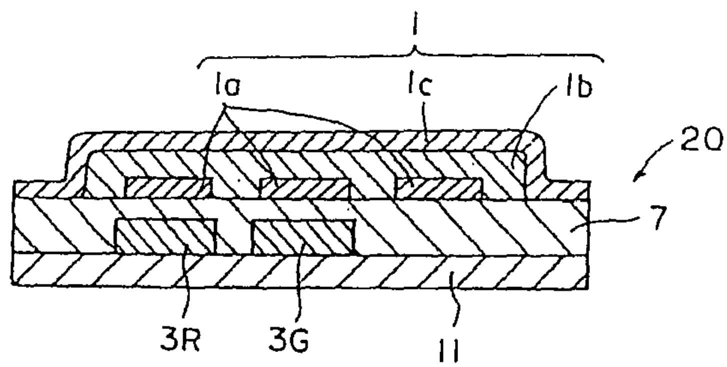


Fig. 15



MULTI-COLOR LIGHT EMISSION APPARATUS WITH ORGANIC ELECTROLUMINESCENT DEVICE

FIELD OF THE INVENTION

This invention relates to a multi-color light emission apparatus and a method for producing thereof. More specifically, this invention relates to a multi-color light emission apparatus suitable for use in multi-color or full-color thin-type displays and a method for producing the multi-color light emission apparatus.

DESCRIPTION OF THE BACKGROUND ART

An electroluminescence device (hereinafter called "EL device") is characterized in exhibiting high visibility due to self-emission and in having excellent impact resistance because of being completely solid. At present, variable EL devices using an inorganic or an organic compound as the emitting layer are proposed and attempts have been made to put them to practical use. One of the EL devices which has been realized is applied as a multi-color light emission apparatus.

Such a multi-color light emission apparatus includes an apparatus produced by combining a color filter of three primary colors (red, green, and blue) with a white-light emitting inorganic EL device and an apparatus produced by patterning inorganic EL devices of three primary colors in order to position the EL devices of three primary colors separately on the same plane and thereby to emit light (Semicond. Sci. Technol. 6 (1991) 305–323) However, there is the problem that the effect of emitting light of each color is limited to 33% of the white light at most if the white color is resolved by the color filter of three primary colors. Further, EL devices which themselves can efficiently emit white light have still not been attained at present.

On the other hand, a photolithography process is used for patterning EL devices. However, it is known that the efficiency and stability of EL devices are greatly reduced in such a wet process.

It is common knowledge that, among EL devices, organic EL devices are promising as highly intense and efficient light emitting devices. In particular, because the light emitting layer is an organic layer, it is highly probable that various emitting colors are produced by the molecular design of organic compounds. Such an organic EL device is expected to be one device which can be used in practice in a multi-color light emitting apparatus.

However, these organic EL devices have the drawback that chemical factors such as external steam, oxygen, organic compound gas, and the like cause deterioration of the EL devices such as reduction in luminance accompanied by the occurrence of dark spots and the like and these devices tend to be destroyed from physical (mechanical) factors such as heat, impact, or the like since the EL devices are composed of a laminate of low molecular organic compounds.

Therefore, the method for separately disposing each of the organic EL devices, which emit lights of three primary colors (RGB), on the same plane can be used in a wet process or a process including heat treatment such as a photolithography process only with difficulty.

In order to solve such a problem, disclosed is a color EL display apparatus (see Japanese Patent Application Laid-open No. 40888/1989). This apparatus is, as shown in FIG. 8, characterized in that an EL emitting layer **1**b sandwiched

between a lower electrode **1**c and a light transmitting upper electrode **1**a is disposed on a substrate **2**, the EL light which is output via the light transmitting electrode **1**a is externally output from a transmitting substrate **8** via a color filter **9** installed on the transmitting substrate **8**, the color filter **9** facing the transmitting electrode **1**a.

This apparatus has, however, the disadvantage that the luminance of the light of each color is reduced to one third of the EL light by the color filter. Also, because the EL device faces the color filter, the light emission life of the EL device is invariably reduced by aqueous vapor, oxygen, gas from organic monomers, low molecular components, and the like generated by the color filter.

To solve these problems, lately disclosed is a technique in which a fluorescent layer absorbing light emitted from an organic EL device and emitting visible fluorescent light is installed in the position (laminated or in parallel) corresponding to the emitting portion of the organic EL device (see Japanese Patent Application Laid-open No. 152897/1991). This technique ensures that the light of a blue or blue-green color emitted from the organic EL device is converted into a fluorescent light which is visible light of a longer wave length. This technique is utilized in a multi-color (three primary colors) light emission apparatus in which fluorescent layers capable of converting the blue or blue-green color into a green or red color are separately disposed on a flat plane (see Japanese Patent Application Laid-open No. 258860/1993).

The installation of the fluorescent layer has the advantage that multi-color light emission which is higher in efficiency than in the case of installing a color filter is expected. Specifically, if the fluorescent layer especially for converting into a green color is expected to absorb 80% or more of the blue color light emitted from the organic EL device, a variety of fluorescent materials capable of emitting fluorescent light at an efficiency of 80% or more are known. Assuming both the light absorbing efficiency and light emitting efficiency of the fluorescent layer to be 80%, it is estimated that the blue light of the organic EL device can be converted into visible light with a long wave length at a yield of 64%.

A multi-color light emission apparatus can be realized using an organic EL device and a fluorescent layer in the above manner. Japanese Patent Application Laid-open No. 258860/1993 proposes the following structure for the multi-color light emission apparatus.

As shown in FIG. 15, fluorescent layers **3R**, **3G** absorbing the light emitted from an organic EL device and emitting a green color and red color respectively are separately disposed on a transparent substrate **11** on the same plane. A polymer and/or cross-linking compound of an organic monomer or oligomer and a transparent insulating rigid plane layer (protective layer) **7** produced by a sol-gel glass method are laminated on the transparent substrate **11** including the fluorescent layers **3R**, **3G** by spin casting. A transparent electrode **1**a of the organic EL device is disposed on the plane layer **7**.

Disclosed as other structures are a structure in which the transparent and insulating flat rigid elements is simply placed on the surface of the fluorescent layer instead of being laminating on the fluorescent layer by spin casting and a structure in which the fluorescent layer is affixed to the back face of the hard element exhibiting the functions of a flat plane layer instead of affixing the fluorescent layer to the surface of the substrate. However, it is reported that the structure shown in FIG. 15 is preferable.

The structure shown in FIG. 15, however, has the problem that the light emission life of the organic EL device is reduced by aqueous vapor, oxygen, gas from monomers and the like which are adsorbed to or included in the organic compound of the flat plane layer in a slight amount whereby the emission is indispensably non-uniform, because the transparent electrode of the organic EL device is only disposed on the same flat layer composed of the polymer and/or cross-linking compound of an organic monomer or oligomer.

Also, a high temperature treatment at 400° C. or more is generally required for the production of the flat plane layer in the sol-gel glass method. This causes the deterioration of the organic fluorescent layer. If the sol-gel glass flat plane is produced by heat treatment (up to the maximum temperature of around 250° C.) which never causes the fluorescent member to deteriorate, there is the problem that the light emission life of the organic EL device is greatly reduced for the same reason as above because water or organic compounds remain.

Also, clear explanations about the hard member in the other structures are not necessarily sufficient.

On the other hand, disclosed is a method in which a glass plate with a color filter formed by printing is disposed under the back face of a glass substrate of an inorganic EL device (see Japanese Patent Application Laid-open No. 119494/1982).

However, a reduction in the emitting efficiency caused by the color filter is easily predicted in this method. Also, since the organic EL device is produced independently of the color filter, camber and distortion of the substrate occur so that the EL device cannot be manufactured in a stable manner, if, for example, the thickness of the substrate of the organic EL device is not increased (around 700 μm or more). As a result of the increase in the thickness of the substrate, the gap between the color filter and the EL device increases, whereby emitted light of a color other than the desired emitted colors leaks to remarkably narrow the angle of view when multi-color light is emitted.

This invention has been achieved in view of this situation and has an object of providing a multi-color light emission apparatus using an organic EL device having superior light emission life and excellent characteristics in the angle of view and a method for manufacturing the multi-color light emission apparatus in a stable and efficient manner.

DISCLOSURE OF THE INVENTION

The above object can be attained in a first invention by the provision of a multi-color light emission apparatus comprising a support substrate, an organic electroluminescence (EL) device disposed on the support substrate, and a fluorescent layer disposed corresponding to a transparent electrode or electrode of the organic EL device to absorb the light emitted from the organic EL device and to emit visible fluorescent light, wherein a transparent inorganic oxide substrate on which a fluorescent layer is placed is disposed between the organic EL device and the fluorescent layer in such a manner as to provide a gap between the fluorescent layer and the organic EL device, and the organic EL device is sealed by a sealing means between the transparent inorganic oxide substrate and the support substrate.

In preferred embodiments, the fluorescent layers are separately disposed on the transparent inorganic oxide substrate on the same plane;

- a protective layer of the fluorescent layers and/or a transparent substrate are further disposed on the fluorescent layer;
- the plate thickness of the transparent inorganic oxide substrate is in a range of from 1 to 200 μm; and
- the transparent inorganic oxide substrate is made of a transparent glass plate.

The above object can be attained in a second invention by the provision of a multi-color light emission apparatus comprising a transparent support substrate, fluorescent layers separately disposed on the transparent support substrate on the same plane, and an organic electroluminescence (EL) device disposed on or above the fluorescent layers, the fluorescent layers being disposed corresponding to a transparent electrode or electrode of the organic EL device so that each of the fluorescent layers absorbs the light emitted from the organic EL device and emits different types of visible fluorescent light, wherein a transparent and insulating inorganic oxide layer with a thickness of from 0.01 to 200 μm is interposed between the fluorescent layer and the organic EL device.

In preferred embodiments, a transparent protective layer of the fluorescent layers and/or a transparent adhesive layer are disposed between the fluorescent layer and the transparent and insulating inorganic oxide layer;

- the transparent and insulating inorganic oxide layer is made of a transparent and insulating glass plate;
- the transparent and insulating inorganic oxide layer is made from one or more compounds selected from a group consisting of silicon oxide, aluminum oxide, and titanium oxide; and
- the transparent and insulating inorganic oxide layer is produced by forming a film of one or more compounds selected from a group consisting of silicon oxide, aluminum oxide, and titanium oxide on at least one of the surface or back face of a transparent and insulating glass plate.

The above object can be attained in a third invention by the provision of a method for manufacturing a multi-color light emission apparatus by separately disposing, on a transparent support substrate, fluorescent layers absorbing the light emitted from an organic EL device and emitting different visible fluorescent light on the same plane and by disposing the organic EL device on or above the fluorescent layer so that a transparent electrode or electrode of the organic EL device corresponds to the fluorescent layer, comprising:

(A) a step of separately disposing the fluorescent layers on the transparent support substrate on the same plane;

(B) a step of disposing a transparent protective layer of the fluorescent layers and/or a transparent adhesive layer on the fluorescent layers and on the transparent support substrate on which the fluorescent layers are separately disposed;

(C) a step of bonding a transparent and insulating glass plate with a thickness of from 1 to 200 μm, in which a transparent electrode is formed or is to be formed, or bonding a member produced by forming a film made of one or more compounds selected from a group consisting of silicon oxide, aluminum oxide, and titanium oxide on at least one of the surface or back face of a transparent and insulating glass plate, to the transparent protective layer of the fluorescent layers or to a transparent adhesive layer; and

(D) a step of laminating an organic compound layer and electrodes of the organic EL device in order on the glass plate in which the transparent electrode is formed.

The first to third inventions can provide a multi-color light emission apparatus using an organic EL device having superior light emission life and excellent characteristics in the angle of view and a method for manufacturing the multi-color light emission apparatus in a stable and efficient manner.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic and typical cross section of an embodiment of the multi-color light emission apparatus (first invention) of the present invention.

FIG. 2 is a schematic and typical cross section of the multi-color light emission apparatus (first invention) of the present invention showing another embodiment using a protective layer of the fluorescent layers.

FIG. 3 is a schematic and typical cross section of the multi-color light emission apparatus (first invention) of the present invention showing an example using a transparent substrate.

FIG. 4 is a schematic and typical cross section of the multi-color light emission apparatus (first invention) of the present invention showing a further embodiment using a fluorescent layer separately disposed.

FIG. 5 is a schematic and typical cross section of the multi-color light emission apparatus (first invention) of the present invention showing an example using a color filter and a black matrix.

FIG. 6 is a schematic and typical cross section of the multi-color light emission apparatus (first invention) of the present invention showing an other embodiment using a protective layer of the fluorescent layers and a transparent substrate.

FIG. 7 is a schematic and typical cross section of a comparative example, relative to the first invention, wherein a fluorescent layer is disposed in the same side as an organic EL device on a transparent glass substrate.

FIG. 8 is a schematic and typical cross section of an example of a conventional multi-color light emission apparatus.

FIG. 9 is a schematic and typical cross section of an embodiment of the multi-color light emission apparatus (second invention) of the present invention.

FIG. 10 is a schematic and typical cross section of the multi-color light emission apparatus (second invention) of the present invention showing another embodiment using a transparent adhesive layer.

FIG. 11 is a schematic and typical cross section of the multi-color light emission apparatus (second invention) of the present invention showing a further embodiment using a transparent adhesive layer and a transparent protective layer of the fluorescent layers.

FIG. 12 is a schematic and typical cross section of the multi-color light emission apparatus (second invention) of the present invention showing a still further embodiment using a transparent protective layer of the fluorescent layers.

FIG. 13 is a schematic and typical broken view of the multi-color light emission apparatus (second invention) of the present invention showing a still further embodiment using a color filter and a black matrix.

FIG. 14 is a schematic and typical cross section of the multi-color light emission apparatus (second invention) of the present invention showing a still further embodiment using a transparent adhesive layer, a protective layer of the fluorescent layers, and two transparent and insulating inorganic oxide layers.

FIG. 15 is a schematic and typical cross section of an example of a conventional multi-color light emission apparatus.

DETAILED DESCRIPTION OF THE INVENTION AND PREFFERED EMBODIMENTS

The multi-color light emitting apparatus of the invention and a method for manufacturing thereof will now be explained in more detail.

The organic EL multi-color light emission apparatus of the present invention must have a structure in which the light (especially a blue color or blue-green color) emitted from an organic EL device is efficiently absorbed by a fluorescent layer, without light reduction and light scattering, and in which a fluorescent light emitted from the fluorescent layer is externally output without light reduction and light scattering.

I. Multi-color Light Emission Apparatus (First invention)

From the above points of view, the first invention is specifically exemplified by the following structures (1)–(3), which are respectively shown in FIGS. 1–3. Incidentally, a fluorescent layer may convert the light emitted from an organic EL device into light of a wave length longer than that of the light emitted from the organic EL device.

(1) Support substrate 2/organic EL device 1 (electrode 1c/organic compound layer 1*b*/transparent electrode 1*a*)/gap 6/transparent inorganic oxide substrate 4/fluorescent layer

(2) Support substrate 2/organic EL device 1 (electrode 1c/organic compound layer 1*b*/transparent electrode 1*a*/gap 6/transparent inorganic oxide substrate 4/fluorescent layer 3/protective layer 7 of the fluorescent layers)

(3) Support substrate 2/organic EL device 1 (electrode 1c/organic compound layer 1*b*/transparent electrode 1*a*/gap 6/transparent inorganic oxide substrate 4/fluorescent layer 3/transparent substrate 8)

In the apparatus of the present invention, the organic EL device 1 is sealed by a sealing means 5 formed by bonding the transparent inorganic oxide substrate 4 to the support substrate 2, for example, using an adhesive.

Also, in the structures (1) to (3), as shown in FIG. 4, the fluorescent layers 3 which emit rays of fluorescent light of different colors are separately disposed on the same plane to obtain emitted light of the three primary colors (RGB). In this case, the plate thickness of the transparent inorganic oxide substrate 4 is preferably in a range of from 1 μm to 200 μm. Further, as shown in FIG. 5, a color filter 9*a* may be arranged on each of the fluorescent layers 3 to control the fluorescent colors and thereby to promote the color purity. Also, a black matrix 9*b* may be disposed between the fluorescent layers or color filters to prevent light leakage and thereby to promote the visibility of multi-color emitted light.

Next, the multi-color light emission apparatus of the present invention will be illustrated in more detail in terms of each structural element. Materials used for these structural elements are not limited to the materials described hereinafter which correspond to the lowest demands of these elements.

1. Organic EL Device

As the organic EL device of the present invention, it is preferable to use organic EL devices which emit lights ranging from near ultraviolet light to light of a green color, more preferably a blue-green color. The following structures are exemplified for the organic EL device of the present invention to obtain such a light emission.

These structures comprises fundamentally an emitting layer composed of an organic compound which is sandwiched between two electrodes (anode) and (cathode) and other layers may be interposed between them as required. Typical structures for the organic EL device used in the present invention are as follows:

(1) Anode/emitting layer/cathode;

(2) Anode/positive hole injection layer/emitting layer/cathode;

(3) Anode/emitting layer/electron injection layer/cathode; and

(4) Anode/positive hole injection layer/emitting layer/electron injection layer/cathode.

(a) Anode

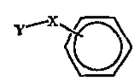
An anode using, as an electrode material, metals, alloys, electro conductive compounds, and mixtures of these which have a high work function (more than 4 ev) are preferably used. Given as examples of such an electrode material are metals such as Au and electro conductive materials such as CuI, ITO, SnO_2, and ZnO. A thin film of each of these electrodes is formed by means of vapor deposition, sputtering, or the like to produce the anode.

If the light emitted from the emitting layer is taken out of the anode in this manner, it is desirable that the transmittance by the anode of the emitted light be more than 10%. In this case, the anode corresponds to the transparent electrode. Also, the sheet resistance of the anode is preferably less than several hundreds Ω/□. The thickness of the anode is usually from 10 nm to 1 μm, preferably from 10 nm to 200 nm, although this depends on the material used.

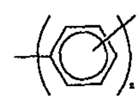
(b) Emitting layer

Major emitting materials for the organic EL device are organic compounds. As specific examples of the organic compounds used for the emitting layer, the following compounds are given, depending on the desired color.

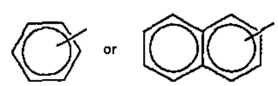
First, emitted light of ultraviolet to the violet color region can be prepared using the organic compounds represented by the following general formula,



wherein X represents the following compound.

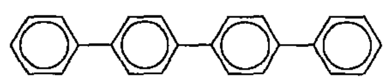


wherein n denotes 2, 3, 4, or 5, and Y represents the following compound.



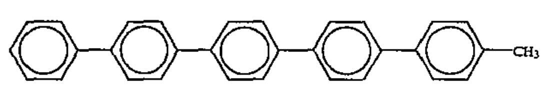
In the above compounds, a phenyl group, phenylene group, and naphthyl group may be substituted with one or more alkyl groups having from 1 to 4 carbon atoms, alkoxy groups, hydroxyl groups, sulphonyl groups, carbonyl groups, amino groups, dimethylamino groups, and diphenylamino groups. Also, these groups may be combined to form a saturated five-membered ring or a saturated six-membered ring. Further, it is preferable that the phenyl group, phenylene group, and naphthyl group be substituted at a para position so as to be easily substituted and to form a smooth deposition film. The compounds represented by the following formula are given as examples of the compounds substituted at a para position. Among these compounds, p-quarterphenyl derivatives and p-quinquephenyl derivatives are preferable.

(1)

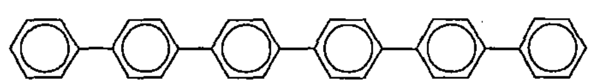


P-quinquephenyl. (PQP)

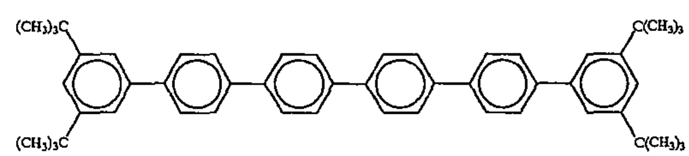
(2)



(3)

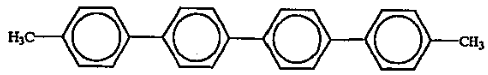


(4)



3, 5, 3'''', 5''''-tetra-t-butyl-sexiphenyl (TBS)

-continued



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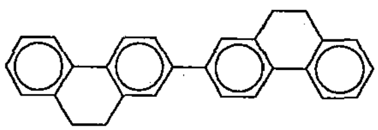

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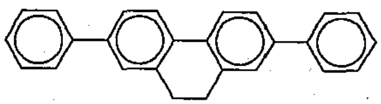

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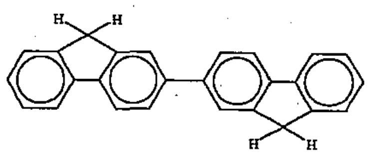

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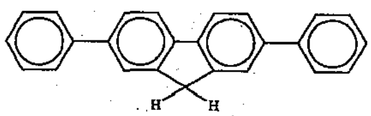

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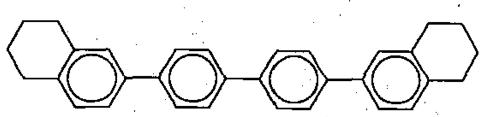

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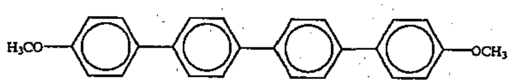

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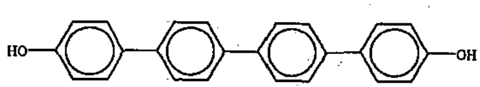

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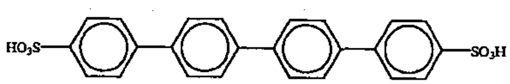

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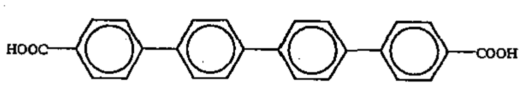

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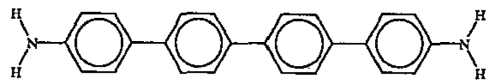

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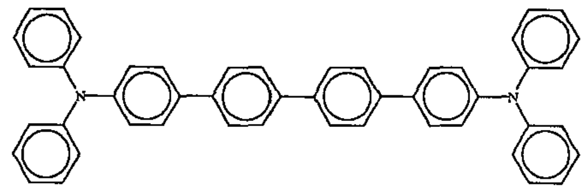

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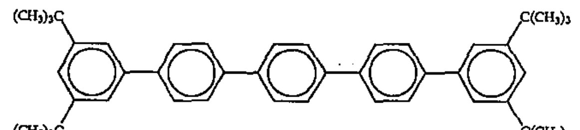

3, 5, 3'''', 5''''-tetra-t-butyl-p-quinquephenyl (TBQ)

Next, given as examples of the organic compounds used for producing emitted light of a blue color to a blue-green color or a green color are fluorescent bleaching agents such as a benzothiazole type, benzoimidazole type, and benzoxazole type; metal chelated oxinoid compounds, and styryl benzene type compounds.

Illustrating specific compounds, for example, the compounds disclosed in Japanese Patent Application Laid-open No. 194393/1984 are exemplified. Among these, typical examples are fluorescent bleaching agents including a benzoxazole type such as 2,5-bis(5,7-di-t-pentyl-2-benzoxazolyl)-1,3,4-thiadiazole, 4,4'-bis(5,7-di-t-pentyl-2-benzoxazolyl)stilbene, 4,4'-bis(5,7-di-(2-methyl-2-butyl)-2-benzoxazolyl)stilbene, 2,5-bis(5,7-di-t-pentyl-2-benzoxazolyl)thiophene, 2,5-bis(5-α,α-dimethylbenzyl-2-benzoxazolyl)thiophene, 2,5-bis(5-7-di(2-methyl-2-butyl)-2-benzoxazolyl)-3,4-diophenylthiophene, 2,5-bis(5-methyl-2-benzoxazolyl) thiophene, 4, 4'-bis(2-benzoxazolyl) biphenyl, 5-methyl-2-[2-[4-(5-methyl-2-benzoxazolyl) phenyl]vinyl]benzoxazole, 2-[2-(4-chlorophenyl)vinyl] naphtho[1,2-d]oxazole, and the like; benzothiazole type such as 2-2'-(p-phenylenedivinylene)-bisbenzothiazole and the like; and benzoimidazole type such as 2-[2-[4-(2-benzoimidazolyl)phenyl]vinyl]benzoimidazole, 2-[2-(4-carboxyphenyl)vinyl]benzoimidazole, and the like. In addition, other useful compounds are enumerated in Chemistry of Synthetic Dyes, 628–637, P640, (1971).

As the above-mentioned chelated oxinoid compounds, the compounds disclosed in Japanese Patent Application Laid-open No. 295695/1988 can be used. Among these, typical examples are 8-hydroxyquinoline type metal complexes such as tris(8-quinolinol) aluminum, bis(8-quinolinol) magnesium, bis(benzo[f]-8-quinolinol) zinc, bis(2-methyl-8-quinolinolate) aluminum oxide, tris(8-quinolinol) indium, tris (5-methyl-8-quinolinol) aluminum, 8-quinolinol lithium, tris (5-chloro-8-quinolinol) gallium, bis(5-chloro-8-quinolinol) calcium, poly[zinc(II)-bis(8-hydroxy-5-quinolinonyl)methane], and the like and dilithium epindridione.

As the above-mentioned styryl benzene type compounds, the compounds disclosed in the specifications of EPCs No. 0319881 and No. 0373582 can be also used. Typical examples of these styryl benzene type compounds are 1,4-bis(2-methylstyryl)benzene, 1,4-bis(3-methylstyryl) benzene, 1,4-bis(4-methylstyryl)benzene, distyrylbenzene, 1,4-bis(3-ethylstyryl)benzene, 1,4-bis(2-methylstyryl)-2-methylbenzene, 1,4-bis(2-methylstyryl)-2-ethylbenzene, and the like.

Further, distyryl pyrazine derivatives disclosed in Japanese Patent Application Laid-open No. 252793/1990 can be used as the material for the emitting layer. Typical examples of these derivatives are 2,5-bis(4-methylstyryl)pyrazine, 2,5-bis(4-ethylstyryl)pyrazine, 2,5-bis[2-(1-naphthyl)vinyl] pyrazine, 2,5-bis(4-methoxystyryl)pyrazine, 2,5-bis[2-(4-biphenyl)vinyl]pyrazine, 2,5-bis[2-(1-pyrenyl)vinyl] pyrazine, and the like.

In addition, the polyphenyl type compounds disclosed in the specification of EPC No. 0387715 can be used as the material for the emitting layer.

Other than the above-mentioned fluorescent bleaching agents, metal chelated oxinoid and styryl benzene, the following compounds can be used as the material for the emitting layer:

12-phthaloperinone (J. Appl. Phys., Vol 27, L713, (1988)), 1,4-diphenyl-1,3-butadiene, 1,1,4,4-tetraphenyl-1,3 butadiene (Appl. Phys. Lett., Vol 56, L799, (1990)), naphthalimide derivatives (Japanese Patent Application Laid-open No. 305886/1990), perillene derivatives (Japanese Patent Application laid-open No. 189890/1990), oxadiazole derivatives (Japanese Patent Application Laid-open No. 216791/1990 or oxadiazole derivatives disclosed by Hamada et al. at the conference of Appl. Phys), aldazine derivatives (Japanese Patent Application Laid-open No. 220393/1990), pyraziline derivatives (Japanese Patent Application Laid open No. 220394/1990), cyclopentadiene derivatives (Japanese Patent Application Laid-open No. 289675/1990), pyrrolopyrrole derivatives (Japanese Patent Application Laid-open No. 296891/1990), styrylamine derivatives (Appl. Phys. Lett., Vol 56, L799, (1990)), coumarine type compounds (Japanese Patent Application Laid-open No. 191694/1990), and macromolecular compounds described in the International Disclosure Official Gazette WO90/13148 or Appl. Phys. Lett., Vol 58, 18, P1982 (1991).

In the present invention, as the materials used for the emitting layer, aromatic dimethylidine type compounds (compounds disclosed in the specification of EPC No. 0388768 or Japanese Patent Application Laid-open NO. 231970/1991) are preferably used. Specific Examples of such compounds are 1,4-phenylenedimethylidyne, 4,4-phenylenedimethylidyne, 2,5-xylenedimethylidyne, 2,6-naphthylenedimethylidyne, 1,4-biphenylenedimethylidyne, 1,4-p-terephenylenedimethylidyne, 9,10-anthracenediyldimethylidyne, 4,4'-bis(2,2-di-t-butylphenylvinyl)biphenyl (hereinafter abbreviated as (DTBPVBi)), 4,4'-bis(2,2-diphenylvinyl)biphenyl (hereinafter abbreviated as (DPVBi), and derivatives of these.

Also, the compounds represented by the general formula $(R_s—Q)_2—AL—O—L$, which are described in Japanese Patent Application Laid-open No. 258862/1993 can be used, wherein L represents a hydrocarbon having 6–24 carbon atoms and including a phenyl group, O-L represents a phenolate ligand, Q represents a substituted 8-quinolinolate ligand, Rs represents an 8-quinolinolate ring substitutional group selected to stereo-chemically prevent three or more substituted 8-quinolinolate ligands from binding with an aluminum atom.

Given as specific examples of such compounds are bis (2-methyl-8-quinolinolate)(para-phenylphenolate) aluminum (III) (hereinafter abbreviated as (PC-7)) and bis(2-methyl-8-quinolinolate)(1-naphtholate) aluminum (III) (hereinafter abbreviated as (PC-17)).

In addition, Japanese Patent Application Laid-open No. 9953/1994 discloses a method for producing mixed emitted light of a blue color and a green color by doping in an efficient manner. When using this method for forming the emitting layer of the present invention, the above-mentioned emitting material is used as a host. As a dopant, a strongly fluorescent coloring material of a blue color to a green color, for example, a coumarin type or fluorescent coloring material similar to those used in the above method can be given. Specifically, as the host, fluorescent materials mainly composed of distyryl arylene, preferably, for example, DPVBi can be given. As the dopant, diphenylaminostyryl arylene, preferably, for example, 1,4-bis{4-N,N'-diphenylamino}styryl}benzene (DPAVB) can be given.

As the methods for forming an emitting layer using the above materials, known methods, for example, a vapor deposition method, a spin-coating method, a LB method, or the like can be applied. A preferred emitting layer is especially a molecularlysedimentary film. The molecularly sedimentary film is a film formed by deposition of a subject compound in a vapor phase or a film formed by solidifying a subject compound in a solution or in a liquid phase. The molecularly sedimentary film is generally distinguished from a thin film (molecularly cumulative film) formed in the LB method by differences in a coagulating structure and a high-order structure, or by a functional difference caused by those structures.

Also, the emitting layer can be formed in a similar manner by a method disclosed in Japanese Patent Application Laid-open No. 51781/1982 in which a binding agent such as a resin and a subject compound are dissolved in a solvent to make a solution and then a thin film is formed from the solution using a spin-coating method or the like.

The thickness of the emitting layer is preferably in a range from 5 nm to 5 μm, though there are no limitations to the thickness of the emitting layer produced in such a manner and the thickness of the emitting layer is optionally selected.

The emitting layer of the organic EL device has also the following functions.

(1) Injection functions which allow positive holes to be injected from an anode or a positive hole injecting layer in the presence of an electric field and allow electrons to be injected from a cathode or an electron injecting layer.

(2) Transferring functions which allow the injected charges (electrons and positive holes) to be transferred by electric field force.

(3) Emitting functions which allows electrons and positive holes to be combined to emit light.

Incidentally, there may be a difference in ease between the injecting of electrons and the injecting of positive holes. Also, there maybe adifference between the transferability of positive holes and that of electrons in terms of mobility. However, it is desirable to transfer either positive holes or electrons.

(c) Positive hole injecting layer

Any material optionally selected from photo-conductive materials conventionally used as a material for transferring a charge of positive holes and from known materials used for a positive hole injecting layer of an organic EL device can be used as the material for the positive hole injecting layer provided as required. The material for the positive hole injecting layer which has a function either as a positive hole injecting layer or as a barrier for an electron may be either an organic or inorganic compound.

Given as examples of these conventional materials are triazole derivatives (see the specification of U.S. Pat. No. 3,112,197, etc.), oxadiazole derivatives (see the specification of U.S. Pat. No. 3,189,447, etc.), imidazole derivatives (Japanese Patent Publication No. 16096/1962, etc.), polyarylalkane derivatives (see the specifications of U.S. Pat. No. 3,615,402, U.S. Pat. No. 3,820,989, U.S. Pat. No. 3,542,544, Japanese Patent Publications No. 555/1970 and No. 10983/1976, and Japanese patent Applications laid-open No. 93224/1976, No. 17105/1980, No. 4148/1981, No. 108667/1980, No. 156953/1980, and No. 36656/1981, etc.), pyrazoline derivatives and pyrazolone derivatives (see the specifications of U.S. Pat. No. 3,180,729, U.S. Pat. No. 4,278,746, and Japanese Patent Applications Laid-open No. 88064/1980, No. 88065/1980, No. 105537/1974, No. 51086/1980, No. 80051/1981, No. 88141/1981, No. 45545/1982, No. 112637/1979, and No. 74546/1980, etc.), phenylenediamine derivatives (see the specifications of U.S. Pat. No. 3,615,404, Japanese Patent Publications No. 10105/1976, No. 3712/1971, and No. 25336/1972, Japanese Patent Applications Laid-open No. 53435/1979, No. 110536/1979, and No. 119925/1979, etc.), arylamine derivatives (see the specifications of U.S. Pat. No. 3,567,450, U.S. Pat. No. 3,240,597, U.S. Pat. No. 3,658,520, U.S. Pat. No. 4,232,103, U.S. Pat. No. 4,175,961, U.S. Pat. No. 4,012,376, Japanese Patent Publications No. 35702/1974 and No. 27577/1964, Japanese Patent Applications Laid-open No. 144250/1980, No. 119132/1981, and No. 22437/1981, and DRP No. 1,110,518, etc.), amino substituted chalcone derivatives (see the specification of U.S. Pat. No. 3,526,501, etc.), oxazole derivatives (see the specification of U.S. Pat. No. 3,257,203, etc.), styrylanthracene derivatives (see the specification of Japanese Patent Application Laid-open No. 46234/1981, etc.), fluorenone derivatives (see the specification of Japanese Patent Application Laid-open No. 110837/1979 and etc.), hydrazone derivatives (see the specifications of U.S. Pat. No. 3,717,462, Japanese Patent Applications Laid-open No. 59143/1979, No. 52063/1980, No. 52064/1980, No. 46760/1980, No. 85495/1980, No. 11350/1982, No. 148749/1982, and No. 311591/1990, etc.), stilbene derivatives (see the specifications of Japanese Patent Applications Laid-open No. 210363/1986, No. 228451/1986, No. 14642/1986, No. 72255/1986, No. 47646/1987, No. 36674/1987, No. 10652/1987, No. 30255/1987, No. 93445/1985, No. 94462/1985, No. 174749/1985, and No. 175052/1985, etc.), silazane derivatives (see the specification of U.S. Pat. No. 4,950,950, etc.), polysilane type (see the specification of Japanese Patent Application Laid-open No. 204996/1990, etc.), aniline type copolymers (see the specification of Japanese Patent Application Laid-open No. 282263/1990, etc.), and electro conductive macromolecular oligomers (especially a thiophene oligomer) disclosed in Japanese Patent Application Laid-open No. 211399/1989.

As the materials used for the positive hole injecting layer, the above compounds can be used. Among these, polphyrin compounds (disclosed in Japanese Patent Application Laid-open No. 2956965/1988) and aromatic tertiary amines and styrylamine compounds (see the specifications U.S. Pat. No. 4,127,412, Japanese Patent Applications Laid-open No. 27033/1978, No. 58445/1979, No. 149634/1979, No. 64299/1979, No. 79450/1980, No. 144250/1980, No. 119132/1981, No. 295558/1986, No. 98353/1986, and No. 295695/1988, etc.) are preferable. It is especially preferable to use the aromatic tertiary amines.

Typical examples of the above porphyrin compounds are porphin, 1,10,15,20-tetraphenyl-21H, 23H-porphin copper (II), 1,10,15,20-tetraphenyl-21H, 23H-porphin zinc (II), 5,10,15,20-tetrakis(pentafluorophenyl)-21H, 23H-porphin, silicon phthalocyanine oxide, aluminum phthalocyanine chloride, phthalocyanine (non-metal), dilithium phthalocyanine, copper tetramethylphthalocyanine, copper phthalocyanine, chromium phthalocyanine, zinc phthalocyanine, lead phthalocyanine, titanium phthalocyanine oxide, magnesium phthalocyanine, copper octamethylphthalocyanine, and the like.

Typical examples of the above aromatic tertiary amine and styrylamine compounds are N,N,N',N'-tetraphenyl-4,4'-diaminophenyl, N,N'-diphenyl-N,N'-bis-(3-methylphenyl)-[1,1'-biphenyl]-4,4'-diamine (hereinafter abbreviated as "TPD"), 2,2-bis (4-di-p-tolylaminophenyl)propane, 1,1-bis (4-di-p-tolylaminophenyl)cyclohexane, N,N,N',N'-tetra-p-tolyl-4,4'-diaminophenyl, 1,1-bis(4-di-p-tolylaminophenyl)-4-phenylcyclohexane, bis(4-dimethylamino-2-methylphenyl)phenylmethane, bis(4-di-p-tolylaminophenyl)phenylmethane, N,N'-diphenyl-N,N'-di (4-methoxyphenyl)-4,4'-diaminobiphenyl, N,N,N',N'-tetraphenyl-4,4'-diaminophenyl ether, 4,4-bis (diphenylamino)quadriphenyl, N,N,N-tri(p-tolyl)amine, 4-(di-p-tolylamino)-4'-[4(di-p-tolylamino)styryl]stilbene, 4-N,N-diphenylamino-(2-diphenylvinyl)benzene, 3-methoxy-4'-N,N-diphenylaminostylbenzene, N-phenylcarbazole, compounds having two condensed aromatic rings in a molecule, for example, 4,4'-bis(N-(1-naphthyl)-N-phenylamino)biphenyl (hereinafter abbreviated as (NPD)) disclosed in U.S. Pat. No. 5,061,569, and compounds in which three triphenylamine units are combined in a star-burst shape, for example, 4,4',4"-tris[N-(3-methylphenyl)-N-phenylamino]triphenylamine (hereinafter abbreviated as (MTDATA)) disclosed in Japanese Patent Application Laid-open No. 308688/1992, and the like.

Also, other than the above-mentioned aromatic dimethylidine compounds shown as the material for the emitting layer, inorganic compounds such as p type Si and p type SiC can be utilized as the material used for the positive hole injecting layer.

The positive hole injecting layer can be produced by forming a thin film of the above-mentioned compound using a conventional method such as a vacuum deposition method, spin-coating method, casting method, LB method, or the like. There are no restrictions as to the thickness of the positive hole injecting layer. However, the thickness of the positive hole injecting layer is generally from 5 nm to 5 μm. This positive hole injecting layer may be structured of one layer made from one or more of the above materials or may be a layer in which other positive hole injecting layers made from compounds differing from the compound of that layer are laminated on that layer.

(d) Electron injecting layer

The electron injecting layer provided as required may have the function of transferring, to the emitting layer, the electrons injected from the cathode. Optionalcompounds selected from conventionally known compounds may be used.

Typical examples of these compounds include nitro-substituted fluorene derivatives; anthraquinodimethane derivatives disclosed in Japanese Patent Applications Laid-open No. 149259/1982, No. 55450/1983, and No. 104061/1988; diphenylquinone derivatives, thiopyrane dioxide derivatives, heterocyclic tetracarboxylic acid anhydrides such as naphthaleneperillene and the like, and carbodiimides which are all disclosed in Polymer Preprints, Japan Vol. 37. No. 3 (1988) p. 681 and the like; fluorenylidenemethane derivatives disclosed in Japanese Journal of Applied Physics, 27, L269 (1988), Japanese Patent Applications Laid-open No. 696657/1985, No. 143764/1986, and No. 148159/1986; anthraquinonedimethane and anthrone derivatives disclosed in Japanese Patent Applications Laid-open No. 225151/1986 and No. 233750/1986; oxadiazole derivatives disclosed by the above-described Hamada et al. at the conference of Appl. Phys; and a series of an electron transfer compounds disclosed in Japanese Patent Application Laid-open No. 194393/1984. Incidentally, though the above electron transfer compounds are disclosed as the materials used for the emitting layer in Japanese Patent Application Laid-open No. 194393/1984, it is confirmed as a result of the studies of the present inventors that these compounds can be used as the materials for the electron injecting layer.

Also, thiazole derivatives produced by replacing an oxygen atom of the above oxadiazole ring with a sulfur atom and quinoxaline derivatives having a quinoxaline ring known as an electron attracting group are given as examples of the materials for the electron injecting layer. Further, included as examples of the materials for the electron injecting layer are metal complexes of 8-quinolinole, specifically, tris(8-quinolinole) aluminum (hereinafter abbreviated as "Alq"), tris(5,7-dibromo-8-quinolinole) aluminum, tris(2-methyl-8-quinolinole) aluminum, tris(5-methyl-8-quinolinole) aluminum, bis(8-quinolinole) zinc (hereinafter abbreviated as "Znq"), and metal complexes produced by replacing the primary metals of these metal complexes with In, Mg, Cu, Ca, Sn, Ga, or Pb.

Other than the above, metal-free or metal phthalocyanine compounds of 8-quinolinole derivatives or compounds produced by replacing the terminal group of these compounds with an alkyl group, sulphonic acid group, or the like. Also, the distyryl pyrazine derivatives can be used as the materials for the electron injecting layer. Similar to the positive hole injecting layer, inorganic semiconductors such as n-type-Si, n-type-SiC, or the like may be used.

The electron injecting layer can be produced by forming a thin film of the above-mentioned compound using a conventional method such as a vacuum deposition method, spin-coating method, casting method, LB method, or the like. There are no restrictions as to the thickness of the electron injecting layer. However, the thickness of the electron injecting layer is generally from 5 nm to 5 μm. This electron injecting layer may be structured of one layer made from one or more of the above materials or may be a layer in which other electron injecting layers made from compounds differing from the compound of that layer are laminated on that layer.

(e) Cathode

As examples of the cathode, those using, as an electrode material, metals (these are called "electron injecting metal"), alloys, electro conductive compounds, and mixtures of these which have a low work function (less than 4 eV) are used. Given as examples of such an electrode material are metals such as sodium, sodium/potassium alloy, magnesium, lithium, magnesium/copper mixtures, magnesium/silver mixtures, magnesium/aluminum mixtures, magnesium/indium mixtures, aluminum/aluminum oxide (Al_2O_3), indium, lithium/aluminum mixtures, and rare earth metals, and the like. Among these, preferred examples are mixtures of the electron injecting metal and a secondary metal which has a high work function and is stable in consideration of electron injecting capability and durability to oxidation as an electrode. Specifically, magnesium/silver mixtures, magnesium/aluminum mixtures, magnesium/indium mixtures, aluminum/aluminum oxide (Al_2O_3), and lithium/aluminum mixtures are given as the preferred examples.

A thin film of each of these electrode materials is formed by means of vapor deposition, sputtering, or the like to produce the cathode.

If the light emitting from the emitting layer is taken out of the cathode in this manner, it is desirable that the transmittance by the cathode of the emitted light be more than 10%. In this case, the cathode corresponds to the transparent electrode.

Here, the sheet resistance of the cathode is preferably less than several hundreds Ω/□. The thickness of the cathode is usually from 10 nm to 1 μm, preferably from 50 nm to 200 nm.

In the multi-color light emission apparatus using an organic EL device as a emitting member, for example, one electrode pattern line perpendicular to another pattern line is usually formed. When forming the electrode on a thin film of an organic compound layer such as an emitting layer or the like using a photolithography method including wet etching, an organic compound layer is caused to greatly deteriorate so that the photography method cannot be used in a stable manner. Therefore, the electrode pattern is formed through a mask having a desired shape when the electrode (anode or cathode) materials are treated by vapor deposition or sputtering. When the electrode is not formed on a thin film of the organic compound layer for example on the glass plate, the pattern of the electrode pattern may be formed by photolithography.

(f) Manufacture of organic EL device (example)

Using the above exemplified materials and methods, anode (for example, transparent electrode), an emitting layer, positive hole injecting layer as required, and electron injecting layer as required are formed and further a cathode (for example, electrode) is formed in that order to manufacture an organic EL device. Also, an organic EL device can be manufactured in the reverse order.

A manufacturing example of an organic EL device having a structure in which an anode, a positive hole injecting layer, a emitting layer, an electron injecting layer, and a cathode are provided in that order on a support substrate is illustrated below.

First, a thin film of a thickness of less than 1 μm, preferably from 10 to 200 nm is formed of an anode material by vapor deposition, sputtering, or the like to form an anode. Next, a positive hole injecting layer is formed on the anode. Formation of the positive hole injecting layer can be carried out, as mentioned above, by means of vacuum deposition, spin-coating, casting, LB, or the like. Among these means, vacuum deposition is preferable to form a homogeneous film with ease and to prevent occurrence of pin holes. When forming the positive hole injecting layer by means of vacuum deposition, the depositing conditions differ depending on the sort of compound (material for the positive hole injecting layer) to be used, the crystalline structure and the recombination structure of the object positive hole injecting layer, and the like. However, it is generally preferable to appropriately select the depositing conditions from a depositing source temperature ranging from 50 to 450° C., a vacuum ranging from 10^{-7} to 10^{-3} torr, a depositing speed ranging from 0.01 to 50 nm/sec, a substrate temperature ranging from −50 to 300° C., and a film thickness ranging from 5 nm to 5 μm.

Next, an emitting layer is formed on the positive hole injecting layer using a desired organic emitting material. Formation of the emitting layer can be carried out by providing a thin film of the organic emitting material by means of vacuum deposition, sputtering, spin-coating, and casting. Among these means, vacuum deposition is preferable to form a homogeneous film with ease and to prevent occurrence of pin holes. When forming the emitting layer by means of vacuum deposition, the depositing conditions differ depending on the sort of compound to be used. Generally, the depositing conditions can be selected from almost the same condition ranges as in the formation of the positive hole injecting layer.

Next, an electron injecting layer is formed on the emitting layer. It is preferable to form the electron injecting layer by vacuum deposition to produce a homogeneous film in the same way as in the formation of the positive hole injecting layer or the emitting layer. The depositing conditions can be selected from almost the same condition ranges as in the formation of the positive hole injecting layer or the emitting layer.

Finally, a cathode is laminated on the electron injecting layer to produce an organic EL element.

The cathode is formed of a metal so that vapor deposition or sputtering can be used. However, vacuum deposition is preferably used to protect the backing organic material from damage in forming a film.

When the organic EL device are produced in the above-mentioned processes, it is preferable that the steps from the step of forming the anode to the step of forming the cathode are thoroughly processed in one evacuating operation.

Incidentally, in the case where a d.c. voltage is applied to the organic EL device, when applying 5–40 volts, allowing the anode and the cathode to be provided with the positive (+) polarity and the negative (−) polarity respectively, luminance can be detected. When both the anode and the cathode are inversely polarized, current never flows and luminance is not detected. Further, if an a.c. voltage is applied, luminance can be detected only at the time when the anode and the cathode are respectively polarized to the (+) polarity and the (−) polarity. The wave form of the a.c. current to be applied is optional.

2. Support Substrate

Materials which are not composed of an organic compound are preferable as the materials for the support substrate used in the present invention. Transparency is not required for the materials of the support substrate. Materials which are shielded from light are rather preferable to output light from the fluorescent layer. It is desirable that at least the surface of the support substrate facing the organic EL device be composed of an insulating material. There are no limitations to the thickness of the support substrate to the extent that it can reinforce a thin transparent glass plate to be laminated subsequently without camber and distortion.

Typically, for example, a ceramic plate, metal plates which are processed by insulating treatment using inorganic oxides such as silica, alumina, or the like can be used as the materials for the support substrate. In the case of using transparent materials such as glass plates (soda lime glass, heat resistance glass, and the like), quartz glass plates, or the like, the surface opposite to the organic EL device may be provided with a light-shielding film, reflecting plate with a black film, or the like.

3. Fluorescent Layer

The fluorescent layer used in the present invention is composed of, for example, a fluorescent coloring material and a resin or of an independent fluorescent coloring material. The fluorescent layer composed of the fluorescent coloring material and the resin are, for example, a solid type produced by dissolving or dispersing the fluorescent coloring material in the binder resin.

Specific examples of types of coloring material will be explained. First given as examples of the coloring material converting ultraviolet or violet emission of the organic EL device to blue emission are stilbene type coloring materials such as 1,4-bis(2-methyl styryl) benzene (hereinafter abbreviated as (Bis-MSB)) and trans-4,4'-diphenyl stilbene (hereinafter abbreviated as (DPS)) and coumarin type coloring materials such as 7-hydroxy-4-methyl coumarin (hereinafter abbreviated as (coumarin 4)).

Given as examples of the coloring material converting blue or blue-green emission of the organic EL device to green emission are a coumarin type coloring material such as 2,3,5,6-1H, 4H-tetrahydro-8-trifluoromethylquinolizino (9,9a,1-gh)coumarin (hereinafter abbreviated as (coumarin 153)), 3-(2'-benzothiazolyl)-7-diethylaminocoumarin (hereinafter abbreviated as (coumarin 6)), and 3-(2'-benzimidazolyl)-7-N,N'-diethylaminocoumarin (hereinafter abbreviated as (coumarin 7)), other coumarin coloring material type dyes such as basic yellow 51, and naphthalimide type coloring materials such as solvent yellow 11 and solvent yellow 116.

Given as examples of the coloring material converting blue-green emission of the organic EL device to orange-red emission are cyanine type coloring materials such as 4-dicyanomethylene- 2-methyl-6-(p-dimethylaminostyryl)-4-H-pyran (hereinafter abbreviated as (DCM)), pyridine type coloring materials such as 1-ethyl-2-(4-(p-dimethylaminophenyl)-1,3-butadienyl)-pyridinium-perchlorate (hereinafter abbreviated as (pyridine 1)), rhodamine type coloring materials such as rhodamine B and rhodamine 6G, and oxazine type coloring materials.

Further, various dyes (direct dye, acidic dye, basic dye, disperse dye) can be used provided that they exhibit fluorescence. Also, pigmental materials in which the above fluorescent coloring material is kneaded in advance in a pigmental resin such as polymethacrylate ester, polyvinyl chloride, vinyl chloride-vinyl acetate copolymer, alkyd resin, aromatic sulphonamide resin, urea resin, melamine resin, benzoguanamine resin, or the like may be used.

In addition, these types of fluorescent coloring materials and pigments may be, as required, used either independently or in combination. The conversion rate of the fluorescent coloring material to red color is low. By mixing the above pigments, the rate of conversion from light emission to fluorescent emission can be increased.

On the other hand, as the binder resin, transparent materials (transmittance of visible rays: more than 50%) are preferable. Given as examples of such transparent materials are transparent resins (polymer) such as polymethyl methacrylate, polyacrylate, polycarbonate, polyvinyl alcohol, polyvinyl pyrrolidone, hydroxyethyl cellulose, and carboxymethyl cellulose.

Incidentally, photosensitive resins which can be used in photolithography are also selected to separately dispose the fluorescent layers on the same plane. For example, photocurable resists having a reactive vinyl group such as an acrylate type, methacrylate type, vinyl polycinnamate type, and cyclic rubber type are given as examples of the photosensitive resins. When using a printing method, printing inks (medium) using a transparent resin are selected. Given as examples of these transparent resins are a polyvinyl chloride resin, melamine resin, phenol resin, alkyd resin, epoxy resin, polyurethane resin, polyester resin, maleic acid resin, monomers, oligomers, and polymers of a polyamide resin, polymethylmethacrylate, polyacrylate, polycarbonate, polyvinyl alcohol, polyvinyl pyrrolidone, hydroxyethyl cellulose, and carboxymethyl cellulose.

The fluorescent layers are commonly manufactured by the following processes. The fluorescent layers mainly composed of fluorescent coloring materials are manufactured by forming a film using a vacuum deposition method or a sputtering method through a mask on which a desired pattern is formed for the fluorescent layers. On the other hand, the fluorescent layers composed of fluorescent coloring materials and a resin are manufactured by mixing fluorescent coloring materials, a resin, and a resist, dispersing or solubilizing to allow the mixture to be liquefied, forming a film using a spin-coating method, roll-coating method, or casting method, and patterning with a desired pattern for the fluorescent layers using a photolithographic method or a screen printing method.

There are no limitations to the thickness of the fluorescent layers to the extent that the emission of the organic EL elements is sufficiently absorbed and the function of emitting fluorescent light is not impaired. The thickness of the fluorescent layers is in a range of from 10 nm to 1 mm approximately.

For the fluorescent layer composed, especially, of fluorescent coloring materials and a binder resin, the concentration of the fluorescent coloring material may be in such a range as that the emission of the organic EL device can be absorbed efficiently without concentration quenching of fluorescence. The concentration of the fluorescent coloring material is in a range of from 1 to 10^{-4} mol/kg approximately to the binder resin to be used, though this depends on the type of the fluorescent coloring material.

In addition, because the fluorescence conversion efficiency, especially, to a red color is low, fluorescent layers of a green color and a red color may be laminated to improve the efficiency.

4. Transparent Inorganic Oxide Substrate

As examples of the transparent inorganic oxide substrate used in the present invention, a substrate composed of a transparent and electrically insulating inorganic oxide layer as shown in the second invention is given. However, the substrate is not necessarily formed of an electrically insulating material.

Such an inorganic oxide substrate has a high efficiency in shielding, especially, aqueous vapor, oxygen, organic compound gas, and the like.

It is desirable that the plate thickness be as small as possible to improve the characteristics in the angle of view, when the fluorescent layers which absorb the light emission from the organic EL device and emit different fluorescent emission are separately disposed on the same plane to emit multi-color light such as the three primary colors (RGB).

Usually, inorganic oxide substrates with a thickness of from 700 μm to 1.1 mm are often used for a liquid crystal. However, in the present case, an inorganic oxide substrate with a thickness of from 1 μm to 700 μm, and preferably from 1 μm to 200 μm is used.

If the thickness of the inorganic oxide substrate is not greater than 1 μm, it is difficult to handle the inorganic oxide substrate which tends to be broken. Also, when such inorganic oxide substrate is applied to the support substrate on which the organic EL devices are laminated, using a sealing means, the inorganic oxide substrate is bent, showing remarkable camber or distortion. On the other hand, if the thickness exceeds 200 μm, there is the case where the light emitted from the organic EL device leaks from gaps between the inorganic oxide substrate and the fluorescent layer, which causes a narrow angle of view for multi-color light emission, thereby reducing practicability, though this depends on the fineness of the fluorescent layer.

5. Sealing Means

There are no limitations as to the sealing means used in the present invention. Materials, for example, composed of an ordinary adhesive may be used as the sealing means.

Specifically, given as examples of the adhesive are photocurable or heatcurable adhesives having a reactive vinyl group of an acrylate type oligomer and methacrylate type oligomer; and moisture-curable adhesives such as 2-cyanoacrylate and the like. In addition, heat and chemical curable type adhesives (two-liquid mixing type) can be used. Also, hotmelt type polyamide, polyester, and polyolefin are given as examples of the adhesive. Adhesives capable of adhering and curing at from room temperature to 80° C. are preferable because there is the case where the organic EL device deteriorates from heat treatment.

Application of the adhesive to a sealing portion may be carried out using a dispenser or by printing such as screen printing.

There is no problem in curing after the application in the case of using visible light. However, there is the case where the organic EL device deteriorates when UV light is used and hence a method in which the organic EL device is never irradiated with UV light such as by masking or the like is effective.

6. Gap

In the present invention, the gap provided between the transparent inorganic oxide substrate and the organic EL device is used to absorb impact or stress on the organic EL device. If a material used for a sealing means is directly applied to the organic EL device, the organic EL device tends to be broken by the stress produced when the material is cured.

It is desirable that inert gas such as nitrogen, argon, or the like, or an inactive liquid such as hydrocarbon fluoride or the like be sealed into the gap, because the organic EL device are liable to be oxidized by air if only air is present in the gap.

If the width of the gap is large in the case of using very fine multi-color light emission, light leakage increases and hence the angle of view is greatly reduced. Therefore, the width of the gap should be preferably small, specifically

from several μm to 200 μm in general, though this depends on the fineness of the multi-color light emission.

7. Protective Layer of the Fluorescent Layers (transparent flat film)

A protective layer of the fluorescent layers (transparent flat film) used as required in the present invention is used so that the fluorescent layer and color filter (including a black matrix) located at the outside of the multi-color light emission apparatus are protected from physical damage and deterioration from externally environmental factors such as water, oxygen, light, and the like. The protective layer is preferably composed of a transparent material with a visible light transmittance of 50% or more.

Specifically, as examples of the material for the protective layer, compounds having a reactive vinyl group of an acrylate type or methacrylate type such as a photocurable resin and/or heat-curable resin can be given.

Also, given as examples of the material for the protective layer are transparent materials such as a melamine resin, phenol resin, alkyd resin, epoxy resin, polyurethane resin, polyester resin, maleic acid resin, monomer, polymer, or oligomer of a polyamide resin, polymethyl methacrylate, polyacrylate, polycarbonate, polyvinyl alcohol, polyvinyl pyrrolidone, hydroxyethyl cellulose, and the like.

A UV ray absorber may be added to the protective layer to improve the light resistance of the fluorescent layer.

The protective layer is prepared by forming a film of the above material by spin-coating, roll coating, casting, or the like when the material is liquid. If the material is a photocurable resin, the film is irradiated with UV rays and is heat-cured as required, whereas if the material is a heat-curable resin, the film is heat-cured as is after the film is formed. On the other hand, when the material is shaped as a film, the material may be applied to the fluorescent layer using an adhesive.

There are no limitations as to the thickness of the protective layer since it has no influence on the angle of view. However, when the thickness is too great, it has some influence on the light transmittance, so that the thickness is preferably in a range from 1μm to 5 mm.

8. Transparent Substrate

Given as examples of the material used for a transparent substrate are transparent glass substrates (ordinary visual light transmittance of 50% or more) including inorganic oxide substrates composed of such materials as soda lime glass, heat resistance glass, quartz plate, and the like, and polymer substrates.

Because the thickness of the transparent substrate has no influence on the angle of view, there are no limitations as to the thickness. However, when the thickness is too great, it has some influence on the light transmittance, so that the thickness is preferably in a range from 1 μm to 5 mm.

This transparent substrate is used for protecting the fluorescent layer. The transparent substrate is also used for a support substrate in the step of forming a film of the fluorescent layer. Specifically, the above-mentioned inorganic oxide substrate is applied to the transparent substrate using an ordinary transparent adhesive used such for the sealing means, after the formation of the film of the fluorescent layer. The resulting substrate may be then combined with the support substrate on which the organic EL device is laminated to seal the organic EL device.

9. Color Filter and Black Matrix

A color filter and black matrix used as required in the present invention are formed, for example, by performing desired patterning on desired positions of a material selected from known materials, by photolithography or printing.

10. Action of the Present Invention

In the present invention, the fluorescent layer is disposed in the position opposite to the organic EL device through the inorganic oxide substrate so that gaseous substances such as organic monomers, aqueous vapor, and the like which cause the device to deteriorate are cut by the inorganic substrate, whereby the life of the organic EL device and hence the life of the multi-color light emission apparatus using the organic EL device can be improved.

Generally, fluorescent layers which each absorb light of one color emitted from the organic EL device are separately disposed on the same plane to obtain light emission of a plurality of colors such as RGB primary colors or the like. The present invention uses the transparent inorganic oxide substrate which is disposed on the fluorescent layer facing the organic EL device whereby the above-mentioned effects are expected. Also, the plate thickness of the transparent inorganic substrate is in a range of from 1 μm to 200 μm in the present invention, whereby not only are the above-mentioned effects obtained, but also the absorption of the light emitted from the organic EL device to a fluorescent layer other than the desired fluorescent layer and light leakage from the gap between the fluorescent layer and the organic EL device decrease and hence light of a desired color can be produced, ensuring improvement in the characteristics in the angle of view for multi-color light emission.

Here, the fluorescent layer is used instead of a color filter because compared with the case of using the color filter highly efficient multi-color light emission can be expected as mentioned above.

When a fluorescent layer is disposed on the outside of a multi-color light emission apparatus, there are cases where the fluorescent layer is damaged by handling and deteriorates from external environmental factors such as water, oxygen, light, and the like. In this invention, however, the protective layer of the fluorescent layers is disposed on the fluorescent layer, thereby protecting the fluorescent layer. Also, the transparent substrate is used for protecting the fluorescent layer or for a support substrate in the step of forming the fluorescent layer.

II. Multi-color Light Emission Apparatus (second invention) and Process for Manufacturing Thereof (third invention)

The second invention of the present application, designated as apparatus 20, has, specifically, a structure selected from the structures (1) to (4) describe below from the above points of view. These structures (1) to (4) are shown in FIGS. 9–12. Incidentally, a fluorescent layer may convert the light emitted from the organic EL device into light of a wave length longer than that of the light emitted from the organic EL device. The converted color is not limited to the following red or green color.

(1) Transparent support substrate **11**/fluorescent layer **3R** for converting into red color (hereinafter called "red color conversion fluorescent layer"), fluorescent layer **3G** for converting into green color (hereinafter called "green color conversion fluorescent layer")/transparent and electrically insulating inorganic oxide layer **12**/organic EL device **1** (transparent electrode **1a**/organic compound layer **1b**/electrode **1c**);

(2) Transparent support substrate **11**/red color conversion fluorescent layer **3R**, green color conversion fluorescent layer **3G**/adhesive layer **13**/transparent and electrically insulating inorganic oxide layer **12**/organic EL device **1** (transparent electrode **1a**/organic compound layer **1b**/electrode **1c**);

(3) Transparent support substrate **11**/red color conversion fluorescent layer **3R**, green color conversion fluorescent layer **3G**/protective layer of the fluorescent layers (transparent flat film) **7**/adhesive layer **13**/transparent and electrically insulating inorganic oxide layer **12**/organic EL device **1** (transparent electrode **1a**/organic compound layer **1b**/electrode **1c**); and

(4) Transparent support substrate **11**/red color conversion fluorescent layer **3R**, green color conversion fluorescent layer **3G**/protective layer of the fluorescent layers (transparent flat film) **7**/transparent and electrically insulating inorganic oxide layer **12**/organic EL device **1** (transparent electrode **1a**/organic compound layer **1b**/electrode **1c**).

A red color filter and a green color filter may be assembled between the red color conversion fluorescent layer 3R and the transparent substrate, and between the green color conversion fluorescent layer 3G and the transparent substrate respectively, thereby adjusting colors of light of a red color and of a green color to improve these color purities.

A blue color filter **14** may be disposed in parallel and between the red color conversion fluorescent layer 3R and the green color conversion fluorescent layer 3G, thereby adjusting the colors of light emitted from the organic EL device to improve the color purities.

Also, as shown in FIG. 13, a black matrix **9b** may be disposed at least in a space between the fluorescent layers 3R and 3G, and/or the color filter **14** to cut leakage of light emitted from the organic EL device 1 and thereby to improve the visibility of multi-color light emission.

Further, as shown in FIG. 14, the transparent and electrically insulating inorganic oxide layer **12** may be composed of two layers, an upper inorganic oxide layer and a lower inorganic oxide layer so that elution of inorganic ions from the lower inorganic oxide layer (for example, soda-lime glass) is restrained by the upper inorganic oxide layer to protect the organic EL device from the eluted ions.

The thickness of the transparent and electrically insulating inorganic oxide layer **12** is defined in a range of from 0.01 μm to 200 μm. If the thickness of the transparent and electrically insulating inorganic oxide layer is not larger than 0.01 μm, it is near that of a monolayer of an inorganic oxide particle and hence deteriorative gas generated from organic compounds of the lower fluorescent layer, protective layer, and the like never cut.

On the other hand, if the thickness of the transparent and electrically insulating layer exceeds 200 μm, the light emitted from the organic EL device leaks from the gap between the inorganic oxide layer and the fluorescent layers 3R, 3G so that the angle of view for multi-color light emission narrows, leading to a reduction in practicability, although this depends on the fineness of the fluorescent layers 3R and 3G.

The multi-color light emission apparatus of the second invention and the process of the third invention for manufacturing same in the present application are now illustrated for every structural element in detail. Materials used for the structural elements are not limited to the essential materials illustrated in the following descriptions. Also, details common with those in the first invention are omitted as far as possible to avoid redundancies.

1. Organic EL Device

The organic EL device of this invention is similar to that used in the first invention.

(a) Anode

Materials similar to those used in the first invention can be used as the materials for the anode.

(b) Emitting layer

Materials similar to those used in the first invention can be used as the materials for an emitting layer.

(c) Positive hole injecting layer

Materials to those used in the first invention can be used as the materials for a positive hole injecting layer.

(d) Electron Injecting Layer

Materials similar to those used in the first invention can be used as the materials for an electron injecting layer.

(e) Cathode

Materials similar to those used in the first invention can be used as the materials for a cathode.

(f) Manufacture of Organic EL Device(example)

The organic EL device used in this invention can be manufactured in the same manner as in the first invention.

2. Transparent Support Substrate

A transparent support substrate used in the present invention is preferably a transparent material (visible light transmittance of 50% or more) such as, for example, a glass plate, plastic plate (polycarbonate, acryl, or the like), plastic film (polyethylene terephthalate, polyether sulfide, or the like), quartz plate, or the like. There are no limitations as to the thickness of the support substrate to the extent that it can reinforce a thin transparent glass plate to be laminated subsequently without camber and distortion.

3. Fluorescent Layer

Materials similar to those used in the first invention can be used as the materials for a fluorescent layer.

4. Transparent and Electrically Insulating Inorganic Oxide Layer

A transparent and electrically insulating inorganic oxide layer used in the present invention can be formed by laminating it on the fluorescent layer, or a protective layer of the fluorescent layers or transparent adhesive layer, such as described below, for example, by vapor deposition, sputtering, dipping, spin-coating, roll-coating, casting, anodic oxidation of metal film, or the like.

The transparent and electrically insulating inorganic oxide layer may be formed of either one layer or two layers. With the two layer structure composed of an upper inorganic oxide layer and a lower inorganic oxide layer, elution of inorganic ions from the lower inorganic oxide layer (for example, soda-lime glass) is restrained by the upper inorganic oxide layer to protect the organic EL device from the eluted ions.

Examples of the materials used for the transparent and electrically insulating inorganic oxide layer include silicon oxide (SiO_2), aluminum oxide (Al_2O_3), titanium oxide (TiO_2), yttrium oxide (Y_2O_3), germanium oxide (GeO_2), zinc oxide (ZnO), magnesium oxide (MgO), calcium oxide (CaO), boron oxide (B_2O_3), strontium oxide (SrO), barium oxide (BaO), lead oxide (PbO), zirconium oxide (ZrO_3), sodium oxide (Na_2O), lithium oxide (Li_2O), potassium oxide (K_2O), and the like. Among these, silicon oxide, aluminum oxide, and titanium oxide are preferable, since the transparency of the layer (film) thereof is high and the film formation temperature is comparatively low (250° C. or less), hence the fluorescent layer or the protective layer deteriorates little.

Also, as the transparent and electrically insulating inorganic oxide layer, it is more preferable to use a glass plate or a glass plate product made by forming a film of one or more compounds selected from a group consisting of silicon oxide, aluminum oxide, titanium oxide, and the like on at least one of the surface or back face of a transparent and insulating glass plate. A low temperature (150° C. or less) operation allowing this glass plate or glass plate product to be applied to the fluorescent layer or the protective layer can be performed so that these layers never entirely deteriorate. Also, the glass plate can especially cut out aqueous vapor, oxygen, deteriorating gases such as monomer gas and the like in an efficient manner.

Compositions of the glass plate are exemplified in Tables 1 and 2. Among these, typical examples are sodalime glass, barium-strontium containing-glass, lead glass, aluminosilicate glass, borosilicate glass, barium borosilicate glass, and the like. Here, the electrically insulating inorganic oxide layer may have a composition containing mainly an inorganic oxide and may contain a nitride (for example, Si_3N_4) or fluoride (for example, CaF_2) It is preferable that the thickness of the electrically insulating inorganic oxide layer be from 0.01 μm to 200 μm, though there are no limitations as to the thickness to the extent that it acts as an obstacle to the light emission of the organic EL device. The glass plate or the glass plate product made by forming a film of one or more compounds selected from a group consisting of silicon oxide, aluminum oxide, titanium oxide, and the like on at least one of the surface or back face of a transparent and insulating glass plate has preferably a thickness of from 1 μm to 200 μm in consideration of the accuracy and strength of a plate glass.

The reason that inorganic oxide compounds including the glass plate are desired is specifically because electro conductive and transparent inorganic materials such as ITO (indium tin oxides), which are often used, can be adopted as a transparent electrode (anode) of the organic EL device and also because these have excellent mutual affinity and adhesion.

Here, aqueous vapor, oxygen, and gas from organic compounds such as monomers and the like exhibit the problem of a reduction in the light emission life of the organic EL device. Therefore, it is necessary for the transparent and electrically insulating inorganic oxide layer to possess characteristics that do not cause generation of aqueous vapor, oxygen, and gases of organic compounds such as monomers and the like and wherein the external intrusion of these harmful compounds can be prevented.

Specifically, the water content of the inorganic oxide layer is measured by thermal analysis (DTA (Differential Thermal Analysis) and DSC (Differential Scanning Calorimeter)). Also, the gas permeability of the inorganic oxide layer for aqueous vapor and for oxygen is measured according to a test method for permeability of JIS K7126 and the like. If, especially, the water content is 0.1% by weight or less and the gas permeability is 10^{-13} cccm/cm^{2}scmHg or less, reduction in the light emission life of the organic EL device, indicated by generation of dark spots can be prevented.

TABLE 1

	Glass composition type
1)	R_2O—R'O—SiO_2
	Na_2O—CaO/MgO—SiO_2 (soda-lime glass)
	Na_2O/K_2O—BaO/SrO—SiO_2
	Na_2O/K_2O—CaO/ZnO—SiO_2
2)	R_2O—PbO—SiO_2
	K_2O/Na_2O—PbO—SiO_2 (lead glass)
3)	R_2O—B_2O_3—SiO_2
	Na_2O—B_2O_3—SiO_2 (borosilicate glass)
	K_2O—B_2O_3—SiO_2
4)	R'O—B_2O_3—SiO_2
	PbO—B_2O_3—SiO_2
	PbO/ZnO—B_2O_3—SiO_2
	PbO—B_2O_3—SiO_2 + filler
	ZnO—B_2O_3—SiO_2

TABLE 1-continued

	Glass composition type
5)	$R'O-Al_2O_3-SiO_2$ $CaO/MgO-Al_2O_3-SiO_2$ (aluminosilicate glass) $MgO-Al_2O_3-SiO_2$ $PbO/ZnO-Al_2O_3-SiO_2$
6)	$R_2O-Al_2O_3-SiO_2$ $Li_2O-Al_2O_3-SiO_2$ $Na_2O-Al_2O_3-SiO_2$
7)	$R'O-TiO_2-SiO_2$ $BaO-TiO_2-SiO_2$
8)	$R_2O-ZrO_2-SiO_2$ $Na_2O/Li_2O-ZrO_2-SiO_2$
9)	$R'O-P_2O_5-SiO_2$ $CaO-P_2O_5-SiO_2$
10)	$R'O-SiO_2$ $CaO/BaO/PbO-SiO_2$
11)	SiO_2
12)	$R_2O-R'O-B_2O_3$ $Li_2O-BeO-B_2O_3$
13)	$R'O-R''_2O_3-B_2O_3$ $CaO/BaO-Al_2O_3-B_2O_3$ $CaO/PbO-Lu_2O_3-B_2O_3$
14)	$R_2O-Al_2O_3-P_2O_5$ $K_2O-Al_2O_3-P_2O_5$
15)	$R'O-Al_2O_3-P_2O_5$ $BaO/CaO-Al_2O_3-P_2O_5$ $ZnO-Al_2O_3-P_2O_5$

R: monovalent element,
R': bivalent element,
R": trivalent element

TABLE 2

Classification	Composition (shown as a unary system-ternary system
1 Simple oxide	SiO_2, B_2O_3, GeO_2, As_2O_3
2 Silicate	Li_2O-SiO_2, Na_2O-SiO_2, K_2O-SiO_2 $MgO-SiO_2$, $CaO-SiO_2$, $BaO-SiO_2$, $PbO-SiO_2$ $Na_2O-CaO-SiO_2$ $Al_2O_3-SiO_2$
3 Borate	$Li_2O-B_2O_3$, $Na_2O-B_2O_3$, $K_2O-B_2O_3$ $MgO-B_2O_3$, $CaO-B_2O_3$, $PbO-B_2O_3$ $Na_2O-CaO-B_2O_3$, $ZnO-PbO-B_2O_3$ $Al_2O_3-B_2O_3$, $SiO_2-B_2O_3$
4 Phosphate	$Li_2O-P_2O_5$, $Na_2O-P_2O_5$ $MgO-P_2O_5$, $CaO-P_2O_5$, $BaO-P_2O_5$ $K_2O-BaO-P_2O_5$ $Al_2O_3-P_2O_5$, SiO2$-P_2O_5$, $B_2O_3-P_2O_5$ $V_2O_5-P_2O_5$, $Fe_2O_3-P_2O_5$, $WO_3-P_2O_5$
5 Germanate glass	Li_2O-GeO_2, Na_2O-GeO_2, K_2O-GeO_2 $B_2O_3-GeO_2$, SiO_2-GeO_2
6 Tungstate	Na_2O-WO_3, K_2O-WO_3
7 Molybdate	Na_2O-MoO_3, K_2O-MoO_3, L_2O-MoO_3
8 Tellurate	Na_2O-TeO_2
9 Borosilicate	$Na_2O-B_2O_3-SiO_2$
10 Aluminosilicate	$Na_2O-Al_2O_3-SiO_2$, $CaO-Al_2O_3-SiO_2$
11 Aluminoborate	$CaO-Al_2O_3-B_2O_3$, $ZnO-Al_2O_3-B_2O_3$
12 Aluminoborosilicate	$Na_2O-Al_2O_3-B_2O_3-SiO_2$
13 Fluoride	BeF_2, $NaF-BeF_2$ $ZrF_4-BaF_2-ThF_4$, $GdF_3-BaF_2-ZrF_4$
14 Phosphorus fluoride	$Al(PO_3)_3-AlF_3-NaF-CaF_2$
15 Oxyhalogenide	$Ag_2O-AgI-P_2O_5$
16 Oxynitride	$MgO-Al_2O_3-AlN-SiO_2$

5. Protective Layer of the Fluorescent Layers (transparent flat film)

Materials similar to those of the first invention may be used as a protective layer of the fluorescent layers (transparent flat film).

However, the thickness of the protective layer in the second invention is preferably from 0.5 μm to 100 μm approximately. It is desirable that the thickness of the protective layer be as small as possible to reduce light leakage from the gap between the fluorescent layer and the organic EL device with respect to the light emitted from the organic EL device. However, if the film thickness is too small, no effect of protecting the fluorescent layer can be obtained, depending on the type of adhesive.

6. Transparent Adhesive Layer

It is desirable that a transparent adhesive layer, which is used as required in the present invention, be used in the case of adopting the substrate produced by forming the fluorescent layer (including a color filter, black matrix, and protective layer as required) on the transparent support substrate and also, especially, in the case of adopting a glass plate as the inorganic oxide layer. A material which is transparent (visible transmittance of 50% or more), at least in the portion where the light emitted from the organic EL device is transmitted is preferable as the material used for the transparent adhesive layer.

Specifically given as examples of the adhesive are photocurable or heat-curable adhesives having a reactive vinyl group of an acrylic acid type oligomer and methacrylic acid type oligomer; and moisture-curable adhesives such as 2-cyanoacrylate and the like. Also, heat-curable and chemical-curable type (two liquid mixture type) adhesives such as an epoxy or the like can be used.

An adhesive having a low viscosity (about 100 cp or less) ensures that there is no formation of air bubbles when it is applied and hence uniform application is allowable. However, the low viscosity adhesive dissolves and erodes the fluorescent layer depending on the conditions so that it is necessary to laminate the above protective layer on the fluorescent layer. An adhesive having a high viscosity (about 100 cp or more) is scarcely dissolved, and erodes the fluorescent layer so that there is the case where the protective layer of the fluorescent layers is not required. On the contrary, this causes formation of air bubbles, hence uniform application can be achieved only with difficulty. The necessity of providing the protective layer of the fluorescent layers may be determined according to the characteristics of the adhesive.

The adhesive is applied on a substrate, on which the fluorescent layer (including a color filter, black matrix, and protective layer as required) is formed to form a film by spin-coating, roll coating, casting, or the like. Then, a glass plate, on which the transparent electrode has been formed or is to be formed, or a glass plate product made by forming a film of one or more compounds selected from a group consisting of silicon oxide, aluminum oxide, titanium oxide, and the like on at least one of the surface or back face of a transparent, insulating glass plate is applied to the substrate through the adhesive film by means of light (UV rays), heat (up to 150° C.), chemical mixing, or the like according to the specification of the adhesive.

It is preferable that the thickness of the adhesive layer be in the order of 0.1 μm to 200 μm. It is desirable that the thickness of the protective layer be as small as possible to reduce light leakage from the gap between the fluorescent layer and the organic EL device with respect to the light emitted from the organic EL device, thereby improving the characteristics of the angle of view . However, if the film thickness is too small, there is the case where uniform application can be attained only with difficulty due to unevenness between the fluorescent layers.

7. Color Filter and Black Matrix

A color filter and a black matrix used as required in the present invention are formed, for example, by appropriately patterning desired positions of a material selected from known materials by photolithography or printing.

8. Action of the Present Invention

In the present invention with the above structure, the inorganic oxide layer with a thickness of from 0.01 to 200 μm cuts out aqueous vapor, oxygen, or gaseous substances such as organic monomers, which are considered to adhere to or to be contained originally in small amounts in organic compounds forming the lower fluorescent layer or the protective layer of the fluorescent layers or which are considered to be generated by the fluorescent layer or the protective layer by heat when the organic EL device emits light. Hence, the causes of deterioration of the organic EL device can be reduced. Especially in the case of using a glass plate as the inorganic oxide layer, such deteriorative gaseous substances can be prevented to a high degree, resulting in improvement in storage stability and in the light emission life of the multi-color light emission apparatus.

Also, the film thickness of the inorganic oxide layer is 200 μm or less in the present invention, so that undesirable light emission caused by absorption of the light emitted from the organic EL device by a fluorescent layer other than the desired fluorescent layer and light leakage from the gap between the fluorescent layer and the organic EL device decrease, hence light of a desired color could be produced, resulting in improvement in the characteristics of the angle of view for multi-color light emission.

Also, the inorganic oxide layer and the transparent electrode (usually composed of ITO (indium or tin oxide) provide a higher quality adhesion than those composed of organic compounds, thereby facilitating the patterning (usually by photolithography) of the transparent electrode.

Also, in the present invention, the transparent adhesive layer is placed on the boundary of the inorganic oxide layer on the side of the fluorescent layer. Especially in the case where the inorganic oxide layer located at the boundary of the transparent electrode of the organic EL device on the side of the fluorescent layer is composed of a glass plate, adhesion between the organic EL device and the fluorescent layer is enhanced and the organic EL device and the fluorescent layer are integrated. Further, when the transparent protective layer of the fluorescent layers is arranged between the adhesive layer and the fluorescent layer, the fluorescent layer is protected from being dissolved and eroded by the adhesive layer. The protective layer ensures that the uneven film thickness of the fluorescent layers to be separately disposed on the same plane is moderated, the deformation of the inorganic oxide layer on the fluorescent layer is reduced, and defects such as cracking and the like in the inorganic oxide layer or the transparent electrode decrease.

If a thin glass plate with a thickness of from 1 μm to 200 μm is used as the inorganic oxide layer, it is difficult to form an organic electroluminescent device directly on the glass plate in a stable manner since the thin film-glass plate which is physically fragile tends to be cambered and distorted. However, in the process of the present invention, this thin glass plate is combined with the transparent support substrate on which the fluorescent layer and the protective layer of the fluorescent layers are laminated via the adhesive layer. Also, the organic electroluminescence devices are laminated in order, so that the multi-color light emission apparatus can be produced in a stable manner.

EXAMPLES

The present invention will be explained in more detail by way of examples, which are not intended to be limiting of the present invention.

Example 1

An methacrylate type resist containing carbon black (CK 2000, manufactured by Fuji Hunt Electronics Technology Co., Ltd.) was applied by spin-coating to one the faces of a support substrate (Glass 7059, manufactured by Corning Co., Ltd.) with dimensions of 25 mm×75 mm×1.1 mm (thickness), which was baked at 200° C. to form a black film (about 2 μm thickness).

Next, the face opposite to the black film of this substrate was washed with IPA and further irradiated with UV light. Then, the substrate was secured to a substrate holder of a vapor deposition unit (manufactured by ULVAC Corporation). As materials for vapor deposition, MTDATA and NPD for a positive hole injecting layer, DPVBi for an emitting material, and Alq for an electron injecting layer were placed in a resistance heating molybdenum boat. Ag was attached to a tungsten filament as a second metal for an electrode (cathode), and Mg was attached to the molybdenum boat as an electron injecting metal for an electrode (cathode).

After that, the pressure in a vacuum vessel was reduced to 5×10^{-7} torr and then the above materials were sequentially laminated in the following order through a mask which enabled film to be formed in a range of 10 mm×60 mm. A vacuum was maintained during the steps between a step of forming electrodes and a step of forming the positive hole injecting layer by one evacuating operation.

First, Mg and Ag were vapor-deposited as the electrode simultaneously at vapor deposition rates of 1.3–1.4 nm/s and 0.1 nm/s respectively to a film thickness of 200 nm. Then, an electron injecting layer was formed by depositing Alq at a vapor deposition rate of 0.1–0.3 nm/s to a film thickness of 20 nm. Next, an emitting layer was formed by depositing DPVBi at a vapor deposition rate of 0.1–0.3 nm/s to a film thickness of 50 nm. Finally, a positive hole injecting layer was formed by depositing NPD at a vapor deposition rate of 0.1–0.3 nm/s to a film thickness of 20 nm and also depositing MTDATA at a vapor deposition rate of 0.1–0.3 nm/s to a film thickness of 200 nm.

Next, the substrate was transferred to a sputtering apparatus. A transparent electrode (anode) film of ITO (indium oxide or tin oxide) with a thickness of 120 nm and a surface resistance of 20 Ω/□ was formed on this substrate at room temperature through a mask which enabled a film to be formed of an area of 10 mm×60 mm to create an organic EL device. Here, the mask was lifted so that the ranges of the electrodes and transparent electrode were crossed (in a range of 10 mm×55 mm) and the terminal of each electrode could be taken.

Next, an epoxy, two-liquid mixing type adhesive (Araldite, manufactured by Ciba Geigy Co., Ltd.) was applied to the peripheries of the crossed portions (10 mm×55 mm) at a width of 1 mm approximately with partial slits using a dispenser to form a substrate A.

Then, a transparent inorganic oxide substrate (barium borosilicate glass) (substrate B) of 25 mm×75 mm×1.1 mm (thickness) was applied to the substrate A and the adhesive was cured. After that, hydrocarbon fluoride (Fluorinert, manufactured by Sumitomo 3M Corp.) was injected under a nitrogen atmosphere, using an injection needle, through the above slits into gaps between the support substrate (substrate A.) and the applied substrate (substrate B). Then, the same adhesive was filled into the slits in the cured adhesive and cured.

Next, characters EL with a width of 1 mm were printed on the substrate within the portion corresponding to the crossed portion (a range of 10 mm×55 mm) through a screen board using an ink (viscosity 8,000 cp) produced by dissolving coumarin 6/polyvinyl chloride resin (molecular weight of

20,000) in cyclohexanone in the coumarin 6 concentration of 0.03 mol/kg (film). The characters were air-dried to prepare a fluorescent pattern of the characters EL (15 μm thickness).

A multi-color light emission apparatus composed of the organic EL device was manufactured in this manner as shown in FIG. 1. When a d.c. voltage of 8 V was applied between the transparent electrode (anode) and the electrode (cathode) of the multi-color light emission apparatus, the crossed portions of the transparent electrodes (anodes) and the electrodes (cathodes) emitted light. The luminance of the light viewed from the portion lacking the fluorescent layer was 100 cd/m^2. The CIE chromaticity coordinates (JIS Z 8701) were as follows: x=0.15, y=0.15. Light of a blue color was detected.

Also, the luminance of the light viewed from the fluorescent layer provided with the patterned characters EL was 120 cd/m^2 and the CIE chromaticity coordinates were as follows: x=0.28, y=0.62. Light of a yellowish green color was detected.

The multi-color light emission apparatus was allowed to stand in the atmosphere for two weeks. As a result, the multi-color light emission apparatus maintained uniform light emission without changes in luminance and chromaticity and also without dark spots appearing as deterioration of the device progressed.

Example 2

A support substrate (substrate A) provided with an organic EL device was combined with a transparent inorganic oxide substrate (substrate B) in the same manner as in Example 1 to form a substrate containing a gap filled with hydrocarbon fluoride. Next, the characters EL with a width of 1 mm were printed on the substrate within the portion corresponding to the crossed portion (range 10 mm×55 mm) of an electrode and a transparent electrode through a screen board using an ink (viscosity 8,000 cp) produced by dissolving 43% (for film) by weight of a pigment containing rhodamine/polyvinyl chloride resin (molecular weight 20,000) in cyclohexanone. The characters were air-dried to prepare a fluorescent pattern of the characters EL (20 μm thickness).

A multi-color light emission apparatus composed of the organic EL device was manufactured in this manner as shown in FIG. 1. When a d.c. voltage of 8 V was applied between the transparent electrode (anode) and the electrode (cathode) of the multi-color light emission apparatus, the crossed portions of the transparent electrodes and the electrodes emitted light. The luminance of the light viewed from the portion lacking the fluorescent layer was 100 cd/m^2. The CIE chromaticity coordinate (JIS Z 8701) was as follows: x=0.15, y=0.15. Light of a blue color was detected.

Also, the luminance of the light viewed from the fluorescent layer provided with the patterned characters EL was 30 cd/m^2 and the CIE chromaticity coordinates were as follows: x=0.60, y=0.31. Light of a red color was detected.

The multi-color light emission apparatus was allowed to stand in the atmosphere for two weeks. As a result, the multi-color light emission apparatus maintained uniform light emission without changes in luminance and chromaticity coordinate and also without dark spots appearing as deterioration of the device progressed.

Example 3

An methacrylate type resist containing carbon black (CK 2000, manufactured by Fuji Hunt Electronics Technology

Co., Ltd.) was applied by spin-coating to one face of a support substrate (Glass 7059, manufactured by Corning Co., Ltd.) of 100 mm×100 mm×1.1 mm (thickness), which was baked at 200° C. to form a black film with a thickness of about 2 μm.

Next, the face opposite to the black film of this substrate was washed with IPA and further irradiated with UV light. Then, the substrate was secured to a substrate holder of a vapor deposition unit (manufactured by ULVAC Corporation). As materials for vapor deposition, MTDATA and NPD for a positive hole injecting layer, DPVBi for a emitting material, and Alq for an electron injecting layer were placed in a resistance heating molybdenum boat. Ag as a second metal for an electrode (cathode) was attached to a tungsten filament, and Mg as an electron injecting metal for an electrode (cathode) was attached to the molybdenum boat.

After that, the pressure in a vacuum vessel was reduced to 5×10^{-7} torr. First, a film with a pattern of an electrode was formed using a mask capable of transferring a stripe pattern of an 1.5 mm pitch (1.4 mm lines and 0.1 mm gaps) in a range of 72 mm×72 mm. Next, films of layers from an electron injecting layer to a positive hole injecting layer were formed using a mask enabling a film to be formed in a range of 72 mm×72 mm. A vacuum was maintained during the steps between the step of forming the electrodes and the step of forming the positive hole injecting layer by one evacuating operation.

First, Mg and Ag were simultaneously vapor-deposited as the electrodes at vapor deposition rates of 1.3–1.4 nm/s and 0.1 nm/s respectively to a film thickness of 200 nm. Then, an electron injecting layer was formed by depositing Alq at a vapor deposition rate of 0.1–0.3 nm/s to a film thickness of 20 nm. Next, an emitting layer was formed by depositing DPVBi at a vapor deposition rate of 0.1–0.3 nm/s to a film thickness of 50 nm. Finally, a positive hole injecting layer was formed by depositing NPD at a vapor deposition rate of 0.1–0.3 nm/s to a film thickness of 20 nm and also depositing MTDATA at a vapor deposition rate of 0.1–0.3 nm/s to a film thickness of 400 nm.

Next, the substrate was transferred to a sputtering apparatus. A film of a transparent electrode (anode) of ITO with a thickness of 120 nm and a surface resistance of 20 Ω/□ was formed on this substrate at room temperature through a mask which enabled a solid film with a stripe pattern of 4.5 mm pitch (4.0 mm lines, 1.0 mm gaps) to be formed in a range of 72 mm×72 mm, to form an organic EL device. Here, the mask was located so that the ranges of the electrodes and transparent electrodes were crossed and the terminal of each electrode could be taken.

Next, an epoxy, two-liquid mixing type adhesive (Araldite, manufactured by Ciba Geigy Co., Ltd.) was applied to the peripheries of the crossed portions (a range of 72 mm×72 mm) at a width of 1 mm approximately with partial slits using a dispenser to form a substrate C.

Then, a transparent inorganic oxide substrate (barium borosilicate glass) (substrate D) of 100 mm×100 mm×0.15 mm was applied to the substrate C and the adhesive was cured. After that, hydrocarbon fluoride (Fluorinert, manufactured by Sumitomo 3M Corp.) was injected under a nitrogen atmosphere, using an injection needle, through the above slits into a gap between the support substrate (substrate C) and the applied substrate (substrate D). Then, the same adhesive was filled into the slits in the cured adhesive and cured.

Next, a pattern of a fluorescent layer A with a thickness of 15 μm was printed by screen printing on the substrate using an ink (viscosity 8,000 cp) produced by dissolving coumarin 6/polyvinyl chloride resin (molecular weight 20,000) in cyclohexanone in the coumarin 6 concentration of 0.03 mol/kg (film) through a screen board which enabled a stripe pattern of 1.4 mm lines and 3.1 mm gaps to be formed after aligning with the electrodes (cathodes) of the organic EL device, followed by air-drying.

Next, a pattern of a fluorescent layer B with a thickness of 20 μm was printed by screen printing on the substrate using an ink (viscosity 8,000 cp) produced by dissolving 43% (for film) by weight of a pigment containing rhodamine/polyvinyl chloride resin (molecular weight 20,000) in cyclohexanone through a screen board which enabled a stripe pattern of 1.4 mm lines and 3.1 mm gaps to be formed after lifting the pattern 1.5 mm from the pattern of the fluorescent layer A in a direction perpendicular to the stripe, followed by air-drying.

A multi-color light emission apparatus composed of the organic EL device (dot matrix type) was manufactured in this manner as shown in FIG. 4. When a d.c. voltage of 8 V was applied between the anode and the cathode of the multi-color light emission apparatus, the crossed portions of the transparent electrodes (anodes) and the electrodes (cathodes) emitted light. The luminance of the light viewed from the portion lacking the fluorescent layer was 100 cd/m^2. The CIE chromaticity coordinate (JIS Z 8701) was as follows: x=0.15, y=0.15. Light of a blue color was detected.

Also, the luminance of the light viewed from the fluorescent layer A was 120 cd/m^2 and the CIE chromaticity coordinates were as follows: x=0.28, y=0.62. Light of a yellowish green color was detected.

On the other hand, the luminance of the light viewed from the fluorescent layer B was 30 cd/m^2 and the CIE chromaticity coordinates were as follows: x=0.60, y=0.31. Light of a red color was detected.

The multi-color light emission apparatus was allowed to stand in the atmosphere for two weeks. As a result, the multi-color light emission apparatus maintained uniform light emission without changes in luminance and chromaticity coordinate and also without dark spots appearing as deterioration of the device progressed. Also, the angle of view defined by the range in which leakage of light (mono-chromatic light) was not confirmed was ±60° which was a practical level.

Example 4

A coating agent composed of an aqueous polyvinyl pyrrolidone (molecular weight 360,000) solution was applied by spin-coating on the fluorescent layer of the multi-color light emission apparatus composed of the organic EL device manufactured in Example 1 and air-dried to laminate a protective layer of the fluorescent layers with a thickness of 10 μm.

A multi-color light emission apparatus composed of the organic EL device was manufactured in this manner as shown in FIG. 2. The multi-color light emission apparatus was allowed to stand in the atmosphere for two weeks. As a result, the multi-color light emission apparatus maintained uniform light emission without changes in luminance and chromaticity coordinates and also without dark spots appearing as deterioration of the device progressed.

Also, because the protective layer was laminated, the fluorescent layer was never damaged even if the fluorescent layer was contacted by a nail and the handling, such as carrying, of the apparatus was easy.

Example 5

An adhesive was applied to a substrate produced by forming an organic EL device on a support substrate in the same manner as in Example 3 to form a substrate X.

Separately, a pattern of a fluorescent layer A with a thickness of 15 μm was printed by screen printing on a transparent substrate (7059, manufactured by Corning Co., Ltd.) of 100 mm×100 mm×0.70 mm (thickness) using an ink (viscosity 8,000 cp) produced by dissolving coumarin 6/polyvinyl chloride resin (molecular weight 20,000) in cyclohexanone in the coumarin 6 concentration of 0.03 mol/kg (film) through a screen board which enabled a stripe pattern of 1.4 mm lines and 3.1 mm gaps to be formed after aligning with the location corresponding to electrodes of the organic EL device, followed by baking at 120° C.

Next, a pattern of a fluorescent layer B with a thickness of 20 μm was printed by screen printing on the substrate using an ink (viscosity 8,000 cp) produced by dissolving 43% (for film) by weight of a pigment containing rhodamine/polyvinyl chloride resin (molecular weight 20,000) in cyclohexanone through a screen board which enabled a stripe pattern of 1.4 mm lines and 3.1 mm gaps to be formed after lifting the pattern 1.5 mm from the pattern of the fluorescent layer A in a direction perpendicular to the stripe, followed by baking at 120° C.

An aqueous polyvinyl pyrrolidone (molecular weight 360,000) solution was applied by spin-coating to the substrate to laminate a protective layer of the fluorescent layers with a thickness of 10 μm. Next, 2-cyanoacrylate type adhesive (*Aron α, manufactured by Toagosei Chemical Industry Co., Ltd.) was applied to the entire substrate by casting to provide an inorganic oxide substrate (aluminoborosilicate glass) of 100 mm×100 mm×0.05 mm (thickness) on the substrate to form a substrate Y.

The substrate Y was applied to the above substrate X so that a 0.05 mm thickness substrate of the substrate Y faced the organic EL device and the fluorescent layers A and B were aligned with the electrodes of the organic EL device and the adhesive was cured. After that, hydrocarbon fluoride (Fluorinate, manufactured by Sumitomo 3M Corp.) was injected under a nitrogen atmosphere using an injection needle, through slits in the cured adhesive into a gap between the support substrate (substrate X) and the applied substrate (substrate Y). Then, the same adhesive was filled into the slits in the cured adhesive and cured.

The luminance and chromaticity coordinate of the light emitted in the multi-color light emission apparatus, composed of the organic EL device shown in FIG. 6 and designated as apparatus 10, which was manufactured in this manner, were the same as those in Example 3. Even if the multi-color light emission apparatus was allowed to stand in the atmosphere for two weeks, the multi-color light emission apparatus maintained uniform light emission without changes in luminance and chromaticity coordinate and also without dark spots as deterioration of the device progressed. Also, the angle of view defined by the range in which leakage of light (mono-chromatic light) emitted from the organic electroluminescence device was not confirmed was ±70° which was a practical level.

Also, because the transparent substrate was laminated, the fluorescent layer was never damaged even if the fluorescent layer was contacted by a nail and the handling, such as carrying of the apparatus, was easy.

Comparative Example 1

First, a substrate A was manufactured in the same manner as in Example 1.

Next, characters EL with a width of 1 mm were printed on the transparent substrate with dimension of 25 mm×75 mm×1.1 mm (thickness) within the portion corresponding to the crossed portion (a range of 10 mm×55 mm) of an electrode and a transparent electrode through a screen board using an ink (viscosity 8,000 cp) produced by dissolving coumarin 6/polyvinyl chloride resin (molecular weight 20,000) in cyclohexanone in the coumarine 6 concentration of 0.03 mol/kg (film). The characters were air-dried to prepare a fluorescent pattern of the characters EL to form a substrate E.

The substrate E was applied to the above substrate A so that the fluorescent layer of the substrate E faced the organic EL device and the adhesive was cured. After that, hydrocarbon fluoride (Fluorinert, manufactured by Sumitomo 3M Corp.) was injected under a nitrogen atmosphere using an injection needle, through slits in the cured adhesive into a gap between the support substrate (substrate A) and the applied substrate (substrate E). Then, the same adhesive was filled into the slits in the cured adhesive and cured.

A multi-color light emission apparatus composed of the organic EL device was manufactured in this manner as shown in FIG. 7. When a d.c. voltage of 8 V was applied between the transparent electrode (anode) and the electrode (cathode) of the multi-color light emission apparatus, the crossed portions of the transparent electrodes and the electrodes emitted light. The luminance and chromaticity coordinates of each light viewed from the portion lacking the fluorescent layer and from the characters EL were the same as those in Example 1.

However, when the multi-color light emission apparatus was allowed to stand in the atmosphere for two weeks, the luminance of the blue light emitting portion decreased to 5 cd/m^2 and the luminance of the light viewed from the characters EL decreased to 7 cd/m^2. Also, dark spots, appearing as deterioration of the device progressed, increased, resulting in nonuniform light emission. It was confirmed that when the fluorescent layer is disposed so as to face the organic EL device contrary to Example 1, the light emission life of the multi-color light emission apparatus was greatly impaired.

Comparative Example 2

A substrate C was manufactured in the same manner as in Example 3.

A transparent inorganic oxide substrate (borosilicate glass) (substrate F) of 100 mm×100 mm×0.30 mm thickness was applied to the above substrate C. Then, a multi-color light emission apparatus composed of an organic EL device (dot matrix type) shown in FIG. 4 was formed in the same manner as in Example 3.

This multi-color light emission apparatus was allowed to emit light to result in obtaining the same luminance and chromaticity as in Example 3.

When the multi-color light emission apparatus was allowed to stand in the atmosphere for two weeks, the multi-color light emission apparatus maintained uniform light emission without changes in luminance and chromaticity coordinates and also without dark spots appearing as deterioration of the device progressed. However, the angle of view defined by the range in which leakage of light (mono-chromatic light) emitted from the organic electroluminescence device was not confirmed was ±30°, so that there were portions (angles) where the light color viewed from a normal sight range differed from the emitted light color, exhibiting a problem in practical use.

Example 6

A pattern of a fluorescent layer A with a thickness of 15 μm was printed by screen printing on a glass substrate (7059, manufactured by Corning Co., Ltd.) of 100 mm×100 mm×1.1 mm (thickness) as a transparent support substrate using an ink (viscosity 8,000 cp) produced by dissolving coumarin 6/polyvinyl chloride resin (molecular weight 20,000) in cyclohexanone in the coumarin 6 concentration of 0.03 mol/kg (film) through a screen board which enabled a stripe pattern of 1.4 mm lines and 3.1 mm gaps to be formed, followed by baking at 120° C. Next, a pattern of a fluorescent layer B with a thickness of 20 μm were printed by screen printing on the substrate using an ink (viscosity 8,000 cp) produced by dissolving 43% (for film) by weight of a pigment containing rhodamine/polyvinyl chloride resin (molecular weight 20,000) in cyclohexanone through a screen board which enabled a stripe pattern of 1.4 mm lines and 3.1 mm gaps to be formed after lifting the pattern 1.5 mm from the pattern of the fluorescent layer A in a direction perpendicular to the stripe, followed by baking at 120° C.

An aqueous solution of 20% by weight of polyvinyl alcohol (molecular weight 50,000) was applied to the entire substrate provided with the patterns of the fluorescent layers by spin-coating. The substrate was baked at 80° C. to prepare a transparent protective layer of the fluorescent layers with a thickness of 5 μm.

Next, a photocurable transparent adhesive of epoxy type oligomer (3102, manufactured by Three Bond corp.) was applied to the protective layer by casting. The glass surface of a glass plate (borosilicate glass) of 100 mm×100 mm×50 μm thickness as an insulating inorganic oxide layer, on which a film of a transparent electrode (anode) of ITO (indium oxide or tin oxide) with a thickness of 0.12 μm and a surface resistance of 20 Ω/□ was formed, was applied to the protective layer. The substrate was irradiated with UV light through the ITO surface at a dose of 3,000 mJ/cm^2 (365 nm), followed by baking at 80° C.

A film of a novolak/quinonediazido type positive resist (HPR 204, manufactured by Fuji Hunt Electronics Technology Co., Ltd.) was laminated by spin-coating. After baking at 80° C., the substrate was placed on a proximity type exposure machine. Then, the substrate was irradiated with light at a dose of 100 mJ/cm^2 (365 nm) using a mask capable of transferring a stripe pattern of 1.2 mm lines and 0.3 mm gaps after aligning the mask with the fluorescent layers A and B.

The resist on the substrate was developed using an aqueous solution of 2.38% by weight of TMAH (Tetra-Methyl Ammonium Hydroxide) and post-baked at 130° C. Then, the exposed ITO film was treated by etching using aqueous hydrobromic acid and, finally, the positive type resist was peeled off to prepare a pattern of the ITO film which constitutes an anode of the organic EL device.

Next, this substrate was washed with IPA and further irradiated with UV light. Then, the substrate was secured to a substrate holder of a vapor deposition unit (manufactured by ULVAC Corporation). As materials for vapor deposition, MTDATA and NPD for a positive hole injecting layer, DPVBi for anemittingmaterial, andAlq for an electron injecting layer, were placed in a resistance heating molybdenum boat. Ag as a second metal for an electrode (cathode) was attached to a tungsten filament, and Mg as an electron injecting metal for an electrode (cathode) was attached to the molybdenum boat.

After that, the pressure in a vacuum vessel was reduced to 5×10^{-7} torr and then the above materials were sequentially laminated in the following order. A vacuum was maintained during the steps between the step of forming the positive hole injecting layer and the step of forming the cathode by one evacuating operation. First, a positive hole injecting layer was formed by depositing MTDATA at a vapor deposition rate of 0.1–0.3 nm/s to a film thickness of 200 nm and also depositing NPD at a vapor deposition rate of 0.1–0.3 nm/s to a film thickness of 20 nm. Next, an emitting layer was formed by depositing DPVBi at a vapor deposition rate of 0.1–0.3 nm/s to a film thickness of 50 nm. Then, an electron injecting layer was formed by depositing Alq at a vapor deposition rate of 0.1–0.3 nm/s to a film thickness of 20 nm. Finally, Mg and Ag were vapor-deposited simultaneously as the cathode at vapor deposition rates of 1.3–1.4 nm/s and 0.1 nm/s respectively to a film thickness of 200 nm through a mask capable of transferring a stripe pattern of 4 mm lines and 0.5 mm gaps which is perpendicular to the stripe pattern of the anode composed of ITO.

A multi-color light emission apparatus composed of the organic EL device was manufactured in this manner as shown in FIG. 11. When a d.c. voltage of 8 V was applied between the anode and the cathode of the multi-color light emission apparatus, the crossed portions of the anodes and cathodes emitted light. The luminance of the light viewed from the portion lacking the fluorescent layer was 100 cd/m^2. The CIE chromaticity coordinate (JIS Z 8701) was as follows: x=0.15, y=0.15. Light of a blue color was detected.

On the other hand, the luminance of the light viewed from the fluorescent layer A was 120 cd/m^2 and the CIE chromaticity coordinates were as follows: x=0.28, y=0.62. Light of a yellowish green color was detected.

Also, the luminance of the light viewed from the fluorescent layer B was 30 cd/m^2 and the CIE chromaticity coordinates were as follows: x=0.60, y=0.31. Light of a red color was detected.

The multi-color light emission apparatus manufactured in the above manner was allowed to stand under a nitrogen stream for two weeks. As a result, the multi-color light emission apparatus maintained uniform light emission without changes in luminance and chromaticity coordinates and also without dark spots appearing as deterioration of the device progressed. Also, the angle of view defined by the range in which leakage of light (mono-chromatic light) emitted from the organic EL device was not confirmed was 60°, which was a practical level.

The water content of the glass substrate with a thickness of 50 μm was 0.1% by weight or less and the gas permeability of the glass substrate for aqueous vapor and for oxygen was 10^{-13} cccm/cm^{2}scmHg or less.

Example 7

A photocurable transparent adhesive of epoxy type oligomer (3112, manufactured by Three Bond corp.) was applied, by casting, to the substrate provided with the fluorescent layers A and B, which was prepared in Example 6. The glass surface of a glass plate (borosilicate glass) of 100 mm×100 mm×50 μm thickness as an insulating inorganic oxide layer on which a film of a transparent electrode (anode) of ITO with a thickness of 0.12 μm and a surface resistance of 20 Ω/□ was formed was applied to the substrate. The substrate was irradiated with UV rays through the surface of ITO at a dose of 3,000 mJ/cm^2 (365 nm), followed by baking at 80° C.

Then, the ITO was patterned and an organic EL device was formed under the same conditions as in Example 6 to prepare a multi-color light emission apparatus composed of the organic EL device shown in FIG. 10.

This multi-color light emission apparatus was allowed to emit light to obtain the same luminance and chromaticity coordinates as in Example 6. When the multi-color light emission apparatus was allowed to stand under a nitrogen stream for two weeks, it maintained uniform light emission without changes in luminance and chromaticity coordinate and also without dark spots as deterioration of the device progressed. Also, the angle of view defined by the range in which leakage of light (mono-chromatic light) emitted from the organic electroluminescence device was not confirmed was ±55°, which was a practical level.

Example 8

A photocurable resist containing carbon black (CK 2000, manufactured by Fuji Hunt Electronics Technology Co., Ltd.) was applied by spin-coating to a glass substrate (7059, manufactured by Corning Co., Ltd.) of 100 mm×100 mm×1.1 mm (thickness) as a transparent support substrate, which was baked at 80° C. Then, an oxygen shielding film of polyvinyl alcohol(CP, manufactured by Fuji Hunt Electronics Technology Co., Ltd.) was formed on the substrate by spin-coating, and was baked at 80° C. Next, the resulting substrate was placed on a proximity type exposure machine. The substrate was then irradiated with light at a dose of 100 mJ/cm^2 (365 nm) using a mask capable of transferring a stripe pattern of 0.3 mm lines and 1.2 mm gaps. The resist on the substrate was developed using aqueous 1N sodium carbonate solution and post-baked at 200° C. to provide a black matrix.

A photocurable resist containing copper phthalocyanine (CB 2000, manufactured by Fuji Hunt Electronics Technology Co., Ltd.) was applied to the substrate by spin-coating and was baked at 80° C. Then, an oxygen shielding film of polyvinyl alcohol (CP, manufactured by Fuji Hunt Electronics Technology Co., Ltd.) was formed on the substrate by spin-coating and was baked at 80° C. Next, the substrate was placed on a proximity type exposure machine. The substrate was then irradiated with light at a dose of 100 mJ/cm^2 (365 nm) using a mask capable of transferring a stripe pattern of 1.4 mm lines and 3.1 mm gaps after aligning the substrate so that the pattern was embedded in gaps of the black matrix. The resist on the substrate was developed using aqueous 1N sodium carbonate solution and post-baked at 200° C. to provide a blue color filter.

Fluorescent layers A and B were printed by screen printing on portions other than the blue color filter of the substrate provided with the black matrix and the blue color filter under the same conditions as in Example 1 after alignment with the gaps of the black matrix. Then, the same glass plate as in Example 1, specifically, a glass plate with a thickness of 50 μm, which was provided with a film of ITO (anode), was applied to the above substrate to form an ITO pattern.

Next, this substrate was washed with IPA and further irradiated with UV light. Then, the substrate was secured to a substrate holder of a vapor deposition unit (manufactured by ULVAC Corporation). As materials for vapor deposition, MTDATA and NPD for a positive hole injecting layer, DPVBi for an emitting material, DPAVB for a dopant, and Alq for an electron injecting layer were placed in a resistance heating molybdenum boat. Ag as a second metal for an electrode (cathode) was attached to a tungsten filament, and Mg as an electron injecting metal for an electrode (cathode) was attached to the molybdenum boat.

After that, the pressure in the vacuum vessel was reduced to 5×10^{-7} torr and the above materials were sequentially laminated in the following order. A vacuum was maintained during the steps between the step of forming the positive hole injecting layer and the step of forming the cathode by one evacuating operation. First, a positive hole injecting layer was formed by depositing MTDATA at a vapor deposition rate of 0.1–0.3 nm/s to a film thickness of 200 nm and also depositing NPD at a vapor deposition rate of 0.1–0.3 nm/s to a film thickness of 20 nm. Then, an emitting layer was formed by depositing DPVBi at a vapor deposition rate of 0.1–0.3 nm/s and also depositing DPAVB at a vapor deposition rate of 0.05 nm/s to a total film thickness of 40 nm (the proportion by weight of dopant to host material was from 1.2 to 1.6). Then, an electron injecting layer was formed by depositing Alq at a vapor deposition rate of 0.1–0.3 nm/s to a film thickness of 20 nm. Finally, Mg and Ag were simultaneously vapor-deposited as the cathode at vapor deposition rates of 1.3–1.4 nm/s and 0.1 nm/s respectively to a film thickness of 200 nm through a mask capable of transferring a stripe pattern of 4 mm lines and 0.5 mm gaps which is perpendicular to the stripe pattern of the ITO anode.

A multi-color light emission apparatus composed of the organic EL device was manufactured in this manner as shown in FIG. 13. When a d.c. voltage of 8 V was applied between the anode and the cathode of the multi-color light emission apparatus, the crossed portions of the anodes and cathodes emitted light. The luminance of the light viewed from the blue color filter was 35 cd/m^2. The CIE chromaticity coordinates (JIS Z 8701) were as follows: x=0.14, y=0.12. Light of a blue color was detected.

On the other hand, the luminance of the light viewed from the fluorescent layer A was 120 cd/m^2 and the CIE chromaticity coordinates were as follows: x=0.28, y=0.62. Light of a yellowish green color was detected.

Also, the luminance of the light viewed from the fluorescent layer B was 30 cd/m^2 and the CIE chromaticity coordinates were as follows: x=0.60, y=0.31. Light of a red color was detected.

The multi-color light emission apparatus manufactured in the above manner was allowed to stand under a nitrogen stream for two weeks. As a result, the multi-color light emission apparatus maintained uniform light emission without changes in luminance and chromaticity coordinate and also without dark spots appearing as deterioration of the device progressed. Also, the angle of view defined by the range in which color mixing was not confirmed when mono-chromatic light was emitted was ±70°, which was a practical level.

Example 9

A methacrylate type photocurable resin (V259PA, manufactured by Nippon Steel Chemical Co., Ltd.) was applied, by spin-coating, to the substrate provided with the fluorescent layers A and B, which was prepared in Example 6. After baking at 80° C., the substrate was irradiated with UV light at a dose of 300 mJ/cm^2 (365 nm). Then, the substrate was baked at 160° C. to laminate a transparent protective layer with a thickness of 5 μm.

Next, a silicon oxide film as as insulating inorganic oxide layer with a thickness of 0.01 μm was laminated over the entire substrate heated at 160° C. using a sputtering apparatus. Then, a film of ITO (anode) with a thickness of 0.12 μm and a surface resistance of 20 Ω/□ was formed on the substrate using a sputtering apparatus, while the substrate was heated at 160° C.

Then, the ITO was patterned and an organic EL device was formed under the same conditions as in Example 6 to prepare a multi-color light emission apparatus composed of the organic EL device shown in FIG. 12. This multi-color light emission apparatus was allowed to emit light to obtain the same luminance and chromaticity coordinates as in those in Example 6. When the multi-color light emission apparatus was allowed to stand under a nitrogen stream for two weeks, the multi-color light emission apparatus maintained uniform light emission with almost no changes in luminance and chromaticity coordinates and also with few dark spots appearing as deterioration of the device progressed. Also, the angle of view defined by the range in which leakage of light (mono-chromatic light) emitted from the organic electroluminescence device was not confirmed was ±90°, which was a practical level.

The water content of the silicon oxide film with a thickness of 0.01 μm was 0.1% by weight or less and the gas permeability of the silicon oxide film for aqueous vapor and for oxygen was 10^{-13} cccm/cm^{2}scmHg or less.

Example 10

An aluminum oxide film as an insulating inorganic oxide layer with a thickness of 0.01 μm was laminated over the entire substrate provided with the fluorescent layers A and B, which was prepared in Example 6, using a sputtering apparatus while heating the substrate at 160° C. Then, a solid film of ITO with a thickness of 0.12 μm and a surface resistance of 20 Ω/□ was formed on the substrate using a sputtering apparatus, while the substrate was heated at 160° C.

Then, the ITO was patterned and an organic EL device was formed under the same conditions as in Example 6 to prepare a multi-color light emission apparatus composed of the organic EL device shown in FIG. 9. This multi-color light emission apparatus was allowed to emit light to obtain the same luminance and chromaticity coordinates as in those in Example 6. When the multi-color light emission apparatus was allowed to stand under a nitrogen stream for two weeks, the multi-color light emission apparatus maintained uniform light emission with almost no changes in luminance and chromaticity coordinate and also with few dark spots appearing as deterioration of the device progressed. Also, the angle of view defined by the range in which leakage of light (mono-chromatic light) emitted from the organic electroluminescence device was not confirmed was ±90°, which was a practical level.

The water content of the aluminum oxide film with a thickness of 0.01 μm was 0.1% by weight or less and the gas permeability of the aluminum oxide film for aqueous vapor and for oxygen was 10^{-13} cccm/cm^{2}scmHg or less.

Example 11

A titanium oxide film as an insulating inorganic oxide layer with a thickness of 0.01 μm was laminated by sputtering over the entire substrate provided with the fluorescent layers A and B, which was prepared in Example 6, while heating the substrate at 160° C. Then, a solid film of ITO with a thickness of 0.12 μm and a surface resistance of 20 Ω/□ was formed on the substrate using a sputtering apparatus, while the substrate was heated at 160° C.

Then, the ITO was patterned and an organic EL device was formed under the same conditions as in Example 6 to prepare a multi-color light emission apparatus composed of the organic EL device shown in FIG. 9. This multi-color light emission apparatus was allowed to emit light to obtain the same luminance and chromaticity coordinates as in those in Example 6. When the multi-color light emission apparatus was allowed to stand under a nitrogen stream for two weeks, the multi-color light emission apparatus maintained uniform light emission with almost no changes in luminance and chromaticity coordinates and also with few dark spots appearing as deterioration of the device progressed. Also, the angle of view defined by the range in which leakage of light (mono-chromatic light) emitted from the organic electroluminescence device was not confirmed was ±90°, which was a practical level.

The water content of the titanium oxide film with a thickness of 0.01 μm was 0.1% by weight or less and the gas permeability of the titanium oxide film for aqueous vapor and for oxygen was 10^{-13} cccm/cm^{2}scmHg or less.

Example 12

A photocurable transparent adhesive of a methacrylate type oligomer (3102, manufactured by 3-Bond corp.) was applied, by casting, to the substrate prepared in Example 6, in which the protective layer was laminated on the fluorescent layers A and B. The glass surface of a glass substrate (soda-lime glass) of 100 mm×100 mm×50 μm thickness as an insulating inorganic oxide layer on which a titanium oxide film with a thickness of 0.05 μm and a film of a transparent electrode of ITO (anode) with a thickness of 0.12 μm were completely formed in order was applied to the substrate. The substrate was irradiated with UV rays through the surface of the ITO at a dose of 3,000 mJ/cm^2 (365 nm), followed by baking at 80° C.

Then, the ITO was patterned and an organic EL device was formed under the same conditions as in Example 6 to prepare a multi-color light emission apparatus composed of the organic EL device shown in FIG. 14. This multi-color light emission apparatus was allowed to emit light to obtain the same luminance and chromaticity coordinate as in those in Example 6. When the multi-color light emission apparatus was allowed to stand under a nitrogen stream for two weeks, the multi-color light emission apparatus maintained uniform light emission with almost no changes in luminance and chromaticity coordinate and also with few dark spots appearing as deterioration of the device progressed. Also, the angle of view defined by the range in which leakage of light (mono-chromatic light) emitted from the organic electroluminescence device was not confirmed was ±60°, which was a practical level.

The water content of the glass substrate with a thickness of 50 μm, on which the titanium oxide film with a thickness of 0.01 μm was formed, in this example, was 0.1% by weight or less and the gas permeability of the glass substrate, on which titanium oxide film was formed, for aqueous vapor and for oxygen was 10^{-13} cccm/cm^2 scmHg or less.

Comparative Example 3 (in the case of no provision for the inorganic oxide layer)

A methacrylate type photocurable resin (V259PA, manufactured by Nippon Steel Chemical Co., Ltd.) was applied, by spin-coating, to the substrate provided with the fluorescent layers A and B, which was prepared in Example 6. After baking at 80° C., the substrate was irradiated with UV light at a dose of 300 mJ/cm^2 (365 nm). Then, the substrate was baked at 160° C. to laminate a transparent protective layer with a thickness of 5 μm.

Next, a film of ITO (anode) with a thickness of 0.12 μm and a surface resistance of 20 Ω/□ was formed on the substrate using a sputtering apparatus, while the substrate was heated at 160° C.

Then, the ITO was patterned and an organic EL device was formed under the same conditions as in Example 6 to prepare a multi-color light emission apparatus composed of the organic EL device shown in FIG. 15. This multi-color light emission apparatus was allowed to emit light to obtain the same luminance and chromaticity as in those in Example 6. However, when the multi-color light emission apparatus was allowed to stand under a nitrogen stream for two weeks, the luminance viewed from the portion lacking the fluorescent layer under the same conditions as in Example 6 decreased to 5 cd/cm^2 and many dark points as deterioration of the device progressed, exhibiting a clear problem.

The total content of water contained in the protective layer was 1.2% by weight and the gas permeability of the protective layer for aqueous vapor and for oxygen was 10^{-13} cccm/cm^{2}scmHg or more.

Comparative Example 4 (in the case where the thickness of the inorganic oxide layer was 0.005 μm)

A methacrylate type photocurable resin (V259PA, manufactured byNippon Steel Chemical Co., Ltd.) was applied, by spin-coating, to the substrate provided with the fluorescent layers A and B, which was prepared in Example 6. After baking at 80° C., the substrate was irradiated with UV light at a dose of 300 mJ/cm^2 (365 nm). Then, the substrate was baked at 160° C. to laminate a transparent protective film with a thickness of 5 μm.

Next, using a sputtering apparatus, a silicon oxide film as an insulating inorganic oxide layer with a thickness of 0.005 μm was laminated over the entire substrate heated at 160° C. and a solid film of ITO with a thickness of 0.12 μm and a surface resistance of 20 Ω/□ was formed over the entire substrate using a sputtering apparatus, while the substrate was heated at 160° C.

Then, the ITO was patterned and an organic EL device was formed under the same conditions as in Example 6 to prepare a multi-color light emission apparatus composed of the organic EL device. This multi-color light emission apparatus was allowed to emit light to obtain the same luminance and chromaticity as in Example 6. However, when the multi-color light emission apparatus was allowed to stand under a nitrogen stream for two weeks, the luminance viewed from the portion lacking the fluorescent layer under the same conditions as in Example 6 decreased to 20 cd/cm^2 and many dark spots as deterioration of the device progressed, exhibiting a clear problem.

The water content of the silicon oxide film with a thickness of 0.005 μm was 0.1% by weight or less. However, the gas permeability of the silicon oxide film with a thickness of 0.005 μm for aqueous vapor and for oxygen was 10^{-13} cccm/cm^{2}scmHg or more.

Comparative Example 5 (in the case where the thickness of the inorganic oxide layer (plate glass) was 300 μm)

The glass surface of a glass plate (borosilicate glass) of 100 mm×100 mm×300 μm thickness as an insulating inorganic oxide layer on which a solid film of ITO (anode) with a thickness of 0.12 μm and a surface resistance of 20 Ω/□ was formed was applied to the substrate prepared in Example 6, on which the patterns of the fluorescent layers A and B, the protective layer, and the adhesive layer were subsequently laminated. The substrate was irradiated with UV rays through the ITO surface at a dose of 3,000 mJ/cm^2 (365 nm), followed by baking at 80° C.

Then, the ITO was patterned and an organic EL device was formed under the same conditions as in Example 6 to prepare a multi-color light emission apparatus composed of the organic EL device. This multi-color light emission apparatus was allowed to emit light to obtain the same luminance and chromaticity as in Example 6. When the multi-color light emission apparatus was allowed to stand under a nitrogen stream for two weeks, the multi-color light emission apparatus maintained uniform light emission with almost no changes in luminance and chromaticity coordinates and also with few dark points appearing with the progress in deterioration of the device. However, the angle of view defined by the range in which leakage of light (mono-chromatic light) emitted from the organic EL device was not confirmed was ±30°. There were portions (angles) where light of a color differing from the emitted color was viewed in a normal sight range, exhibiting a practical problem.

Comparative Example 6 (in the case of forming the protective layer (flat layer) using a sol-gel glass method)

The substrate produced in Example 6, which was provided with the patterns of the fluorescent layers A and B, was dipped into a mixed solution consisting of 10% by weight of tetraethoxysilane ($Si(OC_2H_5)_4$) and water/ethanol (ratio by volume: 1:2) containing 1% by weight of hydrochloric acid.

The substrate was slowly lifted to produce a substrate in which the fluorescent layers A and B were dip-coated with silicon oxide (SiO_2) sol.

The substrate was then heated at 400° C. so that silicon oxide was allowed to gel and thereby a glass-like protective layer was laminated on the fluorescent layers A and B. However, it was confirmed that the patterns of the fluorescent layers A and B were blackened (carbonized) to show deterioration in these layers.

Because of this, the substrate was heated at 160° C. so that silicon oxide was allowed to gel and thereby a glass-like protective layer with a thickness of 0.2 μm was laminated on the fluorescent layers A and B.

Next, a film of ITO (anode) with a thickness of 0.12 μm and a surface resistance of 20 Ω/□ was formed on the entire substrate using a sputtering apparatus, while the substrate was heated at 160° C.

Then, the ITO was patterned and an organic EL device was formed under the same conditions as in Example 6 to provide a multi-color light emission apparatus composed of the organic EL device shown in FIG. 15. This multi-color light emission apparatus was allowed to emit light to obtain the same luminance and chromaticity as in Example 6. However, when the multi-color light emission apparatus was allowed to stand under a nitrogen stream for two weeks, the luminance viewed from the portion lacking the fluorescent layer under the same conditions as in Example 6 decreased to 5 cd/cm^2 and many dark spots appeared as deterioration of the device progressed, exhibiting a clear problem.

The water content contained in the sol-gel silicon oxide film with a thickness of 0.2 μm was 1.5% by weight. Also, the gas permeability of the sol-gel silicon oxide film to aqueous vapor and to oxygen was 10^{-13} cccm/cm^{2}scmHg or more, showing that the protective layer produced by the sol-gel method was inappropriate.

INDUSTRIAL APPLICABILITY

As is clear from the above explanations, the present invention can provide a multi-color light emission apparatus using an organic EL device having an excellent light emission life and excellent characteristics in the angle of view. Also, the present invention can provide a process for manufacturing the multi-color light emission apparatus in a stable and efficient manner.

Accordingly, the present invention can be preferably applied for thin type multi-color or full color displays of various emission types.

What is claimed is:

1. A multi-color light emission apparatus comprising a support substrate, an organic electroluminescence (EL) device disposed on the support substrate, and a fluorescent layer disposed to correspond to a transparent electrode or electrode of the organic EL device to absorb the light emitted from the organic EL device and to emit visible fluorescent light, wherein a transparent inorganic oxide substrate on which the fluorescent layer is placed is disposed between the organic EL device and the fluorescent layer in such a manner as to provide a gap between the fluorescent layer and the organic EL device, and the organic EL device is sealed using a sealing means between the transparent inorganic oxide substrate and the support substrate.

2. The multi-color light emission apparatus according to claim 1, wherein the fluorescent layer is separately disposed on the transparent inorganic oxide substrate on the same plane.

3. The multi-color light emission apparatus according to claim 1 or 2,

wherein at least a transparent protective layer of the fluorescent layer and a transparent substrate are farther disposed on the fluorescent layer.

4. The multi-color light emission apparatus according to claim 1, wherein the thickness of the transparent inorganic oxide substrate is in a range of from 1 to 200 μm.

5. The multi-color light emission apparatus according to claim 1, wherein the transparent inorganic oxide substrate is made of a transparent glass plate.

6. A multi-color light emission apparatus comprising a transparent support substrate, fluorescent layers separately disposed on the transparent support substrate on the same plane, and an organic electroluminescence (EL) device disposed on or above the fluorescent layers, the fluorescent layers being disposed to correspond to a transparent electrode or electrode of the organic EL device so that each of the fluorescent layers absorbs the light emitted from the organic EL device and emits different visible fluorescent light, wherein a transparent and insulating inorganic oxide layer with a thickness of from 0.01 to 200 μm is interposed between the fluorescent layer and the organic EL device wherein at least a transparent protective layer of the fluorescent layers and a transparent adhesive layer are disposed between the fluorescent layers and the transparent and insulating inorganic oxide layer.

7. The multi-color light emission apparatus according to claim 6, wherein the transparent and insulating inorganic oxide layer is made of a transparent and insulating glass plate.

8. The multi-color light emission apparatus according to claim 6, wherein the transparent inorganic oxide layer is made from one or more compounds selected from a group consisting of silicon oxide, aluminum oxide, and titanium oxide.

9. The multi-color light emission apparatus according to claim 6, wherein the transparent and insulating inorganic oxide layer is produced by forming a film of one or more compounds selected from a group consisting of silicon oxide, aluminum oxide, and titanium oxide on at least one of the surface or back face of a transparent and insulating glass plate.

10. The multi-color light emission apparatus according to claim 6, wherein the transparent and insulating inorganic layer contains mainly an inorganic oxide.

* * * * *

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United States Patent [19]

Tang et al.

[11] Patent Number: 5,684,365

[45] Date of Patent: Nov. 4, 1997

[54] **TFT-EL DISPLAY PANEL USING ORGANIC ELECTROLUMINESCENT MEDIA**

[75] Inventors: Ching Wan Tang, Rochester; Biay Cheng Hseih, Pittsford, both of N.Y.

[73] Assignee: Eastman Kodak Company, Rochester, N.Y.

[21] Appl. No.: 355,742

[22] Filed: Dec. 14, 1994

[51] Int. Cl.[6] H01L 27/12

[52] U.S. Cl. 315/169.3; 345/76; 345/92; 313/500; 313/504; 313/506; 257/59; 257/448; 349/42

[58] Field of Search 257/59, 72, 71, 257/448, 92; 313/500, 503, 504, 506, 509; 315/169.3, 169.1; 345/76, 92; 349/42

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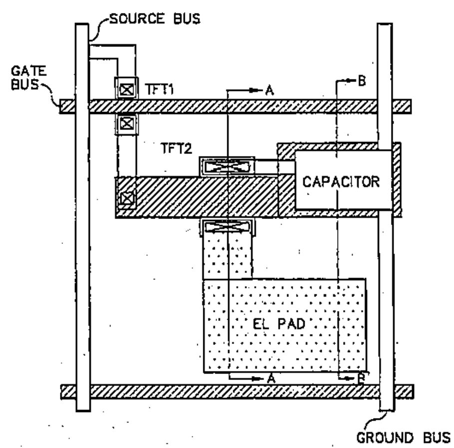
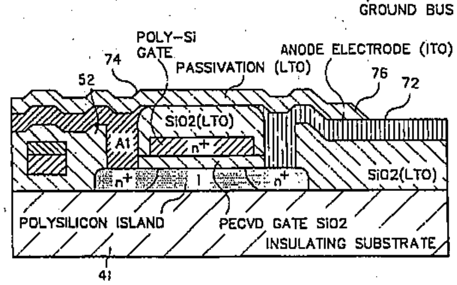
Primary Examiner—Robert Pascal
Assistant Examiner—Arnold Kinkead
Attorney, Agent, or Firm—Raymond L. Owens

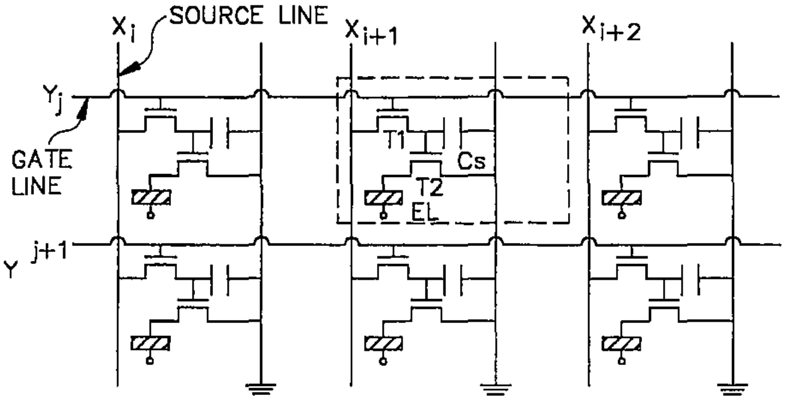
[57] **ABSTRACT**

A flat panel display comprising thin-film-transistor-electroluminescent (TFT-EL) pixels is described. An addressing scheme incorporating two TFTs and a storage capacitor is used to enable the EL pixels on the panel to operate at a duty factor close to 100%. This TFT-EL device eliminates the need to pattern the EL cathode, thus greatly simplifying the procedure to delineate the EL pixels as well as ensuring high resolution. The TFT-EL panel consumes less power than conventional TFT-LCD panels, especially when the usage factor of the screen is less than unity.

12 Claims, 5 Drawing Sheets






SOURCE LINE
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X_{i+2}
Y_j
GATE LINE
T1
Cs
T2
EL
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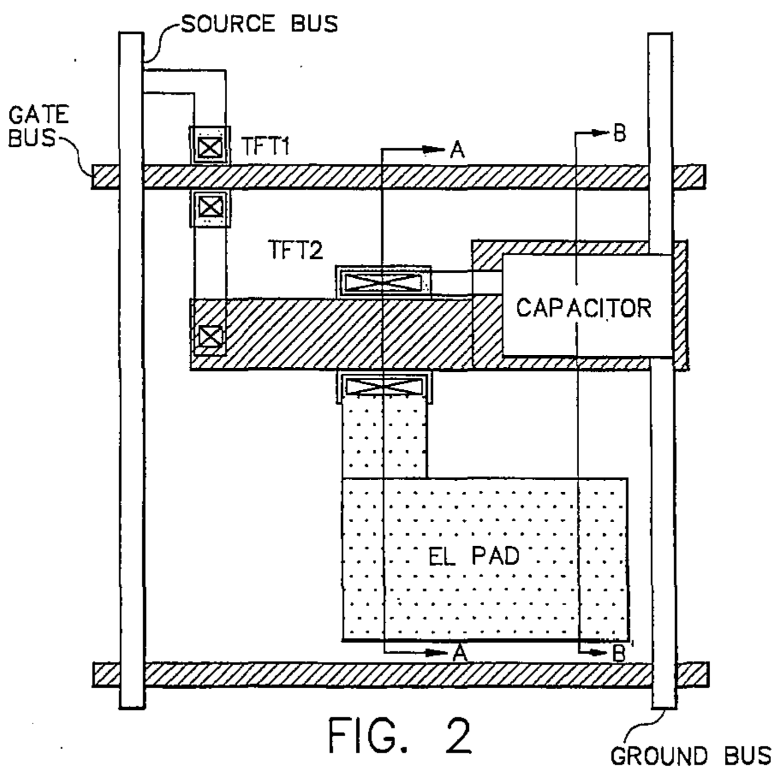
FIG. 1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GATE BUS
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A
B
TFT2
CAPACITOR
EL PAD
A
B'
GROUND BUS

FIG. 2

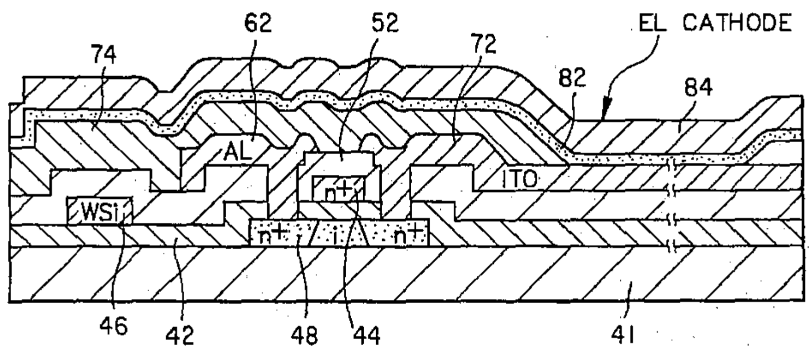

62
52
EL CATHODE
74
72
82
84
AL
ITO
n+
WSi
n+
i
n+
46
42
48
44
41

FIG. 3

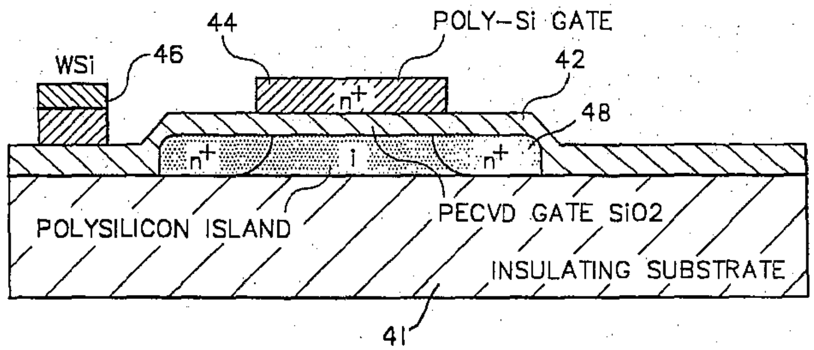
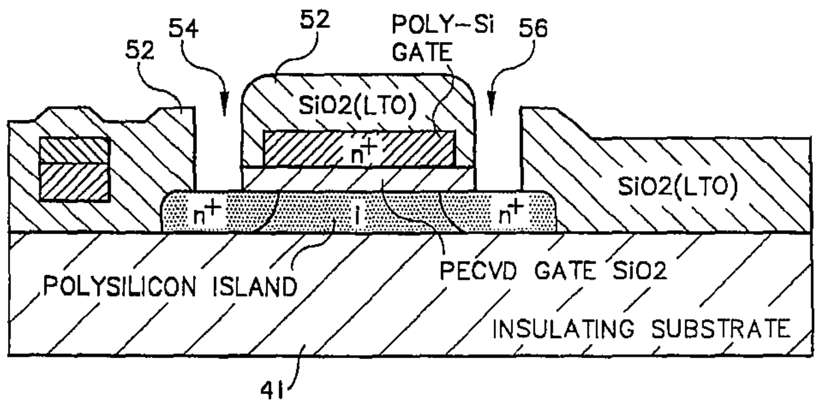

44
POLY-Si GATE
WSi
46
42
n+
48
n+
i
n+
POLYSILICON ISLAND
PECVD GATE SiO2
INSULATING SUBSTRATE
41

FIG. 4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52
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GATE
56
SiO2(LTO)
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n+
i
n+
SiO2(LTO)
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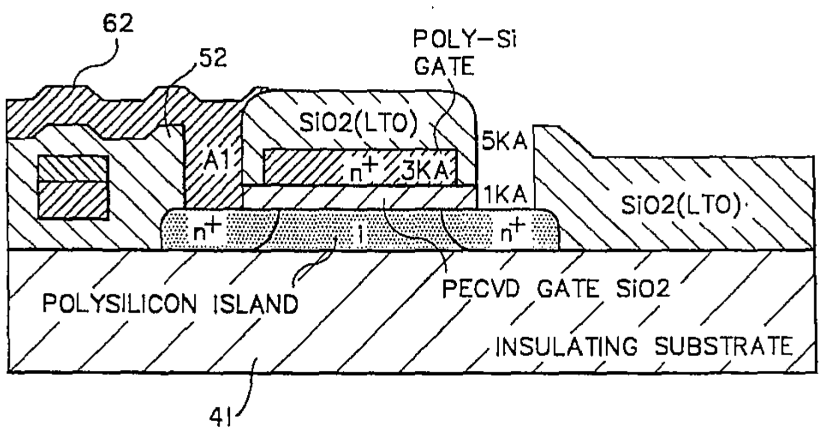
PECVD GATE SiO2
INSULATING SUBSTRATE
41

FIG. 5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PECVD GATE SiO2
INSULATING SUBSTRATE
41

FIG. 6

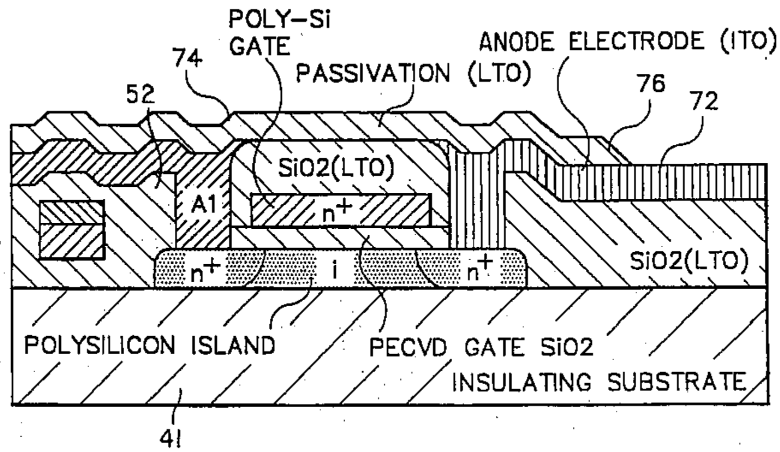

POLY-Si GATE
74
52
PASSIVATION (LTO)
ANODE ELECTRODE (ITO)
76
72
SiO2(LTO)
A1
n+
n+
i
n+
SiO2(LTO)
POLYSILICON ISLAND
PECVD GATE SiO2
INSULATING SUBSTRATE
41

FIG. 7

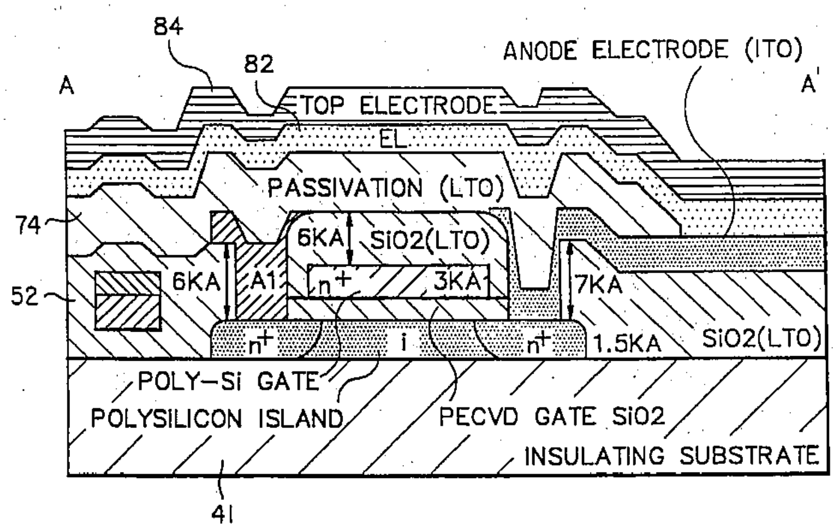

84
82
A
ANODE ELECTRODE (ITO)
A'
TOP ELECTRODE
EL
PASSIVATION (LTO)
74
6KA
SiO2(LTO)
52
6KA
A1
n+
3KA
7KA
n+
i
n+
1.5KA
SiO2(LTO)
POLY-Si GATE
POLYSILICON ISLAND
PECVD GATE SiO2
INSULATING SUBSTRATE
41

FIG. 8

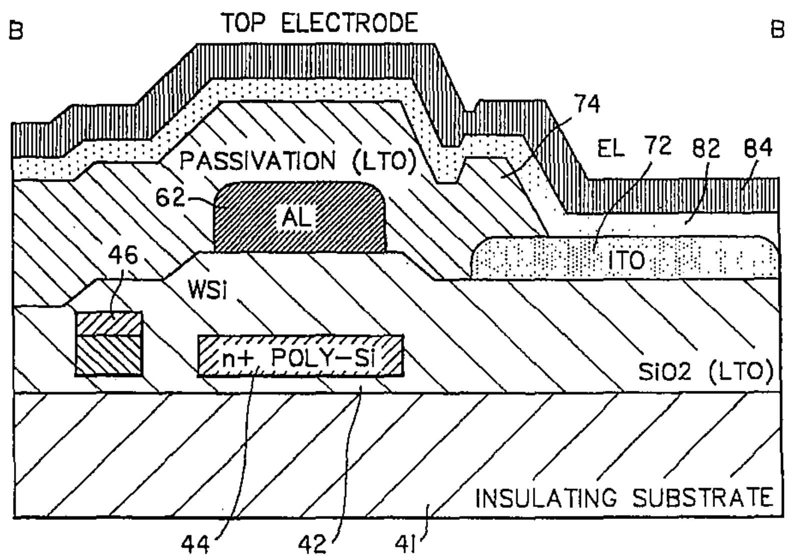

B
TOP ELECTRODE
B'
74
EL
72
82
84
PASSIVATION (LTO)
62
AL
46
ITO
WSi
n+ POLY-Si
SiO2 (LTO)
INSULATING SUBSTRATE
44
42
41

FIG. 9

TFT-EL DISPLAY PANEL USING ORGANIC ELECTROLUMINESCENT MEDIA

CROSS REFERENCE TO RELATED APPLICATIONS

Reference is made to commonly assigned U.S. Ser. No. 08/355,786, now abandoned, entitled "An Electroluminescent Device Having an Organic Electroluminescent Layer" by Tang et al and U.S. Ser. No. 08/355,940, now U.S. Pat. No. 5,550,066, entitled "A Method of Fabricating a TFT-EL Pixel" by Tang et al. both filed concurrently herewith, the disclosures of which are incorporated herein.

FIELD OF THE INVENTION

The present invention relates to an electroluminescent display panel employing thin-film-transistors (TFT) as active-matrix addressing elements, and organic electroluminescent thin films as the emissive medium.

INTRODUCTION

Rapid advances in flat-panel display (FPD) technologies have made high quality large-area, full-color, high-resolution displays possible. These displays have enabled novel applications in electronic products such as lap top computers and pocket-TVs. Among these FPD technologies, liquid crystal display (LCD) has emerged as the display of choice in the marketplace. It also sets the technological standard against which other FPD technologies are compared. Examples of LCD panels include: (1) 14", 16-color LCD panel for work stations (IBM and Toshiba, 1989) (see K. Ichikawa, S. Suzuki, H. Marino, T. Aoki, T. Higuchi and Y. Oano, SID Digest, 226 (1989)), (2) 6", full-color LCD-TV (Phillips, 1987) (see M. J. Powell, J. A. Chapman, A. G. Knapp, I. D. French, J. R. Hughes, A. D. Pearson, M. Allinson, M. J. Edwards, R. A. Ford, M. C. Hemmings, O. F. Hill, D. H. Nicholls and N. K. Wright, Proceeding, International Display Conference, 63, 1987), (3) 4" full-color LCD TV (model LQ424A01, Sharp, 1989) (see Sharp Corporation Technical Literature for model LQ424A01), and (4) 1 megapixel colored TFT-LCD (General Electric) (see D. E. Castleberry and G. E. Possin, SID Digest, 232 (1988)). All references, including patents and publications, are incorporated herein as if reproduced in full below.

A common feature in these LCD panels is the use of thin-film-transistors (TFT) in an active-addressing scheme, which relaxes the limitations in direct-addressing (see S. Morozumi, Advances in Electronics and Electron Physics, edited by P. W. Hawkes, Vol. 77, Academic Press 1990). The success of LCD technology is in large part due to the rapid progress in the fabrication of large-area TFT (primarily amorphous silicon TFT). The almost ideal match between TFT switching characteristics and electrooptic LCD display elements also plays a key role.

A major drawback of TFT-LCD panels is they require bright backlighting. This is because the transmission factor of the TFT-LCD is poor, particularly for colored panels. Typically the transmission factor is about 2–3 percent (see S. Morozumi, Advances in Electronics and Electron Physics, edited by P. W. Hawkes, Vol. 77, Academic Press, 1990). Power consumption for backlighted TFT-LCD panels is considerable and adversely affects portable display applications requiring battery operation.

The need for backlighting also impairs miniaturization of the flat panel. For example, depth of the panel must be increased to accommodate the backlight unit. Using a typical tubular cold-cathode lamp, the additional depth is about ¾ to 1 inch. Backlight also adds extra weight to the FPD.

An ideal solution to the foregoing limitation would be a low power emissive display that eliminates the need for backlighting. A particularly attractive candidate is thin-film-transistor-electroluminescent (TFT-EL) displays. In TFT-EL displays, the individual pixels can be addressed to emit light and auxiliary backlighting is not required. A TFT-EL scheme was proposed by Fischer in 1971 (see A. G. Fischer, IEEE Trans. Electron Devices, 802 (1971)). In Fischer's scheme powdered ZnS is used as the EL medium.

In 1975, a successful prototype TFT-EL panel (6") was reportedly made by Brody et al. using ZnS as the EL element and CdSe as the TFT material (see T. P. Brody, F. C. Luo, A. P. Szepesi and D. H. Davies, IEEE Trans. Electron Devices, 22, 739 (1975)). Because ZnS-EL required a high drive voltage of more than a hundred volts, the switching CdSe TFT element had to be designed to handle such a high voltage swing. The reliability of the high-voltage TFT then became suspect. Ultimately, ZnS-based TFT-EL failed to successfully compete with TFT-LCD. U.S. Patents describing TFT-EL technology include: U.S. Pat. Nos. 3,807,037; 3,885,196; 3,913,090; 4,006,383; 4,042,854; 4,523,189; and 4,602,192.

Recently, organic EL materials have been devised. These materials suggest themselves as candidates for display media in TFT-EL devices (see C. W. Tang and S. A. VanSlyke, Appl. Phys. Lett., 51, 913 (1987), C. W. Tang, S. A. VanSlyke and C. H. Chen, J. Appl. Phys., 65, 3610 (1989)). Organic EL media have two important advantages: they are highly efficient; and they have low voltage requirements. The latter characteristic distinguishes over other thin-film emissive devices. Disclosures of TFT-EL devices in which EL is an organic material include: U.S. Pat. Nos. 5,073,446; 5,047,687, 5,059,861; 5,294,870; 5,151,629; 5,276,380; 5,061,569; 4,720,432; 4,539,507; 5,150,006; 4,950,950; and 4,356,429.

The particular properties of organic EL material that make it ideal for TFT are summarized as follows:

1) Low-voltage drive. Typically, the organic EL cell requires a voltage in the range of 4 to 10 volts depending on the light output level and the cell impedance. The voltage required to produce a brightness of about 20 fL is about 5 V. This low voltage is highly attractive for a TFT-EL panel, as the need for the high-voltage TFT is eliminated. Furthermore, the organic EL cell can be driven by DC or AC. As a result the driver circuitry is less complicated and less expensive.

2) High efficiency. The luminous efficiency of the organic EL cell is as high as 4 lumens per watt. The current density to drive the EL cell to produce a brightness of 20 fL is about 1 mA/cm^2. Assuming a 100% duty excitation, the power needed to drive a 400 cm^2 full-page panel is only about 2.0 watts. The power need will certainly meet the portability criteria of the flat panel display.

3) Low temperature fabrication. Organic EL devices can be fabricated at about room temperature. This is a significant advantage compared with inorganic emissive devices, which require high-temperature (>300° C.) processing. The high-temperature processes required to make inorganic EL devices can be incompatible with the TFT.

The simplest drive scheme for an organic EL panel is to have the organic display medium sandwiched between two sets of orthogonal electrodes (rows and columns). Thus, in this two-terminal scheme, the EL element serves both the display and switching functions. The diode-like nonlinear current-voltage characteristic of the organic EL element should, in principle, permit a high degree of multiplexing in this mode of addressing. However, there are several major factors limiting usefulness of the two-terminal scheme in connection with organic EL:

1) Lack of memory. The rise and decay time of the organic EL is very fast, on the order of microseconds, and it does not have an intrinsic memory. Thus, using the direct addressing method, the EL elements in a selected row would have to be driven to produce an instantaneous brightness proportional to the number of scan rows in the panel. Depending on the size of the panel, this instantaneous brightness may be difficult to achieve. For example, consider a panel of 1000 scan rows operating at a frame rate of 1/60 seconds. The allowable dwell time per row is 17 μs. In order to obtain a time-averaged brightness of, for example, 20 Fl, the instantaneous brightness during the row dwell time would have to be a thousand times higher, i.e., 20,000 Fl, an extreme brightness that can only be obtained by operating the organic EL cell at a high current density of about 1 A/cm^2 and a voltage of about 15–20 volts. The long-term reliability of a cell operating under these extreme drive conditions is doubtful.

2) Uniformity. The current demanded by the EL elements is supplied via the row and column buses. Because of the instantaneous high current, the IR potential drops along these buses are not insignificant compared with the EL drive voltage. Since the brightness-voltage characteristic of the EL is nonlinear, any variation in the potential along the buses will result in a non-uniform light output.

Consider a panel with 1000 rows by 1000 columns with a pixel pitch of 200μ×200μ and an active/actual area ratio of 0.5. Assuming the column electrode is indium tin oxide (ITO) of 10 ohms/square sheet (Ω/□) resistance, the resistance of the entire ITO bus line is at least 10,000 ohms. The IR drop along this bus line for an instantaneous pixel current of 800 μA (2 A/cm^2) is more than 8 volts. Unless a constant current source is implemented in the drive scheme, such a large potential drop along the ITO bus will cause unacceptable non-uniform light emission in the panel. In any case, the resistive power loss in the bus is wasteful. A similar analysis can be performed for the row electrode bus that has the additional burden of carrying the total current delivered to the entire row of pixels during the dwell time, i.e., 0.8 A for the 1000-column panel. Assuming a 1 μm thick aluminum bus bar of sheet resistance about 0.028 ohms/square the resultant IR drop is about 11 volts, which is also unacceptable.

3) Electrode patterning. One set of the orthogonal electrodes, the anode—indium tin oxide, can be patterned by a conventional photolithographic method. The patterning of the other set of electrodes however, presents a major difficulty peculiar to the organic EL device. The cathode should be made of a metal having a work function lower than 4 eV, and preferably magnesium alloyed with another metal such as silver or aluminum (see Tang et al., U.S. Pat. No. 4,885,432). The magnesium-based alloy cathode deposited on top of the organic layers cannot be easily patterned by any conventional means involving photoresists. The process of applying the photoresist from an organic solvent on the EL cell deleteriously affects the soluble organic layer underneath the magnesium-based alloy layer. This causes delamination of the organic layers from the substrate.

Another difficulty is the extreme sensitivity of the cathode to moisture. Thus, even if the photoresist can be successfully applied and developed without perturbing the organic layers of the EL cell, the process of etching the magnesium-based alloy cathode in aqueous acidic solution is likely to oxidize the cathode and create dark spots.

SUMMARY OF THE INVENTION

The present invention provides an active matrix 4-terminal TFT-EL device in which organic material is used as the EL medium. The device comprises two TFTs, a storage capacitor and a light emitting organic EL pad arranged on a substrate. The EL pad is electrically connected to the drain of the second TFT. The first TFT is electrically connected to the gate electrode of the second TFT which in turn is electrically connected to the capacitor so that following an excitation signal the second TFT is able to supply a nearly constant current to the EL pad between signals. The TFT-EL devices of the present invention are typically pixels that are formed into a flat panel display, preferably a display in which the EL cathode is a continuous layer across all of the pixels.

The TFT-organic EL device of the present invention are formed in a multi-step process as described below:

A first thin-film-transistor (TFT1) is disposed over the top surface of the substrate. TFT1 comprises a source electrode, a drain electrode, a gate dielectric, and a gate electrode; and the gate electrode comprises a portion of a gate bus. The source electrode of TFT1 is electrically connected to a source bus.

A second thin-film-transistor (TFT2) is also disposed over the top surface of the substrate, and TFT2 also comprises a source electrode, a drain electrode, a gate dielectric, and a gate electrode. The gate electrode of TFT2 is electrically connected to the drain electrode of the first thin-film-transistor.

A storage capacitor is also disposed over the top surface of the substrate. During operation, this capacitor is charged from an excitation signal source through TFT1, and discharges during the dwell time to provide nearly constant potential to the gate electrode of TFT2.

An anode layer is electrically connected to the drain electrode of TFT2. In typical applications where light is emitted through the substrate, the display is a transparent material such as indium tin oxide.

A dielectric passivation layer is deposited over at least the source of TFT1, and preferably over the entire surface of the device. The dielectric passivation layer is etched to provide an opening over the display anode.

An organic electroluminescent layer is positioned directly on the top surface of the anode layer. Subsequently, a cathode layer is deposited directly on the top surface of the organic electroluminescent layer.

In preferred embodiments, the TFT-EL device of the present invention is made by a method using low pressure and plasma enhanced chemical vapor deposition combined with low temperature (i.e. less than 600° C.) crystallization and annealing steps, hydrogen passivation and conventional patterning techniques.

The thin-film-transistors are preferably formed simultaneously by a multi-step process involving:

the deposition of silicon that is patterned into polycrystalline silicon islands;

chemical vapor deposition of a silicon dioxide gate electrode; and

deposition of another polycrystalline silicon layer which is patterned to form a self-aligned gate electrode so that after ion-implantation a source, drain, and gate electrode are formed on each thin-film-transistor.

The construction of pixels having thin-film-transistors composed of polycrystalline silicon and silicon dioxide provides improvements in device performance, stability, reproducibility, and process efficiency over other TFTs. In comparison, TFTs composed of CdSe and amorphous silicon suffer from low mobility and threshold drift effect.

There are several important advantages in the actual panel construction and drive arrangement of a TFT-organic EL device of the present invention:

1) Since both the organic EL pad and the cathode are continuous layers, the pixel resolution is defined only by the feature size of the TFT and the associated display ITO pad and is independent of the organic component or the cathode of the EL cell.

2) The cathode is continuous and common to all pixels. It requires no patterning for pixel definition. The difficulty of patterning the cathode in the two-terminal scheme is therefore eliminated.

3) The number of scanning rows is no longer limited by the short row dwell time in a frame period, as the addressing and excitation signals are decoupled. Each scan row is operated at close to 100% duty factor. High resolution can be obtained since a large number of scan rows can be incorporated into a display panel while maintaining uniform intensity.

4) The reliability of the organic EL element is enhanced since it operates at a low current density (1 mA/cm^2) and voltage (5 V) in a 100% duty factor.

5) The IR potential drops along the buses are insignificant because of the use of a common cathode and the low current density required to drive the EL elements. Therefore the panel uniformity is not significantly affected by the size of the panel.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram of an active matrix 4-terminal TFT-EL device. T1 and T2 are thin-film-transistors. Cs is a capacitor and EL is an electroluminescent layer.

FIG. 2 is a diagrammatic plan view of the 4-terminal TFT-EL device of the present invention.

FIG. 3 is a cross-sectional view taken along the line A-A' in FIG. 2.

FIG. 4 is a cross-sectional view taken along the line A-A', illustrating the process of forming a self-aligned TFT structure for ion implantation.

FIG. 5 is a cross-sectional view taken along the line A-A', illustrating the processing steps of depositing a passivation oxide layer and opening contact cuts to the source and drain regions of the thin-film-transistor.

FIG. 6 is a cross-sectional view taken along line A-A', illustrating deposition of an aluminum electrode.

FIG. 7 is a cross-sectional view taken along line A-A', illustrating deposition of the display anode and a passivation layer that has been partially etched from the surface of the display anode.

FIG. 8 is a cross-sectional view taken along line A-A', illustrating the steps of depositing an electroluminescent layer and a cathode.

FIG. 9 is a cross-sectional view taken along line B-B' in FIG. 2.

DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 shows the schematic of an active matrix 4-terminal TFT-EL display device. Each pixel element includes two TFTs, a storage capacitor and an EL element. The major feature of the 4-terminal scheme is the ability to decouple the addressing signal from the EL excitation signal. The EL element is selected via the logic TFT (T1) and the excitation power to the EL element is controlled by the power TFT (T2). The storage capacitor enables the excitation power to an addressed EL element to stay on once it is selected. Thus, the circuit provides a memory that allows the EL element to operate at a duty cycle close to 100%, regardless of the time allotted for addressing.

The construction of the electroluminescent device of the present invention is illustrated in FIGS. 2 and 3. The substrate of this device is an insulating and preferably transparent material such as quartz or a low temperature glass. The term transparent, as it is used in the present disclosure, means that the component transmits sufficient light for practical use in a display device. For example, components transmitting 50% or more of light in a desired frequency range are considered transparent. The term low temperature glass refers to glasses that melt or warp at temperatures above about 600° C.

In the TFT-EL device illustrated in FIG. 2, TFT1 is the logic transistor with the source bus (column electrode) as the data line and the gate bus (row electrode) as the gate line. TFT2 is the EL power transistor in series with the EL element. The gate line of TFT2 is connected to the drain of TFT1. The storage capacitor is in series with TFT1. The anode of the EL element is connected to the drain of TFT2.

The construction of the TFT-EL of FIG. 2 is shown in cross-sectional view in FIGS. 3–9. The cross-sectional views shown in FIGS. 3–8 are taken along section line A-A' in FIG. 2. The cross-sectional view in FIG. 9 is taken along line B-B' in FIG. 2.

In the first processing step, a polysilicon layer is deposited over a transparent, insulating substrate 41 and the polysilicon layer is patterned into an island 48 (see FIG. 4) by photolithography. The substrate may be crystalline material such as quartz, but preferably is a less expensive material such as low temperature glass. When a glass substrate is utilized, it is preferable that the entire fabrication of the TFT-EL be carried out at low processing temperatures to prevent melting or warping of the glass and to prevent out-diffusion of dopants into the active region. Thus, for glass substrates, all fabrication steps should be conducted below 1000° C. and preferably below 600° C.

Next, an insulating gate material 42 is deposited over the polysilicon island and over the surface of the insulating substrate. Insulating material is preferably silicon dioxide that is deposited by a chemical vapor deposition (CVD) technique such as plasma enhanced CVD (PECVD) or low pressure CVD (LPCVD). Preferably, the gate oxide insulating layer is about 1000 Å in thickness.

In the next step, a layer of silicon 44 is deposited over the gate insulator layer and patterned by photolithography over the polysilicon island such that after ion implantation, source and drain regions are formed in the polysilicon island. The gate electrode material is preferably polysilicon formed from amorphous silicon. Ion implantation is conducted with N-type dopants, preferably arsenic. The polysilicon gate electrode also serves as the bottom electrode of the capacitor (see FIG. 9).

In a preferred embodiment of the present invention, the thin film transistors do not utilize a double gate structure. Thus manufacturing is made less complex and less expensive.

A gate bus 46 is applied and patterned on the insulating layer. The gate bus is preferably a metal silicide such as tungsten silicide (WSi_2).

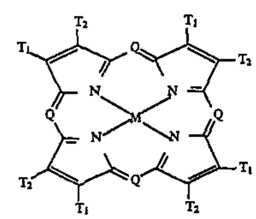
In the next step, an insulating layer, preferably silicon dioxide, 52 is applied over the entire surface of the device.

Contact holes 54 and 56 are cut in the second insulating layer (see FIG. 5) and electrode materials are applied to form contacts with the thin-film-transistors (see FIGS. 6 and 7). The electrode material 62 attached to the source region of TFT2 also forms the top electrode of the capacitor (see FIG. 9). A source bus and ground bus are also formed over the second insulating layer (see FIG. 2). In contact with the drain region of TFT2 is a transparent electrode material 72, preferably ITO, which serves as the anode for the organic electroluminescent material.

In the next step, a passivating layer 74 of an insulating material, preferably silicon dioxide, is deposited over the surface of the device. The passivation layer is etched from the ITO anode leaving a tapered edge 76 which serves to improve the adhesion of the subsequently applied organic electroluminescent layer. A tapered edge is necessary to produce reliable devices because the present invention utilizes relatively thin organic EL layers, typically 150 to 200 nm thick. The passivation layer is typically about 0.5 to about 1 micron thick. Thus, if the edge of the passivation layer forms a perpendicular or sharp angle with respect to the anode layer, defects are likely to occur due to discontinuities in the organic EL layer. To prevent defects the passivation layer should have a tapered edge. Preferably the passivation layer is tapered at an angle of 10 to 30 degrees with respect to the anode layer.

The organic electroluminescent layer 82 is then deposited over the passivation layer and the EL anode layer. The materials of the organic EL devices of this invention can take any of the forms of conventional organic EL devices, such as those of Scozzafava EPA 349,265 (1990); Tang U.S. Pat. No. 4,356,429; VanSlyke et at. U.S. Pat. No. 4,539,507; VanSlyke et at. U.S. Pat. No. 4,720,432; Tang et al. U.S. Pat. No. 4,769,292; Tang et al. U.S. Pat. No. 4,885,211; Perry et al. U.S. Pat. No. 4,950,950; Littman et al. U.S. Pat. No. 5,059,861; VanSlyke U.S. Pat. No. 5,047,687; Scozzafava et al. U.S. Pat. No. 5,073,446; VanSlyke et al. U.S. Pat. No. 5,059,862; VanSlyke et al. U.S. Pat. No. 5,061,617; VanSlyke U.S. Pat. No. 5,151,629; Tang et al. U.S. Pat. No. 5,294,869; and Tang et al. U.S. Pat. No. 5,294,870, the disclosures of which are incorporated by reference. The EL layer is comprised of an organic hole injecting and transporting zone in contact with the anode, and an electron injecting and transporting zone forming a junction with the organic hole injecting and transporting zone. The hole injecting and transporting zone can be formed of a single material or multiple materials, and comprises a hole injecting layer in contact with the anode and a contiguous hole transporting layer interposed between the hole injecting layer and the electron injecting and transporting zone. Similarly, the electron injecting and transporting zone can be formed of a single material or multiple materials, and comprises an electron injecting layer in contact with the cathode and a contiguous electron transporting layer that is interposed between the electron injecting layer and the hole injecting and transporting zone. Recombination of the holes and electrons, and luminescence, occurs within the electron injecting and transporting zone adjacent the junction of the electron injecting and transporting zone and the hole injecting and transporting zone. The components making up the organic EL layer are typically deposited by vapor deposition, but may also be deposited by other conventional techniques.

In a preferred embodiment the organic material comprising the hole injecting layer has the general formula:



wherein:

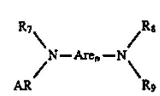
Q is N or C(R)

M is a metal, metal oxide or metal halide

R is hydrogen, alkyl, aralkyl, aryl or alkaryl, and

T, and T_2 represent hydrogen or together complete an unsaturated six membered ring that can include substituents such as alkyl or halogen. Prefred alkyl moieties contain from about 1 to 6 carbon atoms while phenyl constitutes a preferred aryl moiety.

In a preferred embodiment the hole transporting layer is an aromatic tertiary amine. A preferred subclass of aromatic tertiary amines include tetraaryldiamines having the formula:



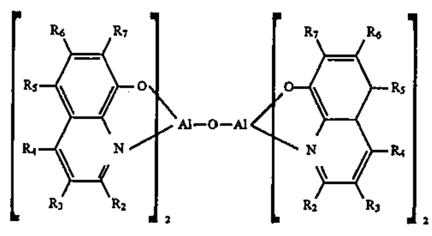
wherein

Are is an arylene-group,

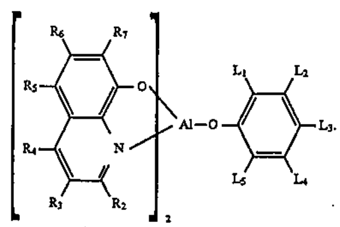
n is an integer from 1 to 4, and

Ar, R_7, R_8 and R_9 are independently selected aryl groups.

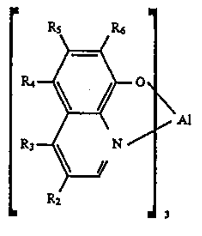
In a preferred embodiment, the luminescent, electron injecting and transporting zone contains a metal oxinoid compound. A preferred example of a metal oxinoid compound has the general formula:



wherein R_2–R_7 represent substitutional possibilities. In another preferred embodiment, the metal oxinoid compound has the formula:



wherein R_2–R_7 are as defined above and L_1–L_5 collectively contain twelve or fewer carbon atoms and each independently represent hydrogen or hydrocarbon groups of from 1 to 12 carbon atoms, provided that L_1 and L_2 together or L_2 and L_3 together can form a fused benzo ring. In another preferred embodiment, the metal oxinoid compound has the formula:



wherein R_2–R_6 represent hydrogen or other substitutional possibilities.

The foregoing examples merely represent some preferred organic materials used in the electroluminescent layer. They are not intended to limit the scope of the invention, which is directed to organic electroluminescent layers generally. As can be seen from the foregoing examples, the organic EL material includes coordination compounds having organic ligands. The TFT-EL device of the present invention does not include purely inorganic materials such as ZnS.

In the next processing step, the EL cathode 84 is deposited over the surface of the device. The EL cathode may be any electronically conducting material, however it is preferable that the EL cathode be made of a material having a work function of less than 4 eV (see Tang et al. U.S. Pat. No. 4,885,211). Low work function metals are preferred for the cathode since they readily release electrons into the electron transporting layer. The lowest work function metals are the

alkali metals; however, their instability in air render their use impractical in some situations. The cathode material is typically deposited by physical vapor deposition, but other suitable deposition techniques are applicable. A particularly desirable material for the EL cathode has been found to be a 10:1 (atomic ratio) magnesium:silver alloy. Preferably, the cathode is applied as a continuous layer over the entire surface of the display panel. In another embodiment, the EL cathode is a bilayer composed of a lower layer of a low work function metal adjacent to the organic electron injecting and transporting zone and, overlying the low work function metal, a protecting layer that protects the low work function metal from oxygen and humidity. Optionally, a passivation layer may be applied over the EL cathode layer.

Typically, the anode material is transparent and the cathode material opaque so that light is transmitted through the anode material. However, in an alternative embodiment, light is emitted through the cathode rather than the anode. In this case the cathode must be light transmissive and the anode may be opaque. A practical balance light transmission and technical conductance is typically in the thickness range of 5–25 nm.

A preferred method of making a thin-film-transistor according to the present invention is described below. In a first step, an amorphous silicon film of 2000±20 Å thickness is deposited at 550° C. in an LPCVD system with silane as the reactant gas at a process pressure of 1023 mTorr. This is followed by a low temperature anneal at 550° C. for 72 hours in vacuum to crystallize the amorphous silicon film into a polycrystalline film. Then a polysilicon island is formed by etching with a mixture of SF_6 and Freon 12 in a plasma reactor. Onto the polysilicon island active layer is deposited a 1000±20 Å PECVD SiO_2 gate dielectric layer. The gate dielectric layer is deposited from a 5/4 ratio of N_2O/SiH_4 in a plasma reactor at a pressure of 0.8 Torr with a power level of 200 W and a frequency of 450 KHz at 350° C. for 18 minutes.

In the next step an amorphous silicon layer is deposited over the PECVD gate insulating layer and converted to polycrystalline silicon using the same conditions as described above for the first step. A photoresist is applied and the second polysilicon layer is etched to form a self-aligned structure for the subsequent ion implantation step. The second polysilicon layer is preferably about 3000 Å thick.

Ion implantation is conducted by doping with arsenic at 120 KeV at a dose of $2\times10^{15}/cm^2$ to simultaneously dope the source, drain and gate regions. Dopant activation is carried out at 600° C. for two hours in a nitrogen atmosphere.

In the next step, a 5000 Å thick silicon dioxide layer is deposited by conventional low temperature methods. Aluminum contacts are formed by a physical vapor deposition and sintered in forming gas (10% H_2, 90% N_2) for thirty minutes at 400° C.

Finally, hydrogen passivation of the thin-film-transistor is carried out in an electron cyclotron resonance reactor (ECR). ECR hydrogen plasma exposure is conducted at a pressure of 1.2×10^{-4} Torr with a microwave power level of 900 W and a frequency of 3.5 GHz. Hydrogen passivation is performed for fifteen minutes at a substrate temperature of 300° C. This procedure results in a thin-film-transistor device having a low threshold voltage, a high effective carrier mobility and an excellent on/off ratio.

As an example of characteristics of the present invention, consider the drive requirements for the following TFT-EL panel:

Number of rows	=	1000
Number of columns	=	1000
Pixel dimension	=	200 μm × 200 μm
EL fill-factor	=	50%
frame time	=	17 ms
row dwell time	=	17 μs
Avg brightness	=	20 fL
EL pixel current	=	0.8 μA
Duty cycle	=	100%
EL power source	=	10 v rms

These drive requirements are met by the following specifications for the TFTs and the storage capacitor:

TFT1		
Gate voltage	=	10 V
Source voltage	=	10 V
On-current	=	2 μA
Off-current	=	10^{-11} A TFT2
Gate voltage	=	10 V
Source voltage	=	5 V
On-current	=	2 × EL pixel current
	=	1.6 μA
Off-current	=	1 nA
Storage capacitor:		
Size	=	1 pf

The on-current requirement for TFT1 is such that it is large enough to charge up the storage capacitor during the row dwell time (17 μs) to an adequate voltage (10 V) in order to turn on the TFT2. The off-current requirement for TFT1 is such that it is small enough that the voltage drop on the capacitor (and TFT2 gate) during the frame period (17 ms) is less than 2%.

The on-current requirement for TFT2 is (designed to be) about 2 times the EL pixel current, 1.6 μA. This factor of two allows for adequate drive current to compensate for the gradual degradation of the organic EL element with operation. The off-current of TFT2 affects the contrast of the panel. An off-current of 1 nA should provide an on/off contrast ratio greater than 500 between a lit and an unlit EL element. The actual contrast ratio of the panel may be lower, depending on the ambient lighting factor.

For a full page panel of 400 cm^2 the power required by the EL elements alone is about 4 watts.

$$\begin{aligned} \text{Power} &= 400\ \text{cm}^2 \times 10\ \text{v} \times 0.001\ \text{A/cm}^2 \\ &= 4\ \text{watts} \end{aligned}$$

This power consumption excludes the power consumed by the TFTs. Since TFT2 is in series with the EL element, any source-drain voltage drop across TFT2 will result in substantial power loss in the TFT2. Assuming a source-drain voltage of 5 volts, the total power loss on TFT2 is 2 watts. The power consumption for TFT1 is estimated to be no greater than 1 watt for the 1000×1000 panel. The power needed for the row (gate) drivers is negligible, on the order of a few tens of milliwatts, and the power for the column (source) drivers is on the order of 0.5 watt (see S. Morozumi, Advances in Electronics and Electron Physics, edited by P. W. Hawkes, Vol. 77, Academic Press, 1990). Thus, the total power consumption for a full page TFT-EL panel is about 7 watts. Realistically, the average power consumption would be much less since the EL screen is not 100% on in average usage.

The TFT-EL panel of the present invention has two important advantages in terms of power requirements over

TFT-LCD panels. First, the TFT-EL power need is relatively independent of whether the panel is monochrome or multicolor, provided that the color materials have a similar luminescent efficiency. In contrast, the TFT-LCD colored panel requires a much higher power than the monochrome panel because the transmission factor is greatly reduced in the colored panel by the color filter arrays. Second, the LCD backlight has to stay on regardless of the screen usage factor. In contrast, the TFT-EL power consumption is highly dependent on this usage factor. The average power consumption is much less since less than 100% of the EL screen is emitting at any given time in typical applications.

The invention has been described in detail with particular reference to preferred embodiments thereof, but it will be understood that variations and modifications can be effected within the spirit and scope of the invention.

Parts List	
42	gate material
44	silicon layer
46	gate bus
52	insulating layer
54	contact hole
56	contact hole
62	electrode material
72	electrode material
74	passivating layer
76	tapered edge
82	EL layer
84	EL cathode

We claim:

1. An electroluminescent flat panel display comprising: a substrate having top and bottom surfaces; and having disposed on said substrate a plurality of pixels, each of said pixels comprising:

a) a first thin-film-transistor disposed over the top surface of said substrate, wherein said first thin-film-transistor comprises a source electrode, a drain electrode, a gate dielectric, and a gate electrode; and wherein said gate electrode comprises a portion of a gate bus;

b) a second thin-film-transistor disposed over the top surface of said substrate; wherein said second thin-film-transistor comprises a source electrode, a drain electrode, a gate dielectric, and a gate electrode; wherein said gate electrode is electrically connected to said drain electrode of said first thin-film-transistor;

c) a capacitor disposed over the top surface of said substrate; said capacitor comprising top and bottom electrodes;

d) a display anode layer electrically connected to said drain electrode of said second thin-film-transistor;

e) a dielectric passivation layer overlying said first and second thin-film-transistors and said capacitor; said dielectric passivation layer having an opening over said anode layer; and further wherein said passivation layer has a tapered edge at said opening such that the bottom edge of said passivation layer extends further over said anode layer than does the top edge of said passivation layer wherein said tapered edge is tapered at an angle of 10° to 30° with respect to the surface of said anode layer;

f) an organic electroluminescent layer positioned directly on the top surface of said anode layer; wherein said organic electroluminescent layer is insulated from said first and second thin-film-transistors, and said capacitor, by said passivation layer; and

g) a cathode layer positioned directly on the top surface of said organic electroluminescent layer;

and further comprising a plurality of column leads connected to the source electrode of said first thin-film-transistor on each pixel and a plurality of row leads connected to the gate electrode of said first thin-film transistor on each pixel and a plurality of ground leads connected to said capacitor of each pixel.

2. The flat panel display of claim 1 wherein said cathode layer is a contiguous sheet overlying said plurality of pixels.

3. The flat panel display of claim 1 wherein said cathode layer consists of a material having a work function of less than 4 eV.

4. The flat panel display of claim 1 wherein said organic electroluminescent layer is a contiguous sheet overlying said plurality of pixels.

5. The flat panel display of claim 1 wherein said substrate is a glass material forming the front screen of said flat panel display.

6. The flat panel display of claim 5 wherein said glass material is a silica-based low temperature glass.

7. The flat panel display of claim 2 wherein said substrate is a low temperature glass.

8. The flat panel display of claim 7 wherein said plurality of pixels are powered by a potential of less than 10 volts.

9. The flat panel display of claim 8 wherein said potential is about 5 volts, and the current density is about 1 mA/cm^2.

10. The flat panel display of claim 1 wherein said capacitor has a storage capacity of about 1 pf.

11. The flat panel display of claim 1 having 1000 rows and 1000 columns, and wherein said each of said pixels is about 0.2 mm×0.2 mm and having a time-averaged brightness of about 20 fL and a power consumption of less than about 7 watts during operation.

12. The flat panel display of claim 2 wherein said top electrode of said capacitor is electrically connected to said source electrode of said second thin-film-transistor, and wherein said bottom electrode of said capacitor comprises a polysilicon layer; and further wherein said gate electrode comprises a polysilicon layer wherein said bottom electrode and said gate electrode are parts of the same polysilicon layer.

* * * * *

US005427858A

United States Patent [19]

Nakamura et al.

[11] **Patent Number: 5,427,858**

[45] **Date of Patent: Jun. 27, 1995**

[54] **ORGANIC ELECTROLUMINESCENCE DEVICE WITH A FLUORINE POLYMER LAYER**

[75] Inventors: **Hiroaki Nakamura; Masahide Matsuura; Tadashi Kusumoto**, all of Sodegaura, Japan

[73] Assignee: **Idemitsu Kosan Company Limited**, Tokyo, Japan

[21] Appl. No.: **877,175**

[22] PCT Filed: **Oct. 23, 1991**

[86] PCT No.: **PCT/JP91/01448**

§ 371 Date: **Jun. 29, 1992**

§ 102(e) Date: **Jun. 29, 1992**

[87] PCT Pub. No.: **WO92/10073**

PCT Pub. Date: **Jun. 11, 1992**

[30] **Foreign Application Priority Data**

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Dec. 28, 1990	[JP]	Japan	2-409017
May 31, 1991	[JP]	Japan	3-129852

[51] **Int. Cl.**^{6} **B32B 9/00**

[52] **U.S. Cl.** **428/421**; 313/512; 428/422; 428/917; 428/209

[58] **Field of Search** 313/504, 505, 506, 511, 313/512, 503; 428/411.1, 209, 422, 917, 690, 421, 422; 118/716

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Primary Examiner—Patrick J. Ryan
Assistant Examiner—Patrick Jewik
Attorney, Agent, or Firm—Frishauf, Holtz, Goodman & Woodward

[57] **ABSTRACT**

Disclosed is a novel organic electroluminescent device which can be used as a pixel for graphic display, a pixel for a television image display device or a surface light source, and this novel organic electroluminescent device overcomes the conventional problem of an organic electroluminescent device having a laminated structure in which at least a light-emitting layer formed of a luminescent organic solid is placed between two mutually opposing electrodes, i.e., a short life, by having a film of an electrically insulating polymer compound as a protection layer provided on the outer surface of the above laminated structure. In producing the novel organic electroluminescent device disclosed herein, particularly preferably, the above laminated structure is prepared in a continuous vacuum environment as a series at least from the formation of the light-emitting layer to the formation of the electrode on the light-emitting layer directly or through the electron-injecting layer or the hole-injecting layer as a series, and then the above protection layer is formed in a vacuum environment continued from the above vacuum environment.

15 Claims, 7 Drawing Sheets

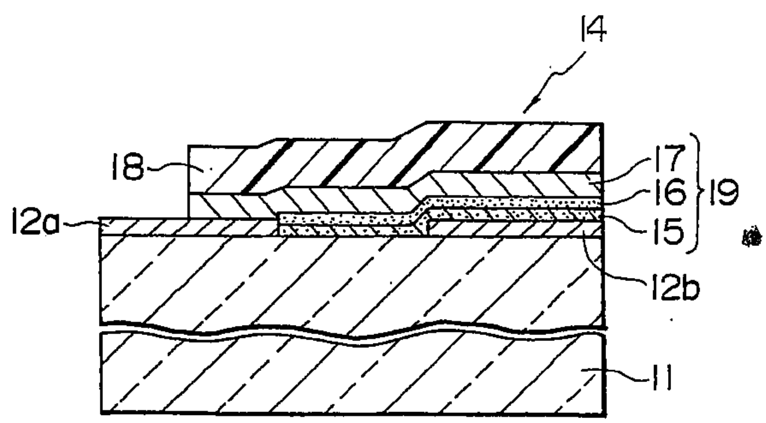


FIG. 1

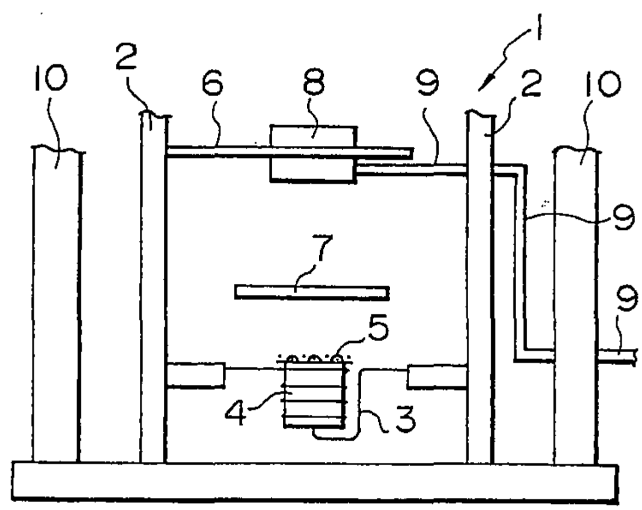


FIG. 2

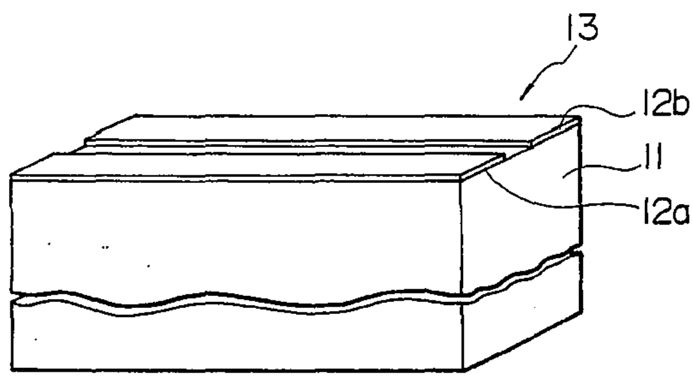


FIG. 3

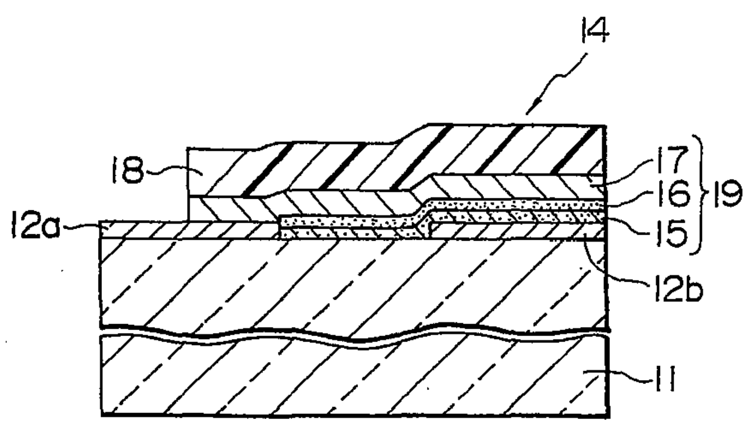


FIG. 4

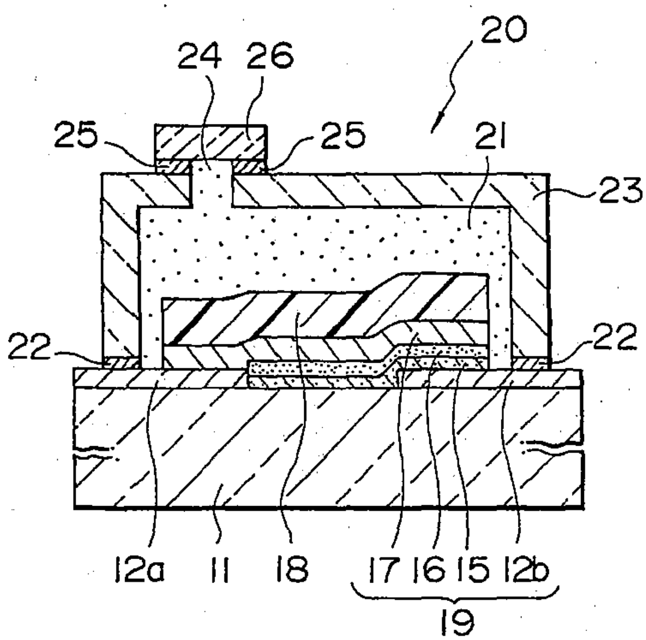


FIG. 5

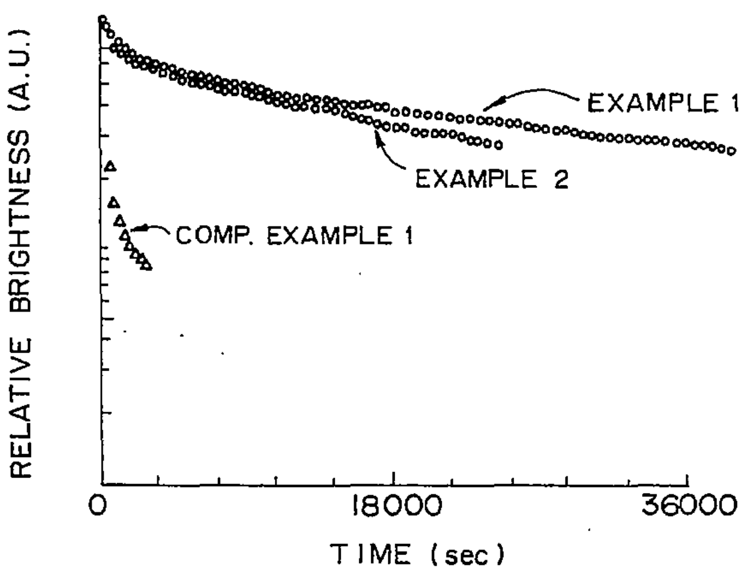

RELATIVE BRIGHTNESS (A.U.)
EXAMPLE 1
EXAMPLE 2
COMP. EXAMPLE 1
0
18000
36000
TIME (sec)

FIG. 6

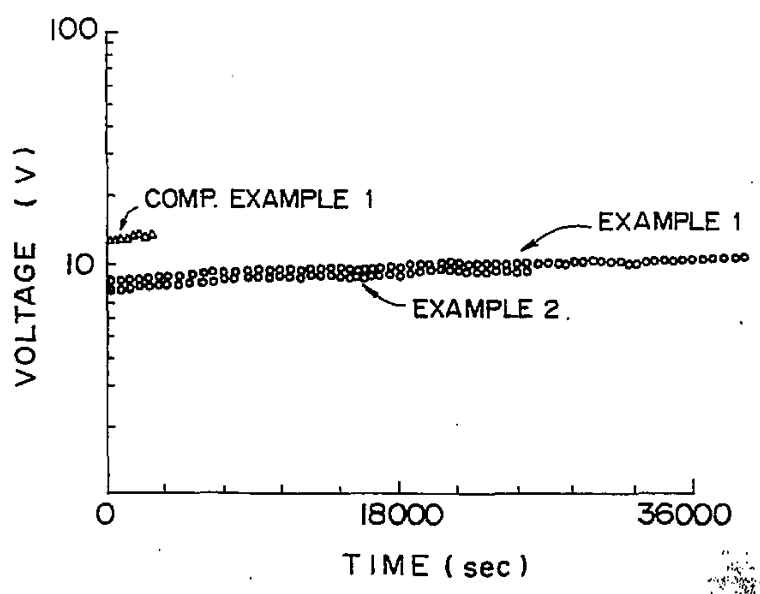

100
10
VOLTAGE (V)
COMP. EXAMPLE 1
EXAMPLE 1
EXAMPLE 2
0
18000
36000
TIME (sec)

FIG. 7

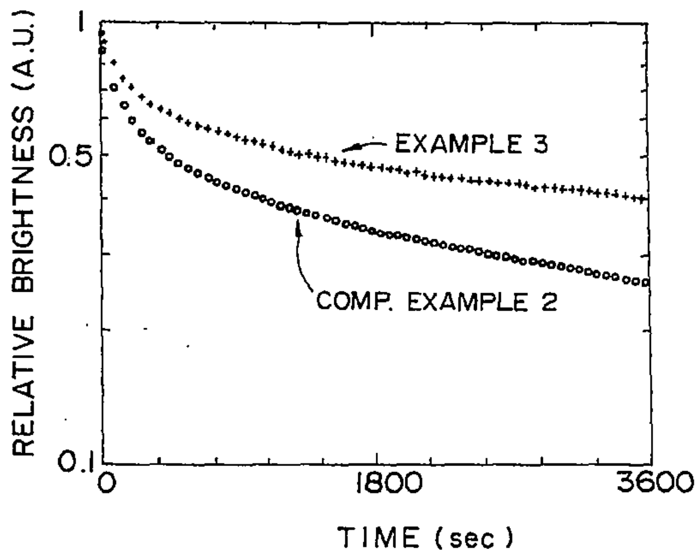

RELATIVE BRIGHTNESS (A.U.)
1
0.5
0.1
0
1800
3600
TIME (sec)
EXAMPLE 3
COMP. EXAMPLE 2

FIG. 8

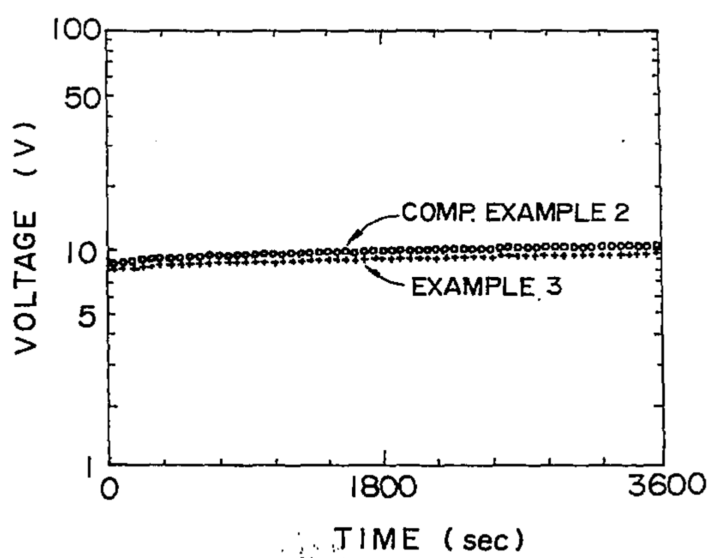

VOLTAGE (V)
100
50
10
5
1
0
1800
3600
TIME (sec)
COMP. EXAMPLE 2
EXAMPLE 3

FIG. 9

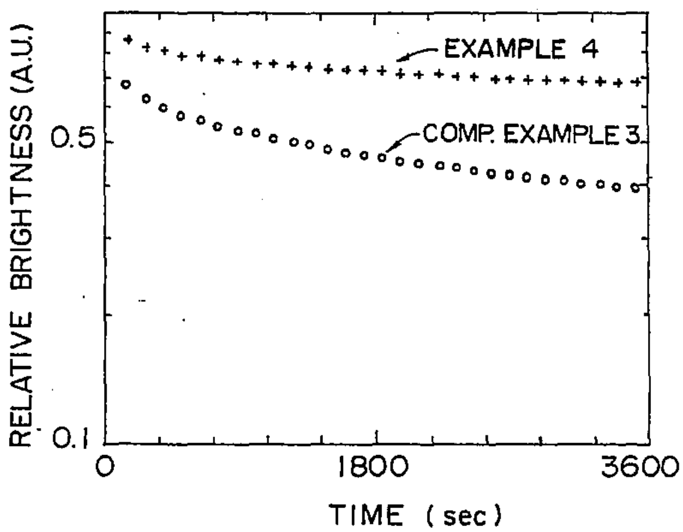

RELATIVE BRIGHTNESS (A.U.)
0.5
0.1
0
1800
3600
TIME (sec)
EXAMPLE 4
COMP. EXAMPLE 3

FIG. 10

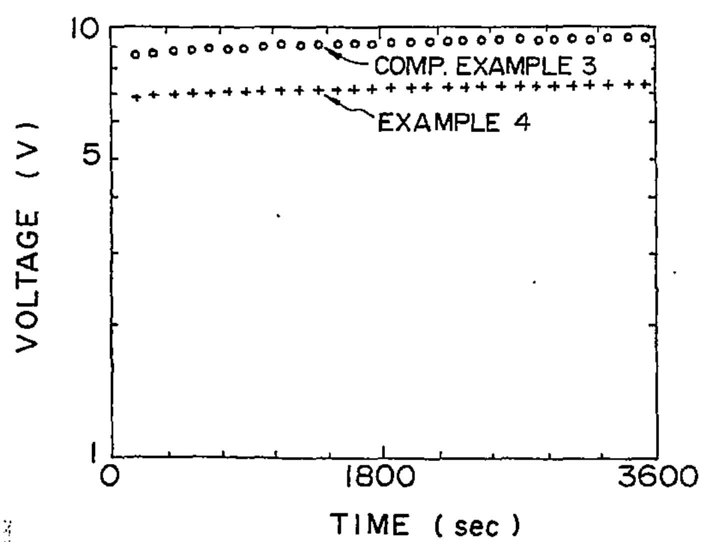
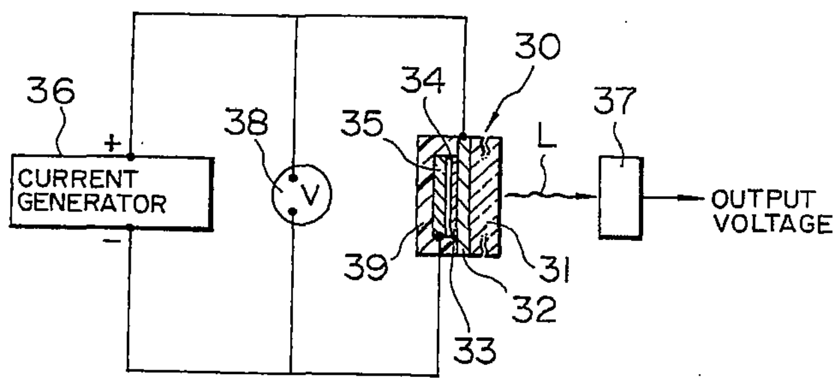

VOLTAGE (V)
10
5
1
0
1800
3600
TIME (sec)
COMP. EXAMPLE 3
EXAMPLE 4

FIG. 11



36
CURRENT GENERATOR
+
−
38
V
35
34
30
L
37
OUTPUT VOLTAGE
39
31
32
33

ORGANIC ELECTROLUMINESCENCE DEVICE WITH A FLUORINE POLYMER LAYER

TECHNICAL FIELD

The present invention relates to an electroluminescence device (to be referred to as "EL device" hereinafter) such as an electroluminescence element and an electroluminescence lamp and it particularly relates to an organic EL device.

TECHNICAL BACKGROUND

An EL device, which can be largely classified into an inorganic EL device and an organic EL device, has high visibility due to its self-emission, and is excellent in impact resistance and easy to handle since it is a completely solid device. For these reasons, research, development and practical utilization thereof as a pixel for graphic display, a pixel for a television image display device or a surface light source are under way.

An organic EL device has a laminated structure in which a light-emitting layer formed of a fluorescent organic solid such as anthracene, etc., and a hole-injecting layer formed of triphenylamine, etc., are provided, a light-emitting layer and an electron-injecting layer formed of a perylene derivative, etc., are provided, or a hole-injecting layer, a light-emitting layer and an electron-injecting layer are provided, between two electrodes (the electrode on the light-emitting side is a transparent electrode). This laminated structure is generally formed on a substrate.

Such an organic EL device utilizes light emission caused when electrons injected into a light-emitting layer and holes are recombined. Therefore, an organic EL device has advantages that it can be actuated at a low voltage, e.g., 4.5 V and response is fast by decreasing the thickness of the light-emitting layer, and it also has advantages that it gives a high-brightness EL device since the brightness is in proportion to an injected electric current. Further, by changing the kinds of fluorescent organic solids of which the light-emitting layer is to be formed, light emission is obtained in all the colors in the visible regions of blue, green, yellow and red. Since an organic EL device has these advantages, particularly an advantage that it can be actuated at a low voltage, studies thereof for practical use are under way at present.

Meanwhile, a fluorescent organic solid used as a material for forming the light-emitting layer of an organic EL device is susceptible to water, oxygen, etc. Further, an electrode (to be sometimes referred to as "opposite electrode" hereinafter), which is formed on a light-emitting layer directly or through a hole-injecting layer or an electron-injecting layer, is liable to deteriorate in properties due to oxidation. As a result, when a conventional EL device is actuated in the atmosphere, its life as a device is short. Therefore, in order to obtain a practically usable organic EL device, it is required to increase the life thereof by protecting the device so that water, oxygen, etc., do not infiltrate the light-emitting layer and that the opposite electrode does not undergo oxidation.

However, no effective protection method has been developed for the organic EL device. For example, when a method of protecting (sealing) an inorganic EL device, i.e., a method in which a back-surface glass plate is provided outside a back electrode (opposite electrode) and a silicone oil is placed between the back

electrode and the back-surface glass and sealed, is applied to the organic EL device, the silicone oil infiltrates the light-emitting layer through the opposite electrode or through the opposite electrode and the hole-injecting layer or the electron-injecting layer, and the light-emitting layer is altered due to the silicone oil. Therefore, the organic EL device immensely deteriorates in light emission properties, or no longer emits light. When a resin coating layer generally used for mechanical protection (the solvent for the coating solution is a cyclic ether-containing solvent such as tetrahydrofuran, etc., a halogen-containing solvent such as chloroform, dichloromethane, etc., or an aromatic hydrocarbon-based solvent such as benzene, toluene, xylene, etc.) is applied to tile protection of the organic EL device, the solvent used in the resin coating solution infiltrates the light-emitting layer like the above silicone oil. Therefore, the organic EL device greatly deteriorates in light emission properties, or does not at all emit light.

It is therefore an object of the present invention to provide an organic EL device which can be produced so that it structurally has a long life.

DISCLOSURE OF THE INVENTION

The organic EL device of the present invention which achieves the above object has a characteristic feature in that the organic EL device having a laminated structure, in which at least a light-emitting layer formed of a luminescent organic solid is placed between two mutually opposing electrodes, has a film of an electrically insulating polymer compound as a protection layer on an outer surface of the above laminated structure.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a schematic view showing the cross section of a vacuum vapor deposition apparatus used in Examples for the production of the organic EL device of the present invention. FIG. 2 is a perspective view schematically showing a transparent substrate used in Example 7. FIG. 3 is a schematic view of the cross section of the organic EL device of the present invention (in which a protection layer alone is newly formed) obtained in Example 7. FIG. 4 is a schematic view of the cross section of the organic EL device of the present invention (in which a shield layer is formed outside a protection layer) obtained in Example 7. FIG. 5 is a chart showing the measurement results of brightness of organic EL devices obtained in Example 1, Example 2 and Comparative Example 1. FIG. 6 is a chart showing the measurement results of voltages applied to organic EL devices obtained in Example 1, Example 2 and Comparative Example 1. FIG. 7 is a chart showing the measurement results of brightness of organic EL devices obtained in Example 3 and Comparative Example 2. FIG. 8 is a chart showing the measurement results of voltages applied to organic EL devices obtained in Example 3 and Comparative Example 2. FIG. 9 is a chart showing the measurement results of brightness of organic EL devices obtained in Example 4 and Comparative Example 3. FIG. 10 is a chart showing the measurement results of voltages applied to organic EL devices obtained in Example 4 and Comparative Example 3. FIG. 11 is a schematic view showing the method of brightness measurement in a life test.

PREFERRED EMBODIMENTS FOR WORKING THE INVENTION

As described above, the organic EL device of the present invention has a film of an electrically insulating polymer compound as a protection layer on the outer surface of a laminated structure in which at least a light-emitting layer formed of a luminescent organic solid is placed between two mutually opposing electrodes. The constitution of the above laminated structure includes the following ① to ④.

① electrode (cathode)/light-emitting layer/hole-injecting layer/electrode (anode)

② electrode (anode)/light-emitting layer/electron-injecting layer/electrode (cathode)

③ electrode (anode)/hole-injecting layer/light-emitting layer/electron-injecting layer/electrode (cathode)

④ electrode (anode or cathode)/light-emitting layer-/electrode (cathode or anode).

Any constitution may be used. In general, the laminated structure is formed on a substrate. The size, form, material, etc., of each of the substrate and the laminated structure are properly selected depending upon use of the intended organic EL device such as a surface light source, a pixel For graphic display, a pixel for a television image display device, etc. In addition, each of the above hole-injecting layer and the above electron-injecting layer refers to a layer having any one of charge injection properties, charge transport properties and charge barrier properties, and may have any one of a single-layered structure and a multi-layered structure. The material for these layers may be any one of an organic material and an inorganic material.

The organic EL device of the present invention has a film formed of an electrically insulating polymer compound as a protection layer on the outer surface of the above laminated structure. The protection layer may be formed at least on a main surface of the opposite electrode. However, the protection layer is particularly preferably formed on the entire outer surface of the laminated structure. Further, when the laminated structure has a layer structure in which the opposite electrode is formed on part of a main surface of one of the light-emitting layer, the hole-injecting layer and the electron-injecting layer, it is preferred to form a protection layer at least on that portion of the main surface of a layer underlying the opposite electrode where the opposite electrode is not formed and on the main surface of the opposite electrode.

The method for forming the protection layer of an electrically insulating polymer compound includes:

(1) a physical vapor deposition method (PVD method),
(2) a chemical vapor deposition method (CVD method),
(3) a casting method, and
(4) a spin coating method.

These methods are respectively detailed hereinafter.

(1) PVD method

(i) Kind, film-forming conditions, etc., of the PVD method

The PVD method includes a vacuum vapor deposition method (including a vapor deposition polymerization method), a sputtering method, etc. The vacuum vapor deposition method and the sputtering method can be sub-classified as below.

Vacuum vapor deposition method

Resistance heating method, electron beam heating method, high-frequency induction heating method, reactive vapor deposition method, molecular beam epitaxy method, hot wall vapor deposition method, ion plating method, ionized cluster beam method, vapor deposition polymerization method, etc.

Sputtering method

Diode sputtering method, diode magnetron sputtering method, triode and tetraode plasma sputtering methods, reactive sputtering method, ionized beam sputtering method, a method using a combination of these.

Any one of these methods can be employed. Concerning the PVD method, a vacuum vapor deposition method is particularly preferred.

The film forming conditions differ depending upon raw materials and the kind of the PVD method. For example, when a vacuum vapor deposition method (resistance heating method, electron beam heating method and high-frequency induction heating method) is used, preferred are conditions where the pressure before the vapor deposition is generally set at not more than 1×10^{-2} Pa, preferably not more than 6×10^{-3} Pa, the temperature for heating a deposition source is generally set at not more than 700° C., preferably not more than 600° C., the substrate temperature is generally set at not more than 200° C., preferably not more than 100° C., and the deposition rate is generally set at not more than 50 nm/second, preferably not more than 3 nm/second.

(ii) Kinds of the polymer compound used as a vapor deposition source.

The following polymer compounds (A) to (C) may be used as a deposition source.

(A) Fluorine-free polymer compounds such as polyethylene, polypropylene, polystyrene, polymethyl methacrylate, polyimide (obtained by depositing two monomers on a substrate to polymerize them, see ULVAC Technical Journal, 1988, 30, 22), polyurea (obtained by depositing two monomers on a substrate to polymerize them, see ULVAC Technical Journal, 1988, 30, 22),etc.

(B) Polytetrafluoroethylene, polychlorotrifluoroethylene, polydichlorodifluoroethylene, chlorotrifluoroethylene, a copolymer of chlorotrifluoroethylene and dichlorodifluoroethylene.

(C) Fluorine-containing copolymers having a cyclic structure in the main copolymerized chain.

(C-1) Fluorine-containing polymer compound disclosed in JP,A 63-18964, fluorine-containing polymer compound disclosed in JP,A 63-22206, fluorine-containing polymer compound disclosed in JP,A 63-238115.

(C-2) Fluorine-containing polymer compound disclosed in JP,A 3-129852.

The form of the polymer compound when it is used as a deposition source is not specially limited. The form may be powdery, particulate, bulk-like, disk-like or pellets-like. The form is properly selected depending upon the kind of the PVD method employed for forming the film.

When the polymer compound (B), (C-1) or (C-2) out of the above polymer compounds is used as a deposition source, there can be obtained, by a PVD method, a deposited film (protection layer) which is formed of the same polymer compound as the polymer compound used as a deposition source and is pin-hole free. Further, the decrease in the electric resistivity, breakdown strength and moisture resistance, entailed when the film thickness is decreased, is small. Therefore, the protection layer is excellent in the electric resistivity, breakdown strength and moisture resistance. Further, since the protection layer is transparent, it has no bad effect on the color of light emitted from the light-emitting layer.

As described above, the above polymer compounds (B), (C-1) and (C-2) are particularly superior as a material for the protection layer. Therefore, these polymer compounds are further detailed.

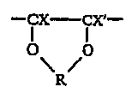
Polymer compound (B)

The molecular weight is not less than 400, preferably from 1,000 to 600,000. When the molecular weight is less than 400, the resultant thin film has low moisture resistance. The molecular weight is particularly preferably 10,000 to 500,000. When a copolymer obtained from chlorotrifluoroethylene and dichlorodifluoroethylene is used, it does not matter what the copolymerization amount ratio in the copolymer is.

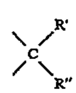
As a deposition source, particularly preferred is a chlorotrifluoroethylene homopolymer (polychlorotrifluoroethylene), and specific examples thereof include Neoflon CTFE (trade name) supplied by Daikin Industries, Ltd. and Kel-F CTFE (trade name) supplied by 3M Co., Ltd.

Polymer compound (C-1)

This polymer compound is a copolymer obtained by copolymerizing a monomer mixture containing tetrafluoroethylene and at least one cyclic ether compound containing a carbon-carbon unsaturated bond, and its copolymer main chain has a cyclic structure represented by the following formula.

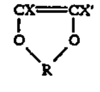


{wherein each of X and X' is F, Cl or H, X and X' may be the same as, or different From, each other, and R is —CF═CF— or has the following formula,



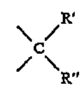
[each of R' and R'' is F, Cl, —COF, a —COO-alkyl group, an alkyl group, a perfluorinated alkyl group or a hydrogen-substituted perfluorinated alkyl group ("alkyl group" is an alkyl group having 1 to 6 carbon atoms)]}.

Particularly preferred is a copolymer obtained by copolymerizing tetrafluoroethylene and a cyclic ether compound containing a carbon-carbon unsaturated bond, at least represented by the following formula (I),



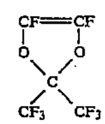
(I)

{wherein each of X and X' is F, Cl or H, X and X' may be the same as, or different from, each other, and R is —CF═CF— or has the Following formula,

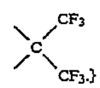


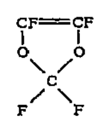
[each of R' and R'' is F, Cl, —COF, a —COO-alkyl group, an alkyl group, a perfluorinated alkyl group or a hydrogen-substituted perfluorinated alkyl group ("alkyl group" is an alkyl group having 1 to 6 carbon atoms)]}.

Specific examples of the cyclic ether compound containing a carbon-carbon unsaturated bond, represented by the formula (I), are particularly preferably as follows.

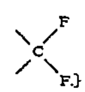


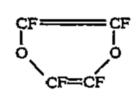
{a compound of the above formula (I) in which both X and X' are F, and R has the formula of





{a compound of the above formula (I) in which both X and X' are F, and R has the formula of





{a compound of the above formula (I) in which both X and X' are F, and R is —CF═CF—.}

In the protection layer, the content of the cyclic ether compound containing a carbon-carbon unsaturated bond, represented by the formula (I), based on the total amount of the tetrafluoroethylene and this compound is preferably 0.01 to 99% by weight, particularly preferably 11 to 80% by weight. The copolymer having such a composition generally has a glass transition point of not less than 50° C.

As a comonomer for the copolymer, a comonomer from the following ① to ③ may be used together with the cyclic ether compound containing a carbon-carbon unsaturated bond, represented by the formula (I).

① Olefin comonomers such as ethylene, 1-butene, isobutylene, trifluoropropene, trifluoroethylene, chlorotrifluoroethylene, etc.

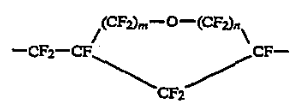
② Vinyl comonomers such as vinyl fluoride, vinylidene fluoride, etc.

③ Perfluoro comonomers such as perfluoropropene, perfluoro(alkyl vinyl ether), methyl 3-[1-[difluoro-[(trifluoroethenyl)oxy]methyl]-1,2,2,2-tetrafluoroethoxy]-2,2,3,3-tetrafluoropropanoate, 3-[1-[difluoro[(trifluoroethenyl)oxy]methyl]-1,2,2,2-tetrafluoroethoxy]-2,2,3,3-tetrafluoropropionate, 2-[1-[difluoro-[(trifluoroethenyl)oxy]methyl]-1,2,2,2-tetrafluoroethoxy]-1,1,2,2-tetrafluoroethanesulfonyl-fluoride, etc.

The content of the comonomer from the above ① to ③ based on the total amount of the tetrafluoroethylene and the compound (comonomer) of the formula (I) is preferably 0.005 to 30% by weight, particularly preferably 1 to 15% by weight. When the comonomer from the above ① to ③ is used in combination with the comonomer of the formula (I), desirably, the amount of the comonomer from the above ① to ③ is the smallest among the amounts of the tetrafluoroethylene, the comonomer of the formula (I) and the comonomer from the above ① to ③.

Polymer compound (C-2)

Particularly preferred is a fluorine-containing copolymer having a cyclic structure of the following formula in the main chain,



(wherein each of m and n is, independently of other, an integer of 0 to 5, and m+n is an integer of 1 to 6) which is obtained by radical-copolymerizing a perfluoroether having a double bond at each of the terminals, represented by the general formula (II),

$$CF_2{=}CF{-}(CF_2)_m{-}O{-}(CF_2)_n{-}CF{=}CF_2 \qquad (II)$$

(wherein m and n are as defined above) and a monomer radical-polymerizable with the perfluoroether of the above general formula (II).

As the perfluoroether of the above general formula (II), preferred are those of the formula (II) in which each of m and n is an integer of 0 to 3 and m+n is an integer of 1 to 4, and particularly preferred are those of the formula (II) in which each of m and n is an integer of 0 to 2 and m+n is an integer of 1 to 3. Specific examples thereof are perfluoroallylvinylether ($CF_2{=}CF{-}O{-}CF_2{-}CF{=}CF_2$), perfluorodiallyether ($CF_2{=}CF{-}CF_2{-}O{-}CF_2{-}CF{=}CF_2$), perfluorobutenylvinylether ($CF_2{=}CF{-}O{-}CF_2{-}CF_2{-}CF{=}CF_2$), perfluorobutenylallylether ($CF_2{=}CF{-}CF_2{-}O{-}CF_2{-}CF_2{-}CF{=}CF_2$), perfluorodibutenylether ($CF_2{=}CF{-}CF_2{-}CF_2{-}O{-}CF_2{-}CF_2{-}CF{=}CF_2$), etc. Of these perfluoroethers, those of the general formula (II) in which one of m and n is 0, i.e., those having one vinylether group represented by $CF_2{=}CF{-}O{-}$ are particularly preferred in view of copolymerization reactivity, ring-closing polymerizability, gelation inhibition, etc., and perfluoroallylvinylether is a particularly preferable example.

On the other hand, the monomer to be copolymerized with the perfluoroether of the above general formula (II) is not specially limited if it is a monomer having radical-polymerizability. It can be properly selected from fluorine-containing monomers, unsaturated hydrocarbon-based monomers and other monomers. These monomers may be used alone or in combination for the radical copolymerization with the perfluoroether of the above formula (II). In order to make the most of the perfluoroether, it is particularly preferred to use, as a copolymerizable monomer, a fluorine-containing monomer typified by tetrafluoroethylene, chlorotrifluoroethylene, perfluorovinylether, vinylidene fluoride, vinyl fluoride, etc.

The above perfluoroether and the above copolymerizable monomer can be radical-copolymerized by a conventional method such as bulk polymerization in which these are directly polymerized, solution polymerization in which these are dissolved in an organic solvent such as fluorinated hydrocarbon, chlorinated hydrocarbon, fluorochlorinated hydrocarbon, alcohol, hydrocarbon, etc., and polymerized in the solvent, suspension polymerization in which these are polymerized in an aqueous medium in the presence or absence of a proper organic solvent, emulsion polymerization in which these are polymerized in an aqueous medium containing an emulsifier, or other method. Although the proportion of the perfluoroether for the production of the copolymer is not specially limited, this proportion is preferably 0.1 to 99 mol. % as a material to be charged based on the above copolymerizable monomer.

The temperature and pressure during the radical copolymerization are not specially limited, and can be properly selected in view of various factors such as the boiling point of the comonomer, a required heating source, removal of polymerization heat etc. The temperature suitable for the polymerization can be set, e.g., in the range of 0° to 200° C. It is practically preferred to set the temperature in the range of room temperature to about 100° C. The polymerization can be carried out under any pressure conditions, such as reduced pressure, atmospheric pressure and elevated pressure. When the pressure is set at atmospheric pressure to about 100 atmospheric pressure, or at atmospheric pressure to about 50 atmospheric pressure, the polymerization can be practically preferably carried out. The initiation of, and proceeding with, the radical copolymerization at such a temperature under such pressure conditions can be carried out by means of an organic radical initiator, an inorganic radical initiator, light, ionizing radiation, heat, etc.

Specific examples of the organic radical initiator include azo compounds such as 2,2'-azobis(N,N'-dimethyleneisobutylamidine)dihydrochloride, 2,2'-azobis(2-amidinopropane)dihydrochloride, 2,2'-azobis(N,N'-dimethyleneisobutylamidine), etc., organic peroxides such as stearoyl peroxide, diisopropyl peroxydicarbonate, benzoyl peroxide, etc., and the like.

Specific examples of inorganic radical initiator include inorganic peroxides such as $(NH_4)_2S_2O_8$, $K_2S_2O_8$, etc. As light, visible light, ultraviolet light, etc., can be used, and a photosensitizer may be used in combination. The ionizing radiation includes γ ray, β ray, α ray, etc., from radioactive isotopes such as ^{60}Co, ^{192}Ir, ^{170}Tm, ^{137}Cs, etc., and electron beam from an electron beam accelerator.

(2) CVD method

It is preferred to use a plasma polymerization method in which a gaseous monomer of ethylene, propylene, tetrafluoroethylene, vinyltrimethoxysilane, hexamethyldisiloxane, tetrafluoromethane, or the like is polymerized to obtain a polymer corresponding to the above monomer.

General pyrolysis CVD is not suitable since the substrate temperature is elevated to a high temperature.

(3) Casting method

A fluorine-containing polymer compound is dissolved in a fluorine-containing solvent such as perfluoroalcohol, perfluoroether, perfluoroamine, or the like and the so-prepared solution was cast on a laminated structure and air-dried for 8 to 16 hours to give a film (protection layer). It .does not matter how long the drying is carried out, if it is carried out for at least 8 hours. Since, however, there is no much difference even if the drying time exceeds 16 hours, such a longer drying time is improper. The drying time is generally properly about 12 hours.

The concentration of the raw material in the solution is selected depending upon the thickness of the intended protection layer.

The fluorine-containing polymer compound for use includes the polymer compounds (B), (C) and (d) described concerning the above PVD method.

(4) Spin coating method

A suitable amount of the same solution as that described in the above (3) is dropped on a laminated structure which is being rotated at 100 to 20,000 rpm, preferably 200 to 8,000 rpm, and the laminated structure is further rotated for 5 to 80 seconds, preferably 10 to 30 seconds. Then, the solution was dried in the same manner as in the casting method to obtain a film (protection layer). The amount of the solution to be dropped differs depending upon the size of the laminated structure or an organic EL device to be sealed. In general, when the laminated structure or the organic EL device has a size of a slide glass (25×75×1.1 mm), the above amount is 0.6 to 6 ml, preferably 0.5 to 3 ml.

The concentration of the raw material in the solution is properly selected depending upon the thickness of the intended protection layer as is done in the casting method. The range thereof is narrower than that in the casting method, and it is 1 to 40 g/100 ml, preferably 4 to 20 g/100 ml from the viewpoint of control of the layer thickness, layer uniformity, etc.

In both the casting method (3) and the spin coating method (4), it is preferred to further dry the air-dried film with a vacuum dryer, etc., at 30° to 100° C., preferably 50° to 80° C. for 1 to 24 hours, preferably 8 to 15 hours.

By any one of the above-detailed methods (1) to (4), the protection layer can be formed on the outer surface of the laminated structure. Although the thickness of the protection layer depends upon used raw materials and a method for the protection layer formation, the lower limit thereof is 1 nm, preferably 10 nm. When the thickness is set at less than 1 nm, it is difficult to obtain a uniform thin film by any one of the methods. The upper limit thereof cannot be defined since it differs depending upon use of the intended organic EL device and a method for the protection layer formation. In the PVD method, it is about 100 μm from the viewpoint of productivity. When the casting method is employed, a film having a thickness of 100 μm or more can be easily formed. When the side on which the protection layer is formed is used as a light-emitting surface, there are selected raw materials and formation methods to obtain a protection layer having excellent light transmission properties to EL light from the light-emitting layer.

The protection layer that can be formed as described above can sufficiently perform its function even if it has a single-layered structure. It may also have a structure having a plurality of layers, at least two layers, as required. When it has a structure having a plurality of layers, the component of each layer may be the same as, or different from, that of other.

In order to obtain an organic EL device having a long life, it is desirable to prevent the property deterioration of the light-emitting layer and the opposite electrode during the step of forming the protection layer. For this reason, it is particularly preferred to form the protection layer in a vacuum environment by a PVD method or a CVD method. And, for the same reason, it is particularly preferred to carry out the steps from the formation of the light-emitting layer as a constituent of the laminated structure to the formation of the protection layer in a continuous vacuum environment as a series. Further, when the light-emitting layer is formed on the hole-injecting layer or the electron-injecting layer, it is preferred to carry out the steps from the formation of the hole-injecting layer or electron-injecting layer which is to underlie the light-emitting layer to the formation of the protection layer in a continuous vacuum environment as a series.

Among the organic EL devices of the present invention, the organic EL device having a laminated structure formed on a substrate can be produced, for example, according to the following procedures.

1. Formation of first electrode on substrate

The first electrode can be formed by a vacuum vapor deposition method, a sputtering method, a CVD method, a plating method, a printing method, etc., depending upon electrode materials.

The electrode material can be selected from electrically conductive metals such as gold, silver, copper, aluminum, indium, magnesium, sodium, potassium, etc., mixtures of these electrically conductive metals such as a mixture of magnesium with indium, etc., alloys such as sodium-potassium, magnesium-copper, tin-lead, silver-tin-lead, nickel-chromium, nickel-chromium-iron, copper-manganese-nickel, nickel-manganese-iron, copper-nickel, etc., oxides such as stannic oxide, indium oxide, zinc oxide, ITO (indium tin oxide), etc., compounds such as copper iodide (CuI), etc., a laminated material of aluminum (Al) and aluminum oxide (Al_2O_3), composite materials such as a combination of synthetic resin and silver, silicone rubber and silver, silver-containing borosilicate glass, etc., and the like, which are conventionally used as an electrically conductive material.

When the first electrode side (substrate side) is used as a light-emitting surface, it is preferred to use a transparent electrode material such as stannic oxide, indium oxide, zinc oxide, ITO, CuI, etc., from the viewpoint of increasing the transmittance to light emitted from the light-emitting layer. The thickness thereof is preferably 10 nm to 1 μm, particularly preferably not more than 200 nm. Due to this, it is preferred to employ a vacuum vapor deposition method, a sputtering method or a CVD method to form a film as an electrode.

The first electrode may be any one of an anode and a cathode. When it is used as an anode, it is preferred to use an electrically conductive material having a larger work function than the material for the second electrode (opposite electrode) to be described later. When it is used as a cathode, it is preferred to use an electrically conductive material having a smaller work function. Further, the anode material preferably has a work function of at least 4 eV, and the cathode material preferably has a work function of less than 4 eV.

In addition, the material for the substrate on which the first electrode is to be formed can be selected from conventional materials such as glass, plastic, quartz, ceramics, etc. When the substrate side is used as a light-emitting surface, a transparent material is used. It is preferred to wash the material by an ultrasonic washing method, etc., before the formation of the first electrode.

When the organic EL device is used as a surface light source, a substrate formed of an electrically conductive material can be used as a substrate, and in this case, the substrate can be used as a first electrode.

2. Formation of light-emitting layer on first electrode

The light-emitting layer can be formed by a vacuum vapor deposition method, a sputtering method, spin coating method, a casting method, etc., while the vacuum vapor deposition method is preferred to obtain a film (layer) which is homogeneous and smooth and which has no pin hole. The light-emitting layer may be formed directly on the first electrode, or may be formed on the first electrode through a hole-injecting layer or an electron-injecting layer.

The material for the light-emitting layer is properly selected from fluorescent organic solids conventionally used as a light-emitting layer material such as a phthaloperinone derivative, a thiadiazole derivative, a stilbene derivative, a coumarin derivative disclosed in JP,A 2-191694, a distyrylbenzene derivative disclosed in JP,A 2-60894, JP,A 2-209988 or JP,A 63-295695, a chelated oxinoid compound, etc., depending upon the emission color kind and electrical and optical properties required of the intended organic EL device or the layer constitution of the laminated structure. The thickness of the light-emitting layer is preferably 5 nm to 5 μm.

The material for the hole-injecting layer which is to be formed between the light-emitting layer and the first electrode as required is preferably selected from materials having a hole mobility of at least 10^{-6} cm^2/V.second under 10^4 to 10^6 V/cm as is done for conventional devices. Specifically, it is selected from a triphenylamine derivative, a polyarylalkane derivative, a pyrazoline derivative, a pyrazolone derivative, an arylamine derivative, a hydrazone derivative, a stilbene derivative, a phenylenediamine derivative, p-type a-Si, P-type SiC, p-type Si crystal, CdS, etc.

The material for the electron-injecting layer which is to be formed between the light-emitting layer and the first electrode as required can be selected from materials used for the electron-injecting layer of conventional organic EL devices such as a nitro,substituted fluorenone derivative, an anthraquinonedimethane derivative, a diphenylquinone derivative, a dioxazole derivative, a thiopyran dioxide derivative, a fluorenylidenemethane derivative, an anthrone derivative, a dioxane derivative, n-type a-Si, n-type SiC, n-type Si crystal, etc.

The hole-injecting layer and the electron-injecting layer from the organic material can be formed in the same manner as in the formation of the light-emitting layer, and the hole-injecting layer and the electron-injecting layer from the inorganic material can be formed by a vacuum vapor deposition method, a sputtering method, etc. For the same reasons described concerning the light-emitting layer, however, a vacuum vapor deposition method is preferred to form it.

3. Formation of second electrode (opposite electrode) on light-emitting layer

The second electrode can be formed in the same manner as in the formation of the first electrode, while it is preferred to form it by a vacuum vapor deposition method, a sputtering method or a CVD method in order to prevent the infiltration of water and oxygen into the light-emitting layer. The second electrode may be formed directly on the light-emitting layer or may be formed on the light-emitting layer through the hole-injecting layer or the electron-injecting layer. However, when it is formed on the light-emitting layer through the hole-injecting layer, the premise therefore is that no hole-injecting layer is present between the first electrode and the light-emitting layer. When the second electrode is formed on the light-emitting layer through electron-injecting layer, the premise is that no electron-injecting layer is present between the first electrode and the light-emitting layer.

When the second electrode is formed directly on the light-emitting layer, it is preferred to form it by a vacuum vapor deposition method.

The material for the second electrode can be selected from materials similar to those used for the first electrode. When the first electrode is used as an anode, it is used as a cathode. When the first electrode is used as a cathode, it is used as an anode. Accordingly, the material therefor is properly selected.

The materials for the hole-injecting layer and the electron-injecting layer which are to be formed between the second electrode and the light-emitting layer as required are as described previously. It is preferred to form these layers by a vacuum vapor deposition method for the same reason as that described in the formation of the light-emitting layer.

The formation of the second electrode (opposite electrode) finishes the formation of the laminated structure on the substrate.

4. Formation of protection layer

This procedure relates to the formation of the characteristic part of the organic EL device of the present invention, and the materials therefor and the method of the formation thereof are as already described.

By the formation of this protection layer, there is obtained the organic EL device of the present invention. A shield layer may be formed on the outer surface of the protection layer for tile purpose of further sufficiently achieving the prevention of infiltration of water and oxygen into the light-emitting layer and mechanically protecting the device.

The shield layer is preferably formed from an electrically insulating glass, an electrically insulating polymer compound or an electrically insulating airtight fluid. At this stage, the laminated structure is protected by the protection layer, and therefore, various methods can be applied to the formation of the shield layer. The method of formation of the shield layer will be described hereinafter with respect to each material.

a. Electrically insulating glass

After the protection layer is formed on the outer surface of the laminated structure formed on the substrate such as a glass substrate, this electrically insulating glass is covered over the protection layer, and the marginal portion of the substrate and the marginal portion of the electrically insulating glass,are bonded together with an adhesive, etc., whereby a shield layer is formed.

That surface of this electrically insulating glass which is on the protection layer side is preferably a polished surface of a photomask grade. This glass is preferably selected from those which have little alkali content, and has a high volume resistance (at least 10^7 Ωm at 350° C.). Specifically, there can be selected #7059 supplied by Corning Co., Ltd.

The above electrically insulating glass may be provided so that it is directly in contact with the protection layer, or it may be provided on the outer surface of the protection layer through a moisture absorbent layer formed of polyvinyl alcohol, nylon 66, or the like. When the moisture absorbent layer is formed in between, it is preferred to form the moisture absorbent layer on a surface of the electrically insulating glass in advance. In this case, the glass may have a surface rougher than a photomask grade.

b. Electrically insulating polymer compound

A shield layer is formed from an electrically insulating liquid resin or solid resin, for example, by the following method. By an immersing method and a transfer molding method among the below-described methods, the device as a whole (including the substrate when the laminated structure is formed on the substrate) is covered with a shield layer. Therefore, a material for the shield layer is selected to obtain practically sufficient light transmission property to EL light from the organic EL device to be sealed. In other methods, a shield layer can be formed on the surface on the protection layer side alone when the laminated structure is formed on the substrate. Therefore, it is not necessary to consider the light transmission property of the shield layer as far as the surface on the protection layer side is not used as a light-emitting surface.

1. When liquid resin is used

Casting method: In this method, a shield layer is formed by placing the organic EL device (to be sometimes referred to as "protection layer-coated device" hereinafter) in a mold container, injecting a liquid resin, to which a catalyst and a curing agent have been added, into the mold container to cover the protection layer side surface of the protection layer-coated device with this liquid resin, curing it, removing the mold, and then completely curing it in an oven. More preferably, the curing is carried out in a temperature-controlled oven.

In this case, the liquid resin may be any one of thermosetting and photosetting resins if they are electrically insulating (to be sometimes referred to as "condition (i)" hereinafter). When the surface on the protection layer side is used as a light-emitting layer, there is selected a resin which gives a resin layer having practically sufficient light transmission property to EL light from the organic EL device to be sealed (to be sometimes referred to as "condition (ii)" hereinafter). Concerning the thermosetting resin, it is preferred to use one of which the curing temperature is lower than the softening point of the electrically insulating polymer compound forming the protection layer (to be sometimes referred to as "condition (iii)" hereinafter).

The thermosetting liquid resin that satisfies the conditions (i) and (ii) preferably includes an epoxy resin, a silicone resin, an epoxysilicone resin, a phenolic resin, a diallylphthalate resin, an alkyd resin, etc. For practical use, a liquid resin is selected depending upon whether or not it satisfies the condition (iii).

The photosetting liquid resin that satisfies the conditions (i) and (ii) includes ultraviolet light-curing resins such as BY-300B (trade name of an ene.thiol type photosetting liquid resin, supplied by Asahi Denka Co., Ltd.), BU-230U (trade name of acrylic photosetting liquid resin, supplied by Toagosei Chemical Industries Co., Ltd.), UV1001 (trade name of a polyester-based photosetting liquid resin, supplied by Sony Chemical Co., Ltd.), etc., and visible light-curing resins such as LCR000 (trade name, supplied by I.C.I. Japan), etc.

The curing temperatures and curing times of these liquid resins differ depending upon the resins. For example, when a thermosetting epoxy resin is used, it is cured at 160° to 180° C. for 1 to 2 minutes. In any one of the thermosetting and photosetting liquid resins, it is preferred to add a step of degassing in vacuum after a catalyst and a curing agent are added to the resins.

Vacuum potting method: In this method, a shield layer is formed by carrying out all the steps of the above-described casting method in vacuum. This method is more preferable than the casting method.

Dipping method: In this method, a shield layer is formed by dipping the protection layer-coated device in the above liquid resin, pulling it up, and then curing a coating of a liquid from the liquid resin on the protection layer-coated device by heat-treating it or air-drying it.

A variety of thermoplastic resins, thermosetting or photosetting resins may be used if they satisfy the conditions (i) and (ii).

Others: A shield layer may be formed by applying a liquid resin to the protection layer side surface of the protection layer-coated device with a spatula, etc., and curing it. The liquid resin can be selected directly from the above-described liquid resins, When the surface on the protection layer side is not used as a light-emitting layer, even a resin that does not satisfy the condition (ii) may be used.

2. When liquid resin is used while it is in a solid state:

Hot-melt method: In this method, a shield layer is formed by casting or vacuum-potting a heated and molten resin. The resin used in this method is preferably selected from thermoplastic resins which satisfy the condition (i) and which also has the melting point which is lower than the softening point of the electrically insulating polymer compound forming the protection layer (to be sometimes referred to as "condition (iv)" hereinafter).

Specific examples of the thermoplastic resins which satisfy the condition (i) include halogenated vinyl polymers or halogenated vinyl copolymers such as polyvinyl chloride, polyvinyl bromide, polyvinyl fluoride, a vinyl chloride-vinyl acetate copolymer, a vinyl chloride-ethylene copolymer, a vinyl chloride-propylene copolymer, a vinyl chloride-vinylidene chloride copolymer, a vinyl chloride-butadiene copolymer, a vinyl chloride-acrylic acid ester copolymer, a vinyl chloride-acrylonitrile copolymer, a vinyl chloride-styrene-acrylonitrile terpolymer, a vinyl chloride-vinylidene chloride-vinyl acetate copolymer, polyvinylidene chloride, polytetrafluoroethylene, polyvinylidene fluoride, polychlorotrifluoroethylene, a fluorine-containing polymer compound disclosed in JP,A 63-18964, a fluorine-containing polymer compound disclosed in JP,A 63-22206, a fluorine-containing polymer compound disclosed in JP,A 63-238115, etc.;

polymers of unsaturated alcohols or unsaturated ethers, or copolymers of unsaturated alcohols and unsaturated ethers such as polyvinyl alcohol, polyallyl alcohol, polyvinyl ethel, polyallyl ether, etc.;

polymers or copolymers obtained from unsaturated carboxylic acids such as acrylic acid, mothacrylic acid, etc.;

polymers or copolymers of those having an unsaturated bond in the alcohol moiety, i.e., polyvinyl esters such as polyvinyl acetate and polyacrylic esters such as polyphthalic acid;

polymers or copolymers of those having unsaturated bond(s) in the acid moiety or in the acid moiety and the alcohol moiety such as polyacrylic acid ester, polymethacrylic acid ester, a maleic acid ester polymer, a fumaric acid ester polymer, etc.;

an acrylonitrile polymer, a methacrylonitrile polymer, a copolymer obtained from acrylonitrile and methacrylonitrile, polyvinylidene cyanide, a malononitrile polymer, a fumarononitrile polymer, a copolymer obtained from malononitrile and fumarononitrile;

polymers of aromatic vinyl compounds such as polystyrene, poly-α-methylstyrene, poly-p-methylstyrene, a styrene-p-methylstyrene copolymer, polyvinylbenzene, polyhalogenated styrene, etc.;

polymers or copolymers of heterocyclic compounds such as polyvinylpyridine, poly-N-vinylpyrrolidine, poly-N-vinylpyrrolidone, etc.;

polyester condensates such as polycarbonate, etc., and polyamide condensates such as nylon 6, nylon 66, etc.;

a polymer obtained from at least one substance selected from the group consisting of maleic anhydride, fumaric anhydride, an imidation compound of maleic anhydride and imidation compound of fumaric anhydride, or a copolymer obtained from at least two substances selected from the above group;

heat-resistant polymer compounds such as polyamide, polyetherimide, polyimide, polyphenylene oxide, polyphenylene sulfide, polysulfone, polyethersulfone, polyarylate, etc.;

polyethylene, polypropylene, polyethylene terephthalate, polymethyl methacrylate, and a thermotropic liquid crystal polymer disclosed in JP,A 2-253952.

A resin for practical use is properly selected depending upon whether it satisfies the condition (iv).

Fluidization dipping method: There is used a container having a micropore bottom plate, a porous bottom plate and an air (compressed air) reservoir positioned below the porous bottom plate. A solid resin (powdered resin) pulverized to a size of 200 to 300 mesh is placed on the micropore bottom plate, and compressed air is flowed from below through the porous bottom plate, whereby the powdered resin can be handled like a fluid.

In this method, therefore, a shield layer is formed by tilting the container while the compressed air is flowed through the powdered resin, and placing the protection layer-coated device heated to a temperature higher than the softening point of the powdered resin thereby to fuse the powdered resin and attach it to the heated protection layer-coated device.

The resin for use in this method is preferably selected from the thermoplastic resins described as examples concerning the hot-melt method.

Transfer molding method: In this method, a shield layer is formed by placing the protection layer-coated device in a mold (having an aperture), introducing a resin melted in a pot into the cavity of the mold through the aperture and curing the resin.

The resin for use in this method is preferably selected from those thermoplastic resins which are described as examples concerning the hot-melt method and satisfy the foregoing condition (ii).

Others: A shield layer may be formed by applying a resin solution to the protection layer side surface of the protection layer-coated device and dissipating the solvent in the resin solution by heat treatment or air-drying. In this case, there may be used a resin which at least satisfies the condition (i) and which is soluble in any one of a halogen-containing solvent, an aromatic hydrocarbon solvent and a fluorine-containing solvent. An acrylic resin, polystyrene, etc., are selected as a preferred resin. Further, an organic solvent dissipation type adhesive is one of preferred resins. Specifically, there are 1001B (trade name of an elastomer-type, organic solvent dissipation type adhesive, supplied by Nippon Zeon Co., Ltd.), SG4693 (trade name of an organic solvent dissipation type adhesive, supplied by 3M Co., Ltd.), etc.

3. Film sealing

In this method, a shield layer is formed by covering the protection layer-coated device with a polymer film. In this case, the protection layer-coated device as a whole (including the substrate when the laminated structure is formed on the substrate) may be covered with a polymer film, or in the protection layer-coated device in which the laminated structure is formed on the substrate, the protection layer side surface alone may be covered with a polymer film.

When the protection layer-coated device as a whole is covered with a polymer film, the protection layer-coated device is covered with polymer films from above and below, and the upper-positioned and lower-positioned polymer films are thermally fused and bonded to each other along the marginal portion of the protection layer-coated device. When the protection layer side surface alone is covered with a polymer film, the marginal portion of the polymer film and the substrate are bonded to each other with an adhesive, or when the laminated structure is formed on a polymer substrate, the marginal portion of the polymer film and the substrate are thermally fused and bonded to each other.

Concerning the material of the polymer film, preferred is a polymer film which satisfies the conditions (i) and (ii). Specific examples thereof include polyethylene, polypropylene, polyethylene terephthalate, polymethyl methacrylate, polystyrene, polyether sulfone, polyarylate, polycarbonate, polyurethane, an acrylic resin, polyacrylonitrile, polyvinyl acetal, polyamide, polyimide, a diacrylphthalate resin, a cellulose-containing plastic, polyvinyl acetate, polyvinyl chloride, polyvinylidene chloride, and copolymers obtained from two or at least three of these. Particularly preferred as a polymer film are films obtained by subjecting to a stretching method, etc., polymer compounds having low water vapor permeability such as polyvinyl fluoride, polychlorotrifluoroethylene, polytetrafluoroethylene, a fluorine-containing polymer compound disclosed in JP,A 65-18964, a fluorine-containing polymer compound disclosed in JP,A 63-22206, a fluorine-containing polymer compound disclosed in JP,A 63-238115, and the like. In addition, the polymer film used for covering the surface of the protection layer-coated device other than the light-emitting surface may be a film which does not satisfy the condition (ii).

The polymer film used here may be a single-layered film, while it is more preferred to use a polymer film having a structure of a plurality of layers in which a moisture absorbent layer of nylon 66, polyvinyl alcohol, or the like is formed. The polymer film having a structure of a plurality of layers in which the moisture absorbent layer is formed is used so that the moisture absorbent layer is in contact at least with the protection layer.

c. Electrically insulating airtight fluid

A shield layer is formed by sealing both the organic EL device provided with the protection layer (protection layer-coated device) and a gas or a liquid satisfying the condition (i) in a container such as glass container, a ceramic container, a plastic container, or the like which satisfies the above condition (i). When the container wall and the airtight fluid are positioned outside the light-emitting surface of the protection layer-coated device, these are required to satisfy the above conditions (ii) as well.

In the protection layer-coated device in which the laminated structure is formed on the substrate, the substrate may be used as part of the above container. The container is formed by bonding necessary members with a low-melting-point glass, solder, an airtight-sealing epoxy resin, or the like.

The gas sealed in the container preferably includes inert gases such as a He gas, an Ar gas, a Ne gas, etc. The liquid includes a silicone oil, etc. When the substrate is used as part of the container in which the liquid is sealed in, a moisture absorbent such as silica gel, activated carbon, or the like may be included on the premise that the protection layer side of the protection layer-coated device will not be used as a light-emitting surface.

When the shield layer is provided outside the protection layer as described above, the infiltration of water, oxygen, etc., into the light-emitting layer is further inhibited by these two layers. Therefore, there can be obtained an organic EL device having a longer life than an organic EL device provided with the protection layer alone.

As explained above, the organic EL device of the present invention has the protection layer on the outer surface of the laminated structure. Even when this protection layer is formed by a formation method different from that for the light-emitting layer or by means of a film-forming apparatus different from that for the light-emitting layer, it can be produced for a short production time for which the light-emitting layer is exposed to the atmosphere. Therefore, it can be formed while fully preventing the infiltration of water, oxygen, etc., into the light-emitting layer at the production step. After the protection layer is formed, the infiltration of water, oxygen, etc., into the light-emitting layer can be fully prevented by this protection layer.

Therefore, the organic EL device of the present invention has a longer life than any conventional organic EL device.

Further, a vacuum vapor deposition method is applied to the method of forming the laminated structure on the substrate and the method of forming the protection layer, whereby the formation of the laminated structure and the formation of the protection layer can be carried out as a series in one vapor deposition apparatus. In this case, the interface between one layer and a neighboring layer does not contact water, oxygen, etc., and therefore, there can be obtained an organic EL device having a much longer life.

When the shield layer is formed outside the protection layer, the infiltration of water, oxygen, etc., into the light-emitting layer can be further inhibited. Therefore, there can be obtained an organic EL device having a longer life than an organic EL device provided with the protection layer alone.

As described above, the organic EL device of the present invention is an organic EL device which can be structurally produced as a device having a long life.

Examples of the present invention will be described hereinafter. In the following Examples, organic EL devices of the present invention which were provided with a protection layer alone are consecutively referred to as an organic EL device A_1, an organic EL device A_2, . . . an organic EL device A_n, and organic EL devices which were provided with a shield layer outside the protection layer as well are consecutively referred to as an organic EL device B_1, an organic EL device B_2, . . . an organic EL device B_n.

EXAMPLE 1

A glass plate having a size of 28×75×1.1 mm on which an ITO electrode having a film thickness of 100 nm was formed (supplied by HOYA Corp.) was used as a transparent substrate. This transparent substrate was subjected to ultrasonic cleaning with isopropyl alcohol for 30 minutes, and then cleaned with pure water for 30 minutes. Further, it was subjected to ultrasonic cleaning with isopropyl alcohol for 30 minutes.

The cleaned transparent substrate was fixed on a substrate holder in a commercially available vacuum vapor deposition apparatus (supplied by Nihon Shinku Gijutsu K. K. (ULVAC)]. And, 200 mg of N,N'-diphenyl-N,N'-bis-(3-methylphenyl) -(1,1'-bisphenyl)-4,4'-diamine (to be referred to as "TPDA" hereinafter) as a material for a hole-injecting layer was placed in a molybdenum resistance heating boat, and 200 mg of tris(8-quinolinol)aluminum (to be referred to as "Alq." hereinafter) as a material for a light-emitting layer was placed in other molybdenum resistance heat boat. The pressure in the vacuum chamber was reduced to 1×10^{-4} Pa.

Then, the molybdenum resistance heating boat in which TPDA was placed was heated up to 215° to 220° C. to deposit TPDA on the ITO film constituting the transparent substrate at a deposition rate of 0.1 to 0.3 nm, whereby a hole-injecting layer having a layer thickness of 60 nm was formed. At this time, the substrate temperature was at room temperature. Then, while the transparent substrate on which the hole-injecting layer was formed was fixed on the substrate holder, the molybdenum resistance heating boat in which Alq. was placed was heated up to 265° to 273° C. to deposit Alq. on the hole-injecting layer at a deposition rate of 0.1 to 0.2 nm, whereby a light-emitting layer having a layer thickness of 60 nm was formed. At this time, the substrate temperature was also at room temperature.

Then, 1 g of magnesium as a material for an electrode was placed in the molybdenum resistance heating boat, 500 mg of indium was placed in the other molybdenum resistance heating boat, and the pressure inside the vacuum chamber was reduced to 2×10^{-4} Pa. Then, the molybdenum resistance heating boat in which magnesium was placed was heated up to about 500° C., and the molybdenum resistance heating boat in which indium was placed was heated up to about 800° C. to concurrently deposit magnesium on the light-emitting layer at a deposition rate of 1.7 to 2.8 nm and indium at a deposition rate of 0.03 to 0.8 nm, whereby there was formed a 150 nm thick electrode (opposite electrode) of a mixed metal of magnesium and indium. At this time, the substrate temperature was also at room temperature.

Thereafter, a protection layer was formed on the outer surface of the laminated structure formed, on the glass plate, of the ITO electrode, the hole-injecting layer, the light-emitting layer and the opposite electrode, by means of the same vacuum deposition apparatus as that used for the formation of the laminated structure in the following manner.

At first, as shown in FIG. 1, an alumina crucible 4 containing 1.5 g of a commercially available chlorotrifluoroethylene homopolymer (trade name: Kel-F, supplied by 3M Co., Ltd., molecular weight 100,000, to be referred to as "PCTFE" hereinafter) as a deposition source for a protection layer was placed in a tungsten basket resistance heater S positioned in a vacuum chamber 2 constituting a vacuum vapor deposition apparatus 1, and a 12 μmØ stainless mesh 5 was covered on the alumina crucible 4. Further, the transparent substrate 6 on which the laminated structure was formed was arranged above the tungsten basket resistance heater 3 through a shutter 7.

Then, the pressure in the vacuum chamber 2 was reduced to 1×10^{-4} Pa, and electricity was applied to the tungsten basket resistance heater 3 to heat the deposition source (PCTFE) to 478° C. and form a fluorine-containing polymer layer [PCTFE thin film (protection layer)] having a thickness of 1.2 μm on the outer surface of the laminated structure at a deposition rate of 0.5 nm/s. The substrate temperature at this time was again at room temperature. The formation of the protection layer on the outer surface of the laminated structure gave an organic EL device A_1 of the present invention.

In addition, the layer thickness and deposition rate of each of the layers other than the ITO electrode were controlled by monitoring the thickness of each deposition layer with a quartz oscillator type film thickness monitor 8 (supplied by Nihon Shinku Gijutsu K. K. (ULVAC)) arranged in the vacuum chamber 2. Each of the so-obtained layers was measured for a thickness with a probe type film thickness measuring device, and it was confirmed that the so-obtained values were in agreement with reading by the quartz oscillator type film thickness monitor 8. The quartz oscillator type film thickness monitor 8 was provided with a support tool 9 including a tube for coolant water for cooling the quartz oscillator type film thickness monitor 8, and this support tool 9 was supported by a support wall 10 positioned outside the vacuum chamber 2.

EXAMPLE 2

Example 1 was repeated except that the thickness of the PCTFE thin film was changed to 400 nm (0.4 μm) to give an organic EL device A_2 of the present invention.

EXAMPLE 3

A laminated structure having an ITO electrode, a hole-injecting layer, a light-emitting layer and an opposite electrode was formed on a glass plate exactly in the same manner as in Example 1.

Then, a fluorine-containing polymer layer [Teflon AF thin film (protection layer)] having a layer thickness of 0.8 μm (800 nm) was formed on the outer surface of the laminated structure formed on the glass plate in the same manner as in Example 1 except that 1.5 g of an amorphous copolymer powder (trade name: Teflon AF, supplied by E. I. du Pont de Nemoure & Co.) obtained from tetrafluoroethylene and perfluoro-2,2-dimethyl-1,3-dioxole was used as a deposition source for a protection layer and that the temperature for heating this deposition source was set at 455° C. At this time, the substrate temperature was at room temperature. The formation of the protection layer on the outer surface of the laminated structure gave an organic EL device A_3 of the present invention.

EXAMPLE 4

The same transparent substrate as that used in Example 1 was subjected to ultrasonic cleaning with isopropyl alcohol for 5 minutes, cleaned with pure water for 5 minutes and then subjected to ultrasonic cleaning with isopropyl alcohol for 5 minutes.

Then, a hole-injecting layer, a light-emitting layer and an opposite electrode were formed on the cleaned transparent substrate in the same manner as in Example 1 to give a laminated structure having an ITO electrode, the hole-injecting layer, the light-emitting layer and the opposite electrode.

Thereafter, a fluorine-containing polymer layer [Cytop thin film (protection layer)] having a layer thickness of 0.8 μm (800 nm) was formed on the outer surface of the laminated structure formed on the glass plate in the same manner as in Example 1 except that 1.5 g of an amorphous radical copolymer powder (trade name: Cytop, supplied by Asahi Glass Co., Ltd., intrinsic viscosity 0.425) of 65.8 mol. % of tetrafluoroethylene and 34.2 mol. % of perfluoroallylvinyl ether (CF_2=CF—O—CF_2—CF=CF_2) was used as a deposition source for a protection layer and that the temperature for heating this deposition source was set at 460° C. At this time, the substrate temperature was at room temperature. The formation of the protection layer on the outer surface of the laminated structure gave an organic EL device A_4 of the present invention.

EXAMPLE 5

An ITO film having a thickness of 100 nm was formed on a glass plate having a size of 25×75×1.1 mm (white sheet glass, supplied by HOYA Corp.) as a substrate, and used as a transparent electrode (the substrate on which the ITO film was formed is referred to as "transparent substrate" hereinafter). This transparent substrate was subjected to ultrasonic cleaning with isopropyl alcohol for 30 minutes, cleaned with pure water for 5 minutes and then rinsed with isopropyl alcohol, and it was dried by blowing an N_2 gas against it. Then, the transparent substrate was cleaned with a UV ozone cleaning apparatus (supplied by Samco International) for 10 minutes.

A hole-injecting layer having a thickness of 60 nm was formed from TPDA on the ITO film of the cleaned transparent substrate in the same manner as in Example 1. Further, a light-emitting layer having a thickness of 60 nm was formed from Alq. on the hole-injecting layer in the same manner as in Example 1. During the formation of these, the substrate temperature was at room temperature.

After the light-emitting layer was formed, a molybdenum resistance heating boat in which 1 g of magnesium had been placed prior to the formation of the hole-injecting layer and a molybdenum resistance heating boat in which 500 mg of silver had been similarly placed were respectively heated without destroying the vacuum environment. And, the magnesium was deposited at a deposition rate of about 1.5 nm/s, and at the same time, the silver was deposited at a deposition rate of about 0.1 nm/s to form a 150 nm thick electrode (opposite electrode) of a mixed metal of magnesium and silver. The formation of the ITO film (electrode), the hole-injecting layer, the light-emitting layer and the opposite electrode on the substrate gave an organic EL device. In this organic EL device, the laminated structure was formed of the ITO film (electrode), the hole-injecting layer, the light-emitting layer and the opposite electrode.

Thereafter, a fluorine-containing polymer layer [Teflon AF thin film (protection layer)] having a layer thickness of 0.8 μm (800 nm) was formed on the outer surface of the laminated structure in the same manner as in Example 3. However, Teflon AF as a deposition source for the protection layer had been placed in an alumina crucible prior to the formation of the hole-injecting layer, and the crucible had been placed in a tungsten basket prior to the formation of the hole-injecting layer. And, the protection layer was formed without destroying the vacuum environment in the vacuum vapor deposition apparatus after the formation of the opposite electrode, in other words, in a vacuum environment as a series starting the formation of the hole-injecting layer. The substrate temperature at a protection layer formation time was at room temperature. The formation of the protection layer on the outer surface of the laminated structure gave an organic EL device A_5 of the present invention.

EXAMPLE 6

At first, an organic EL device A_5 was obtained in the same manner as in Example 5.

Then, this organic EL device A_5 was taken out of the vacuum chamber, and a shield layer was formed outside the protection layer in the following manner.

An electrically insulating glass substrate (the glass had a size of 25×75×1.1 mm) having a 350 nm thick polyvinyl alcohol (to be referred to as "PVA" hereinafter) layer as a moisture absorbent layer on one main surface was prepared. This glass substrate had been obtained by dropping 1 ml of a solution prepared by mixing 3% by weight of a PVA powder, 0.05% by weight of hydrochloric acid and 96.5% by weight of water on a slide glass, spin-coating it with a spin-coating apparatus (supplied by Mikasa K. K.) at 500 rpm for 30 seconds, air-drying it for 8 hours, and drying it in a vacuum dryer (supplied by Yamato Kagaku Co., Ltd.) at 60° C. for 10 hours.

Then, an epoxy-based adhesive (Cemedine Hisuper 5, supplied by Cemedine Co., Ltd.) was applied to the marginal portion of the PVA layer side of the above glass substrate so that the applied portion was about 0.5 mm wide, and thereafter, this glass substrate and the organic EL device A were attached to each other. This attaching was carried out such that the PVA layer and the protection layer were in contact with each other. The epoxy-based adhesive was used after its main component and its curing agent were stirred with a spatula 20 times.

Thereafter, the epoxy-based adhesive was cured in atmosphere for 10 hours, whereby the shield layer of an electrically insulating glass was formed outside the protection layer. The formation of this shield layer gave an organic EL device B_1 of the present invention.

EXAMPLE 7

An organic EL device (provided with no protection layer) was prepared in the same manner as in Example 5, and then, after the vacuum environment of the vacuum vapor deposition apparatus used for the formation of the laminated structure was once destroyed, a protection layer was formed on the outer surface of the laminated structure with the same vacuum vapor disposition apparatus as that used for the formation of the laminated structure.

At first, an alumina crucible containing 1 g of high-density polyethylene (trade name 440M, supplied by Idemitsu Petrochemical Co., Ltd.) as a deposition source was placed in a tungsten basket, and a 12 μmØ stainless steel mesh was covered on this alumina crucible. Then, the above-obtained organic EL device was set on a sample holder, and the pressure in the vacuum chamber was reduced to 1×10^{-4} Pa. Thereafter, the deposition source was heated to 400° C. by applying electricity to the tungsten basket to form a 0.3 μm (300 nm) thick high-density polyethylene thin film (protection layer) on the outer surface of the laminated structure at a deposition rate of 0.5 nm/s. The formation of the protection layer on the outer surface of the laminated structure gave an organic EL device A_6 of the present invention.

Thereafter, the organic EL device A_6 was taken out of the vacuum chamber, and an epoxy-based adhesive (Cemedine Super 5, supplied by Cemedine Co., Ltd.) was applied to the protection layer such that the adhesive thickness was 2 mm thick. The organic EL device A_6 was allowed to stand in the atmosphere for 5 hours to cure the epoxy-based adhesive, whereby a shield layer was formed. The formation of this shield layer gave an organic EL device B_2 of the present invention. In addition, the epoxy-based adhesive was applied with it on a spatula after its main component and curing agent were stirred with the spatula 20 times.

EXAMPLE 8

As shown in FIG. 2, a glass plate **11** (white sheet glass supplied by HOYA Corp.) having a size of 25×75×1.1 mm on which 10 mm×75 mm×100 nm ITO films **12a** and **12b** were Formed was used as a transparent substrate **13**, and an organic EL device A_7 was obtained in the following manner.

A mask was covered on the ITO Film **12a**, and then a hole-injecting layer and a light-emitting layer were formed in the same manner as in Example 5. Thereafter, the mask covering the ITO film **12a** was removed by means of the automatic mask exchange mechanism fixed to a vapor deposition apparatus. Then a mask was covered on the marginal portion, 5 mm wide, of the ITO film **12a** along the longitudinal direction with the above mechanism. Thereafter, an opposite electrode and a protection layer were formed in the same manner as in Example 5 to give an organic EL device A_7.

As shown in FIG. 3, in the so-obtained organic EL device A_7 **14**, a hole-injecting layer **15** was formed from that surface portion of the glass plate **11** which was positioned between the two ITO films **12a** and **12b** to the main surface of the ITO film **12b**, and a light-emitting layer **16** was formed on this hole-injecting layer **15**. And, the opposite electrode **17** was formed on the light-emitting layer **18** and on that half of the main surface of the ITO film **12a** which was to the center, and a protection layer **18** was formed on the main surface of the opposite electrode **17**. In this organic EL device A_7 **14**, a laminated structure **19** was formed of the ITO electrode **12b**, the hole-injecting layer **15**, the light-emitting layer **16** and the opposite electrode **17**. Thus, all the layers from the hole-injecting layer to the protection layer were produced in a vacuum environment as a series.

Thereafter, the organic EL device A_7 **14** was taken out of the vacuum chamber, and a protection layer **18** was formed outside the protection layer **18** in the following manner.

At first, those portions of the hole-injecting layer **15**, the light-emitting layer **16**, the opposite electrode **17** and the protection layer **18** which were spreading 5 mm wide in the marginal portion of the ITO film **12b** along its longitudinal direction were cut off. Those portions of the hole-injecting layer **15**, the light-emitting layer **16**, the opposite electrode **17** and the protection layer **18** which were spreading 5 mm wide along tile width direction of the glass plate **11** were also cut off such that the remaining thickness was substantially a sum of the thickness of the glass plate **11** and the ITO film thickness.

Then, there was prepared a glass plate (outer diameter: 20×75×5 mm, to be referred to as "shield glass" herein after) having a 18×75×2 mm concave portion and a through hole (to be referred to as "inlet" hereinafter) having a diameter of 2 mm, provided in the bottom of the concave portion. This shield glass and the organic EL device A_7 **14** were bonded to each other with an epoxy-based adhesive (trade name: Cemedine Hisuper 5, supplied by Cemedine Co., Ltd.). The epoxy-based adhesive was applied to the marginal portion of the above organic EL device A_7 **14** so that a 20×75 mm rectangular form having a line width of 1 mm was formed, after its main component and curing agent were mixed and stirred with a spatula 20 times. Further, the bonding of the shield glass and the organic EL device A_7 **14** was carried out such that the opposite electrode **17** and the protection layer **18** went into the concave portion of the shield glass. After the bonding, the device was allowed to stand in the atmosphere for 10 hours to cure the epoxy-based adhesive.

Then, a silicone oil (trade name: TSK451, supplied by Toshiba Corp., to be referred to as "insulating oil" hereinafter) in which 8% by volume of silica gel (particle diameter 50 μm) for moisture absorption was dispersed was injected through the inlet provided in the shield glass so that the space formed with the concave portion of the shield glass and the organic EL device A_7 **14** was filled with the insulating oil. This insulating oil corresponds to a shield layer.

Thereafter, the inlet was sealed with a glass cover to give an organic EL device B_3 in which the shield layer was formed outside the protection layer. The glass cover was bonded to tile shield glass with the above epoxy-based adhesive.

FIG. 4 schematically shows the end face of the Finally obtained organic EL device B_3. As shown in FIG. 4, the organic EL device B_3 **20** had a laminated structure **19** formed of the ITO film **12b** formed on the surface of the glass plate **11**, the hole-injecting layer **15**, the light-emitting layer **16** and the opposite electrode **17**; and the protection layer **18** formed of a Teflon AF thin film was provided on the outer surface of the laminated structure **19**. The shield layer **21** formed of the insulating oil was provided outside the protection layer **18**, and the shield glass **23** which was bonded in place with the epoxy-based adhesive **22** to form tile shield layer **21** was positioned outside the shield layer **21**. Further, the inlet **24** provided in the shield glass **23** was sealed with a glass cover **26** which was bonded in place with the epoxy-based adhesive **25**. The opposite electrode **17** was also in contact with the ITO Film **12a** Formed on the surface of the glass plate **11**.

EXAMPLE 9

A laminated structure having an ITO electrode, a hole-injecting layer, a light-emitting layer and an opposite electrode was formed on a glass plate in the same manner as in Example 5.

Then, a fluorine-containing polymer layer [PCTFE thin film (protection layer)] having a layer thickness of 1.2 μm (1,200 nm) was formed on the outer surface of the laminated structure formed on the glass plate in the same manner as in Example 5 except that 1.8 g of pellets of polychlorotrifluoroethylene (PCTFE) (trade name: Kel-F, supplied by 3M Co., Ltd.) was used as a deposition source and that the temperature for heating the deposition source was set at 478° C. At this time, the substrate temperature was at room temperature. The formation of the protection layer on the outer surface of the laminated structure gave an organic EL device A_8 of the present invention.

Thereafter, a shield layer was formed outside the protection layer in the same manner as in Example 6 to give an organic EL device B_4 of the present invention.

EXAMPLE 10

A laminated structure having an ITO electrode, a hole-injecting layer, a light-emitting layer and an opposite electrode was formed on a glass plate in the same manner as in Example 5.

Then, a fluorine-containing polymer layer [Cytop thin film (protection layer)] having a layer thickness of 0.8 μm (800 nm) was formed on the outer surface of the laminated structure formed on the glass plate in the same manner as in Example 5 except that 1.5 g of a press plate of an amorphous radical polymer powder (trade name: Cytop, supplied by Asahi Glass Co., Ltd., intrinsic viscosity 0.425) obtained from 65.8 mol. % of tetrafluoroethylene and 34.2 mol % of perfluoroallylvinyl ether (CF_2=CF—O—CF_2—CF=CF_2) was used as a deposition source for a protection layer and that the temperature for heating this deposition source was set at 460° C., At this time, the substrate temperature was at room temperature. The formation of the protection layer on the outer surface of the laminated structure gave an organic EL device A_9 of the present invention.

A shield layer was formed outside the protection layer in the same manner as in Example 6 to give an organic EL device B_5 of the present invention.

COMPARATIVE EXAMPLE 1

Example 1 was repeated except that the fluorine-containing polymer layer [PCTFE thin film] was not formed, to give an organic EL device.

COMPARATIVE EXAMPLE 2

Example 3 was repeated except that the fluorine-containing polymer layer [Teflon AF thin film] was not formed, to give an organic EL device.

COMPARATIVE EXAMPLE 3

Example 4 was repeated except that the fluorine-containing polymer layer [Cytop thin film] was not formed, to give an organic EL device.

COMPARATIVE EXAMPLE 4

An organic EL device (having no protection layer) was obtained in the same manner as in Example 5, and neither a protection layer nor a shield layer was formed on this organic EL device.

COMPARATIVE EXAMPLE 5

An organic EL device (having no protection layer) was obtained in the same manner as in Example 5, and a cured layer of an epoxy-based adhesive was formed directly on the opposite electrode of this organic EL device in the same manner as in Example 7.

The organic EL devices obtained in the above Examples 1 to 10 and Comparative Examples 1 to 5 were tested on their lives in the following manner.

Life Test 1

The organic EL devices obtained finally in Example 1, Example 2, Example 3, Example 4, Comparative Example 1, Comparative Example 2 and Comparative Example 3 were allowed to stand in the atmosphere for 2 days, and then, while a direct current at a constant value (1.0 mA) was being applied to each sample, the brightness and charged voltage were measured in the atmosphere at predetermined time intervals.

Of these measurement results, the results of measurement of the organic EL devices obtained in Example 1, Example 2 and Comparative Example 1 for a brightness are shown in FIG. 5, the results of measurement of the organic EL devices obtained in Example 1, Example 2 and Comparative Example 1 for a charged voltage, in FIG. 6, the results of measurement of the organic EL devices obtained in Example 3 and Comparative Example 2 for a brightness, in FIG. 7, the results of measurement of the organic EL devices obtained in Example 3 and Comparative Example 2 for a charged voltage, in FIG. 8, the results of measurement of the organic EL devices obtained in Example 4 and Comparative Example 3 for a brightness, in FIG. 9, and the results of measurement of the organic EL devices obtained in Example 4 and Comparative Example 3 for a charged voltage, in FIG. 10.

The measurement of the brightness was carried out, as shown in FIG. 11, by continuously providing a current from a current generator 36 to an organic EL device 30 in which an ITO electrode 32 formed on the surface of a substrate 31 of the organic EL device 30 was an anode and an opposite electrode 35 formed on the ITO electrode 32 through a hole-injecting layer 33 and a light-emitting layer 34 was a cathode, photoelectrically transferring light L from the organic EL device 30 with a photodiode 37 and calculating a relative brightness on the basis of the value of an output voltage from the photodiode 37. Further, the charged voltage was measured with time by means of a voltmeter 38 as shown in FIG. 11. In addition, in the organic EL device 30 shown in FIG. 11, a laminated structure having the ITO electrode 32, the hole-injecting layer 33, the light-emitting layer 34 and the opposite electrode 35 was provided with a protection layer 39 on the outer surface thereof.

As is clear in FIGS. 5 to 10, the lives of the organic EL devices of the present invention obtained in Examples 1 to 4 are overwhelmingly longer than those of the organic EL devices of Comparative Examples 1 to 3 which were provided with no protection layer on the outer surfaces of their laminated structures. This shows that the infiltration of water and oxygen into the light-emitting layers has been prevented by the protection layers.

Life Measurement 2

The organic EL devices finally obtained in Example 1, Example 4, Example 3, Example 6, Example 7, Example 8, Example 9, Example 10 and Comparative Example 5 were allowed to stand in atmosphere for 7 days, and then a direct current was provided to each sample such that the initial brightness was 100 cd/m^2. Thereafter, each sample was measured for a brightness at a constant current (direct current value at which the initial brightness was 100 cd/m^2) in the atmosphere at predetermined time intervals, and a time required for the brightness to be reduced to ½ of the initial brightness was measured. Further, while a current was continuously applied after the brightness was reduced to ½, a time required for the brightness to be reduced to 0 cd/m^2 was measured, and this time was taken as a destruction time of the device.

In addition, the brightness was measured by continuously providing a current from a direct current source to the organic EL device in which the ITO film on which the electron-injecting layer was formed was an anode and the opposite electrode formed on the ITO film through the hole-injecting layer and the light-emitting layer was a cathode, photoelectrically transferring EL light from the organic EL device with a photodiode and calculating the brightness on the basis of the so-obtained output voltage.

Table 1 shows the measurement results.

TABLE 1

Organic EL device	Time required for brightness to be reduced to ½ of initial brightness*	Destruction time of device
Organic EL device A_1 of Example 1	120 hours	1,500 hours
Organic EL device A_4 of Example 4	100 hours	1,000 hours
Organic EL device A_5 of Example 5	100 hours	1,000 hours
Organic EL device B_1 of Example 6	1,200 hours	5,000 hours or more
Organic EL device B_2 of Example 7	700 hours	3,000 hours or more
Organic EL device B_3 of Example 8	1,100 hours	5,000 hours or more
Organic EL device B_4 of Example 9	1,500 hours	5,000 hours or more
Organic EL device B_5 of Example 10	1,200 hours	5,000 hours or more
Organic EL device of Comparative Example 4	30 hours	300 hours
Organic EL device of Comparative Example 5	Device was too corroded with adhesive to emit light	

*: Initial brightness was 100 cd/m^2.

As is shown in Table 1, any one of the organic EL devices having protection layers (organic EL devices A and organic EL devices B), obtained in Examples, has a much longer life than the organic EL device having no protection layer, obtained in Comparative Example. And, each of the organic EL devices having shield layers outside the protection layers, obtained in Examples 6 to 10, has a longer life than any one of the organic EL devices A of the present invention having the protection layers alone (organic EL devices A obtained in Examples 1, Example 4 and Examples 5).

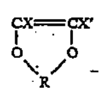
As is clear from the results of the above-described life test 1 and life test 2, organic EL devices having a long life can be provided by working the present invention.

We claim:

1. An organic electroluminescent device comprising

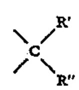
(a) a laminated structure including a light-emitting layer formed of a luminescent organic solid which is disposed between mutually opposing positive and negative electrodes, the luminescent organic solid being injectable with electrons from the negative electrode and holes from the positive electrode when direct current is charged between the positive electrode and the negative electrode and thereby having an excited state therein to recombine the electrons and the holes injected into the luminescent organic solid for light emission, and

(b) a film of an electrically insulating polymer compound as a protection layer which is deposited on an outer surface of the laminated structure, said film being formed of at least one layer of a fluorine-containing copolymer obtained by copolymerizing a monomer mixture containing tetrafluoroethylene and at least one cyclic ether compound having a carbon-carbon unsaturated bond of the formula



wherein each of X and X' is selected from the group consisting of F, Cl and H,

X and X' are the same or different from each other, and R is —CF=CF— or has the formula



wherein each of R' and R" is selected from the group consisting of F, Cl, —COF a —COO C_1–C_6-alkyl group, a C_1–C_6-alkyl group, an unsubstituted perfluorinated C_1–C_6-alkyl group and a hydrogen-substituted perfluorinated C_1–C_6-alkyl group.

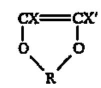
2. The organic electroluminescent device according to claim 1 wherein the protection layer is a film of an electrically insulating polymer compound formed by a physical vapor deposition method.

3. The organic electroluminescent device according to claim 2, wherein the physical vapor deposition method is a

4. An organic electroluminescent device comprising

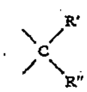
(a) a laminated structure comprising a light-emitting layer formed of a luminescent organic solid which is disposed between mutually opposing positive and negative electrodes, the luminescent organic solid being injectable with electrons from the negative electrode and holes from the positive electrode when direct current is charged between the positive electrode and the negative electrode and thereby having an excited state therein to recombine the electrons and the holes injected into the luminescent organic solid for light emission, and

(b) a film of an electrically insulating polymer compound as a protection layer deposited on an outer surface of the laminated structure, said protection layer with moisture resistance being provided with a shield layer on an outer surface of the protection layer, the film of the polymer having a layer structure formed of at least one layer of a fluorine-containing copolymer, wherein the fluorine-containing copolymer is a copolymer obtained by copolymerizing a monomer mixture containing tetrafluoroethylene and at least one cyclic ether compound having a carbon-carbon unsaturated bond of the formula



wherein each of X and X' is selected from the group consisting of F, Cl and H,

X and X' are the same or different from each other, and R is —CF=CF— or has the formula



wherein each of R' and R" is selected from the group consisting of F, Cl, —COF a —COO C_1–C_6-alkyl group, a C_1–C_6-alkyl group, an unsubstituted perfluorinated C_1–C_6-alkyl group and a hydrogen-substituted perfluorinated C_1–C_6-alkyl group.

5. The organic electroluminescent device according to claim 4, wherein the shield layer is formed of one selected from the group consisting of an electrically insulating glass, an electrically insulating polymer compound and an electrically insulating airtight fluid contained in an electrically insulating container.

6. An organic electroluminescent device comprising

(a) a laminated structure comprising a light-emitting layer formed of a luminescent organic solid which is disposed between mutually opposing positive and negative electrodes, the luminescent organic solid being injectable with electrons from the negative electrode and holes from the positive electrode when direct current is charged between the positive electrode and the negative electrode and thereby having an excited state therein to recombine the electrons and the holes injected into the luminescent organic solid for light emission, and

(b) a film of an electrically insulating polymer compound as a protection layer deposited on an outer surface of the laminated structure, said protection layer with moisture resistance being provided with a shield layer on an outer surface of the protection layer, the film of the polymer having a layer structure formed of at least one layer of a fluorine-containing copolymer, wherein the fluorine-containing copolymer is a copolymer obtained by radical-polymerizing (i) a perfluoroether having a double bond at each of the two terminals, represented by the formula (II),

$$CF_2{=}CF{-}(CF_2)_n{-}O{-}(CF_2)_m{-}CF{=}CF_2 \qquad (II)$$

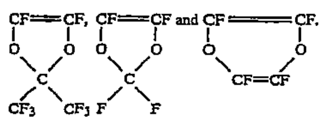
wherein each of m and n is independently of each other, an integer of 0 to 5, and m+n is an integer of 1 to 6 and (ii) a monomer radical-polymerizable with the perfluoroether of the formula (II).

7. The organic electroluminescent device according to claim 1, wherein said cyclic ether compound is in an amount of 0.01 to 99% by weight based on the total amount of the tetrafluoroethylene.

8. The organic electroluminescent device according to claim 1, wherein said cyclic ether compound is in an amount of 11 to 80% by weight based on the total amount of the tetrafluoroethylene.

9. The organic electroluminescent device according to claim 8, wherein the fluorine-containing copolymer has a glass transition point of not less than 50° C.

10. The organic electroluminescent device according to claim 9, wherein the cyclic ether compound is selected from the group consisting of

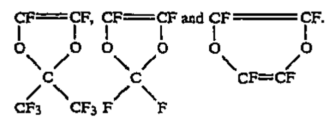


11. The organic electroluminescent device according to claim 13, wherein cyclic ether compound is in an amount of 0.01 to 99% by weight based on the total amount of the tetrafluoroethylene.

12. The organic electroluminescent device according to claim 13, wherein the cyclic ether compound is in an amount of 11 to 80% by weight based on the total amount of the tetrafluoroethylene.

13. The organic electroluminescent device according to claim 12, wherein the fluorine-containing copolymer has a glass transition point of not less than 50° C.

14. The organic electroluminescent device according to claim 13, wherein the cyclic ether compound is selected from the group consisting of



15. The organic electroluminescent device according to claim 6, wherein the perfluoroether is selected from the group consisting of perfluoroallylvinylether, perfluorodiallyether, perfluorobutenylvinylether, perfluorobutenylallylether and perfluorodibutenylether.

* * * * *

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04/12/94 XR 5,302,966

US005302966A

United States Patent [19]

Stewart

[11] **Patent Number: 5,302,966**

[45] **Date of Patent: Apr. 12, 1994**

[54] **ACTIVE MATRIX ELECTROLUMINESCENT DISPLAY AND METHOD OF OPERATION**

[75] Inventor: **Roger G. Stewart**, Neshanic Station, N.J.

[73] Assignee: **David Sarnoff Research Center, Inc.**, Princeton, N.J.

[21] Appl. No.: **892,464**

[22] Filed: **Jun. 2, 1992**

[51] **Int. Cl.**[5] **G09G 3/30**

[52] **U.S. Cl.** **345/76; 345/77;** 345/147; 315/169.3

[58] **Field of Search** ..... 340/781, 793, 718, 719, 340/784 CL, 825.81; 315/169.3; 307/264; 313/498; 345/76, 77, 78, 79, 80, 90, 89, 92, 55, 205, 206, 208, 209

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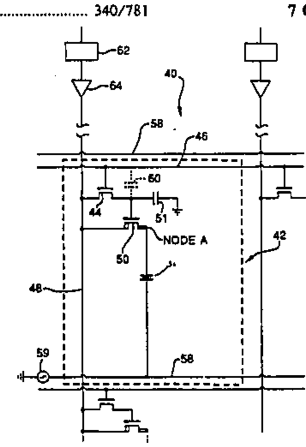
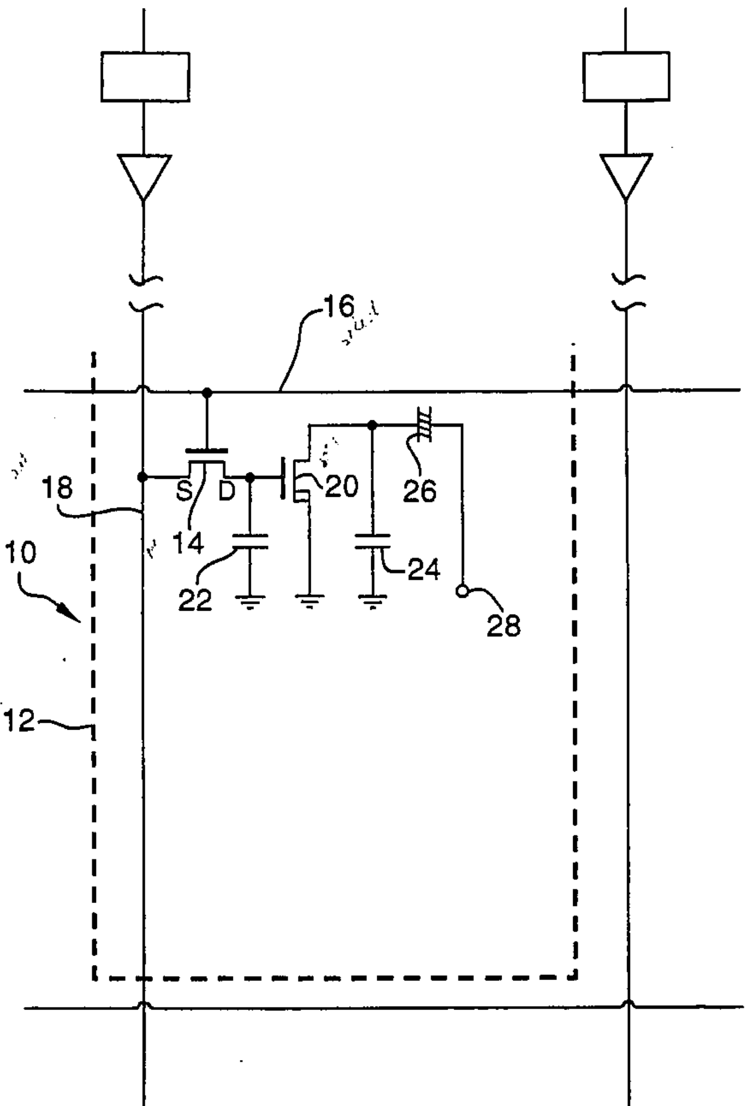
Primary Examiner—Tommy P. Chin
Assistant Examiner—A. Au
Attorney, Agent, or Firm—William J. Burke

[57] **ABSTRACT**

An active matrix electroluminescent display (AMELD) having an improved light emitting efficiency and methods of operating the AMELD to produce gray scale operation comprises a plurality of pixels, each pixel including a first transistor having its gate connected to a select line, its source connected to a data line and its drain connected to the gate of a second transistor, the second transistor having its source connected to the data line and its drain connected to a first electrode of an electroluminescent (EL) cell. The EL cell's second electrode is connected to alternating high voltage means. A method for producing gray scale performance including the step of varying the length of time the second transistor is on while the alternating voltage is applied to the EL cell is also disclosed.

7 Claims, 7 Drawing Sheets





PRIOR ART

Fig. 1

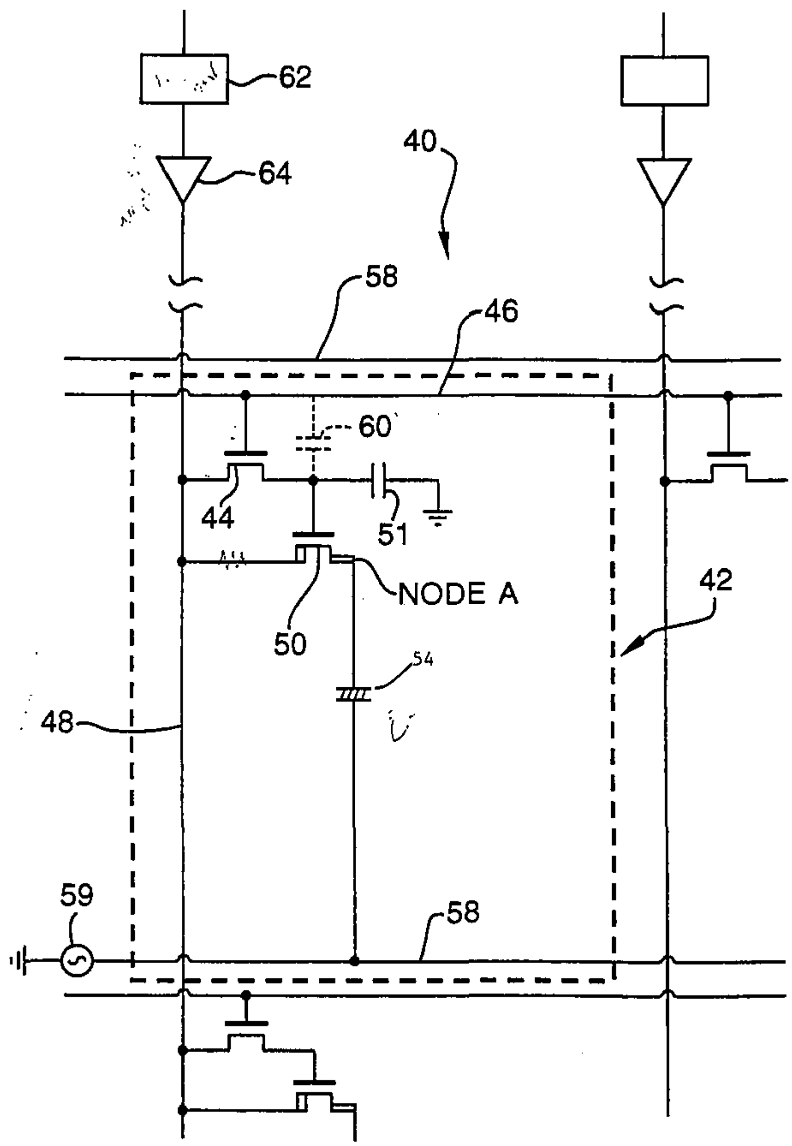


Fig. 2

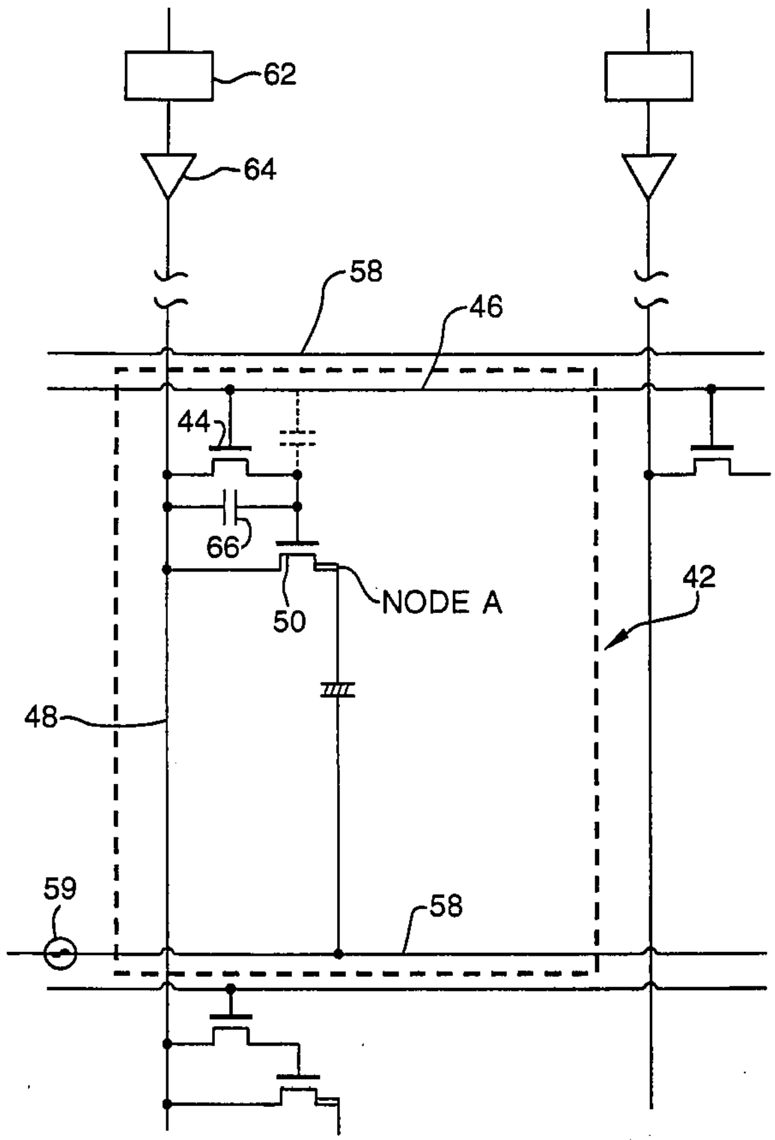


Fig. 2(a)

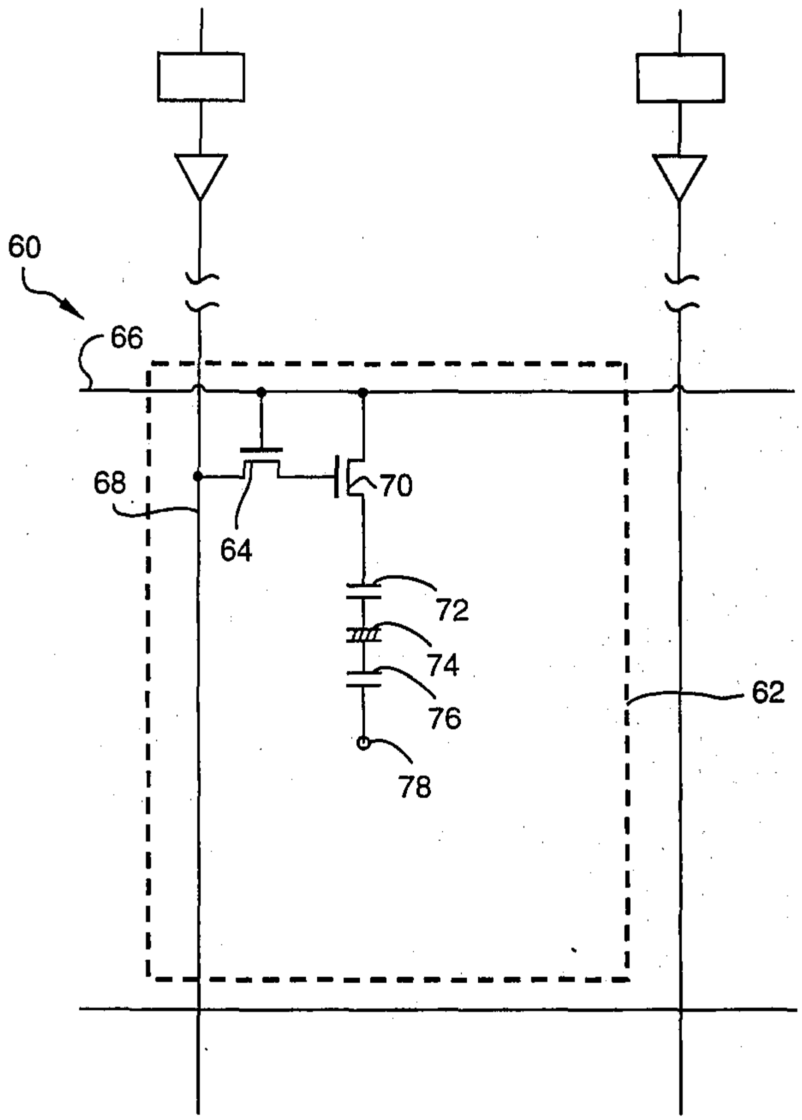
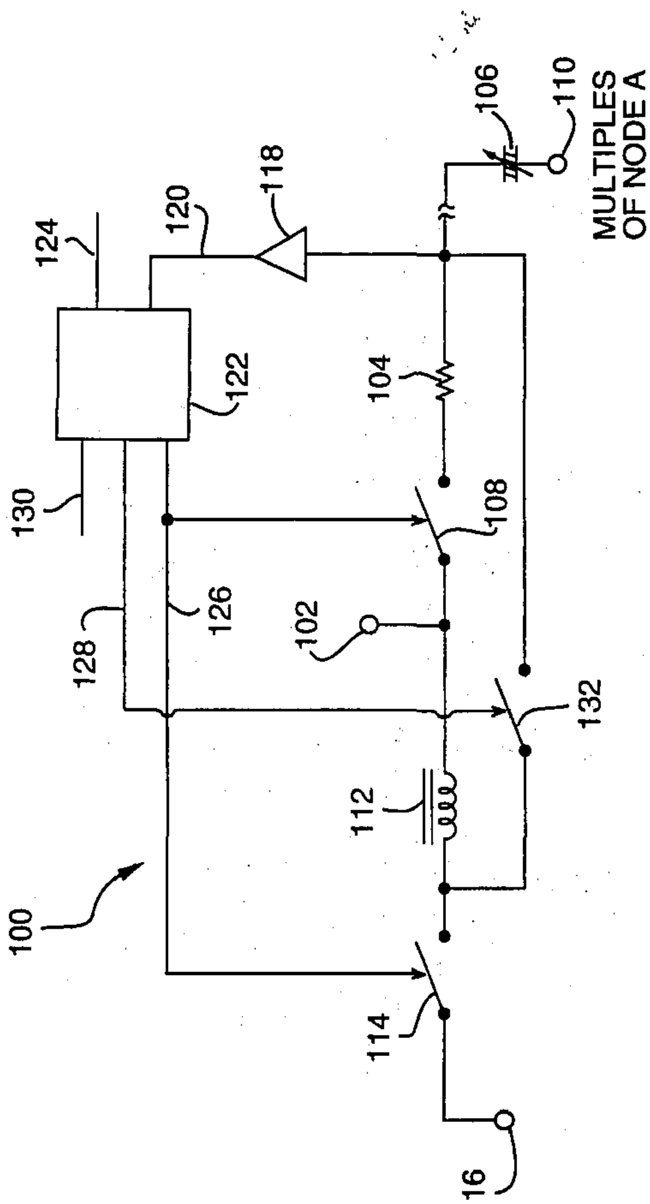


Fig. 3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MULTIPLES OF NODE A
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Fig. 4

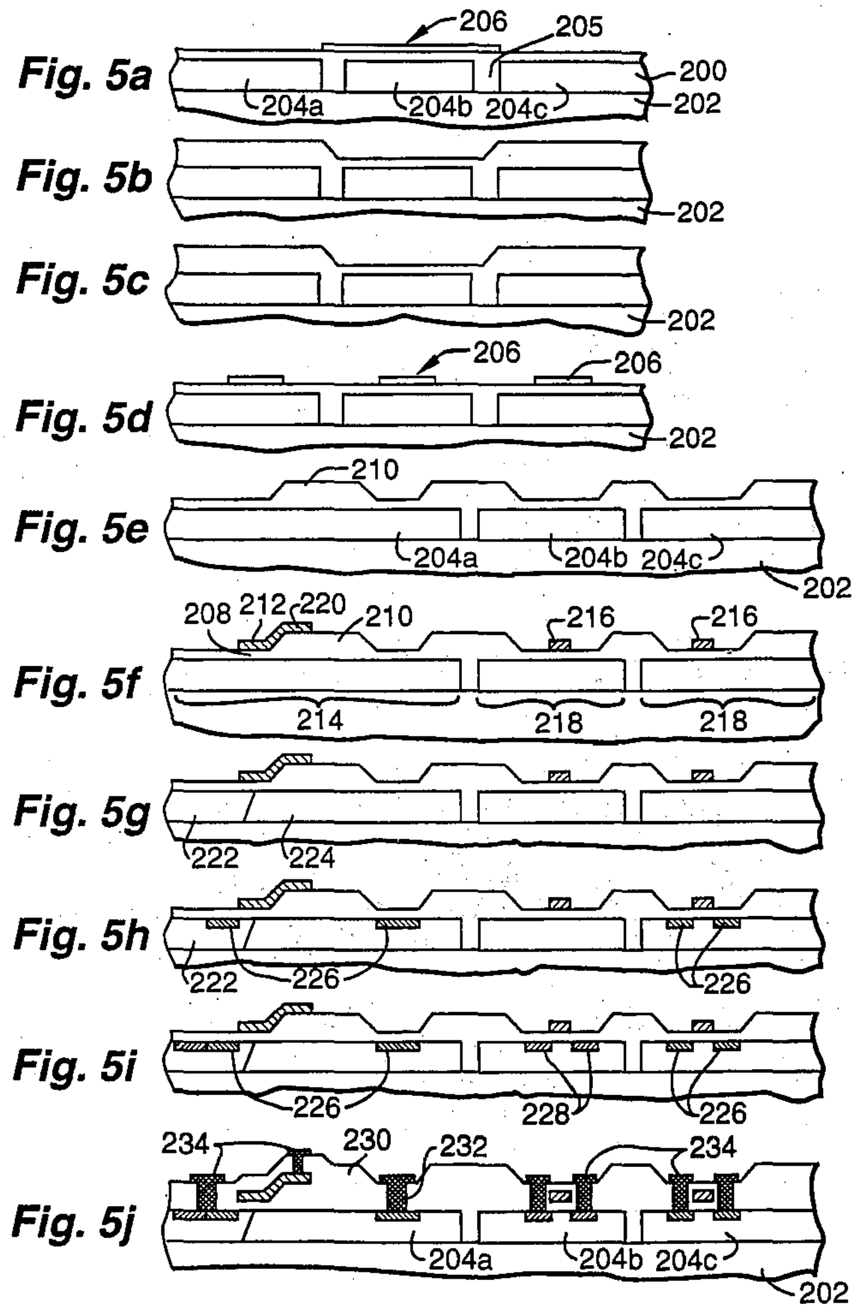
Fig. 5a
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204b
204c
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Fig. 5b
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Fig. 5c
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Fig. 5d
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Fig. 5e
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Fig. 5f
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Fig. 5g
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Fig. 5h
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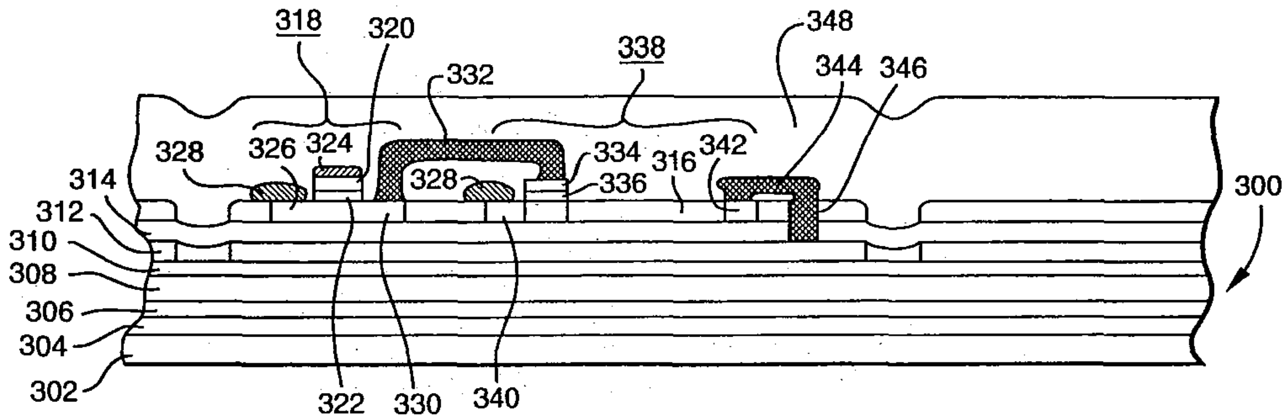
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Fig. 6

ACTIVE MATRIX ELECTROLUMINESCENT DISPLAY AND METHOD OF OPERATION

The invention is an active matrix electroluminescent display (AMELD) having an improved light emitting efficiency and methods of operating the AMELD to produce gray scale operation.

BACKGROUND OF THE INVENTION

Thin film electroluminescent (EL) displays are well known in the art and are used as flat screen displays in a variety of applications. A typical display includes a plurality of picture elements (pixels) arranged in rows and columns. Each pixel comprises an EL phosphor active layer between a pair of insulators and a pair of electrodes.

Early EL displays were only operated in a multiplexed mode. Recently active matrix technology known in the liquid crystal display art has been applied to EL displays. A known AMELD includes a circuit at each pixel comprising a first transistor having its gate connected to a select line, its source connected to a data line and its drain connected to the gate of a second transistor and through a first capacitor 22 to ground. The drain of the second transistor is connected to ground potential, its source is connected through a second capacitor to ground and to one electrode of an EL cell. The second electrode of the EL cell is connected to a high voltage alternating current source for excitation of the phosphor.

This AMELD operates as follows. During a first portion of a frame time (LOAD) all the data lines are sequentially turned ON. During a particular data line ON, the select lines are strobed. On those select lines having a select line voltage, transistor 14 turns on allowing charge from data line 18 to accumulate on the gate of transistor 20 and on capacitor 22, thereby turning transistor 20 on. At the completion of the LOAD cycle the second transistors of all activated pixels are on. During the second portion of the frame time (ILLUMINATE), the AC high voltage source 28 is turned on. Current flows from the source 28 through the EL cells 26 and the transistor 20 to ground in each activated pixels, producing an electroluminescent light output from the activated EL cell.

This AMELD and known variants require a number of components at each pixel and do not have gray scale operation. Thus there is a need for alternative AMELDs having fewer components and gray scale operation.

SUMMARY OF THE INVENTION

The invention is an AMELD comprising a plurality of pixels, each pixel including a first transistor having its gate connected to a select line, its source connected to a data line and its drain connected to the gate of the second transistor; the second transistor having its source connected to the data line and its drain connected to a first electrode of an electroluminescent (EL) cell and the EL cell having its second electrode connected to means for providing alternating voltage between the second electrode of the EL cell and a source of reference potential. The invention is also a method for producing gray scale performance by varying the length of time that the EL cell of a given pixel is on during the period of high voltage excitation of the pixel array.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a schematic circuit diagram for a pixel of a prior art AMELD.

FIG. 2 is a schematic circuit diagram for a pixel of an AMELD of the invention.

FIG. 2(*a*) an another embodiment of the AMELD of FIG. 2.

FIG. 3 is a schematic circuit diagram for a pixel of another embodiment of the AMELD of the invention.

FIG. 4 is schematic circuit diagram for a high voltage alternating current source used in the AMELD of the invention.

FIG. 5(*a*) to (*j*), is a schematic cross-sectional illustration of steps in a process for forming the active matrix circuitry.

FIG. 6 is a cross-sectional illustration of the structure of an alternative embodiment of the AMELD of the invention.

DETAILED DESCRIPTION

In FIG. 1 a prior art AMELD 10 includes a plurality of pixels arranged in rows and columns. The active matrix circuit at a pixel 12, i.e. the pixel in the Ith row and the Jth column comprises a first transistor 14 having its gate connected to a select line 16, its source connected to a data line 18 and its drain connected to the gate of a second transistor 20 and through a first capacitor 22 to ground. The source of transistor 20 is connected to ground, its drain is connected through a second capacitor 24 to ground and to one electrode of an EL cell 26. The second electrode of the EL cell 26 is connected to a high voltage alternating current source 28.

During operation, the 60 Hertz (Hz) field period of a frame is subdivided into separate LOAD and ILLUMINATE periods. During a LOAD period, data is loaded, one at a time, from the data line through transistor 14 allowing charge from data line 18 to accumulate on the gate of transistor 20 and on capacitor 22, in order to control the conduction of transistor 20. At the completion of the LOAD period, the second transistors of all activated pixels are on. During the ILLUMINATE period, the high voltage alternating current source 28 connected to all pixels is turned on. Current flows from the source 28 through the EL cell 26 and the transistor 20 to ground in each activated pixels, producing an electroluminescent light output from the pixel's EL cell.

In FIG. 2 an AMELD 40 includes a plurality of pixels arranged in rows and columns. The active matrix circuit at a pixel 42 comprises a first transistor 44 having its gate connected to a select line 46, its source connected to a data line 48 and its drain connected to the gate of a second transistor 50. A capacitor 51 is preferably connected between the gate of the second transistor 50 and the source of reference potential. The source of transistor 50 is also connected to the data line 48 and its drain connected to one electrode of an EL cell 54. The second electrode of the EL cell 54 is connected to a bus 58 for a single, resonant, 10 kilohertz (KHz)-AC high-voltage power source, such as that shown in FIG. 4, to illuminate the entire array at the same time. Also shown therefore a parasitic capacitor 60 which is between the gate and drain of the transistor 44 therefore is typically present in this structure. Each data line of the AMELD 40 is driven by circuitry including an analog-to-digital converter 62 and a low impedance buffer amplifier 64. Despite its complicated appearance the active matrix

PREFERRED EMBODIMENTS FOR WORKING THE INVENTION

As described above, the organic EL device of the present invention has a film of an electrically insulating polymer compound as a protection layer on the outer surface of a laminated structure in which at least a light-emitting layer formed of a luminescent organic solid is placed between two mutually opposing electrodes. The constitution of the above laminated structure includes the following ① to ④.

① electrode (cathode)/light-emitting layer/hole-injecting layer/electrode (anode)

② electrode (anode)/light-emitting layer/electron-injecting layer/electrode (cathode)

③ electrode (anode)/hole-injecting layer/light-emitting layer/electron-injecting layer/electrode (cathode)

④ electrode (anode or cathode)/light-emitting layer-/electrode (cathode or anode).

Any constitution may be used. In general, the laminated structure is formed on a substrate. The size, form, material, etc., of each of the substrate and the laminated structure are properly selected depending upon use of the intended organic EL device such as a surface light source, a pixel For graphic display, a pixel for a television image display device, etc. In addition, each of the above hole-injecting layer and the above electron-injecting layer refers to a layer having any one of charge injection properties, charge transport properties and charge barrier properties, and may have any one of a single-layered structure and a multi-layered structure. The material for these layers may be any one of an organic material and an inorganic material.

The organic EL device of the present invention has a film formed of an electrically insulating polymer compound as a protection layer on the outer surface of the above laminated structure. The protection layer may be formed at least on a main surface of the opposite electrode. However, the protection layer is particularly preferably formed on the entire outer surface of the laminated structure. Further, when the laminated structure has a layer structure in which the opposite electrode is formed on part of a main surface of one of the light-emitting layer, the hole-injecting layer and the electron-injecting layer, it is preferred to form a protection layer at least on that portion of the main surface of a layer underlying the opposite electrode where the opposite electrode is not formed and on the main surface of the opposite electrode.

The method for forming the protection layer of an electrically insulating polymer compound includes:

(1) a physical vapor deposition method (PVD method),

(2) a chemical vapor deposition method (CVD method),

(3) a casting method, and

(4) a spin coating method.

These methods are respectively detailed hereinafter.

(1) PVD method

(i) Kind, film-forming conditions, etc., of the PVD method

The PVD method includes a vacuum vapor deposition method (including a vapor deposition polymerization method), a sputtering method, etc. The vacuum vapor deposition method and the sputtering method can be sub-classified as below.

Vacuum vapor deposition method

Resistance heating method, electron beam heating method, high-frequency induction heating method, reactive vapor deposition method, molecular beam epitaxy method, hot wall vapor deposition method, ion plating method, ionized cluster beam method, vapor deposition polymerization method, etc.

Sputtering method

Diode sputtering method, diode magnetron sputtering method, triode and tetraode plasma sputtering methods, reactive sputtering method, ionized beam sputtering method, a method using a combination of these.

Any one of these methods can be employed. Concerning the PVD method, a vacuum vapor deposition method is particularly preferred.

The film forming conditions differ depending upon raw materials and the kind of the PVD method. For example, when a vacuum vapor deposition method (resistance heating method, electron beam heating method and high-frequency induction heating method) is used, preferred are conditions where the pressure before the vapor deposition is generally set at not more than 1×10^{-2} Pa, preferably not more than 6×10^{-3} Pa, the temperature for heating a deposition source is generally set at not more than 700° C., preferably not more than 600° C., the substrate temperature is generally set at not more than 200° C., preferably not more than 100° C., and the deposition rate is generally set at not more than 50 nm/second, preferably not more than 3 nm/second.

(ii) Kinds of the polymer compound used as a vapor deposition source.

The following polymer compounds (A) to (C) may be used as a deposition source.

(A) Fluorine-free polymer compounds such as polyethylene, polypropylene, polystyrene, polymethyl methacrylate, polyimide (obtained by depositing two monomers on a substrate to polymerize them, see ULVAC Technical Journal, 1988, 30, 22), polyurea (obtained by depositing two monomers on a substrate to polymerize them, see ULVAC Technical Journal, 1988, 30, 22),etc.

(B) Polytetrafluoroethylene, polychlorotrifluoroethylene, polydichlorodifluoroethylene, chlorotrifluoroethylene, a copolymer of chlorotrifluoroethylene and dichlorodifluoroethylene.

(C) Fluorine-containing copolymers having a cyclic structure in the main copolymerized chain.

(C-1) Fluorine-containing polymer compound disclosed in JP,A 63-18964, fluorine-containing polymer compound disclosed in JP,A 63-22206, fluorine-containing polymer compound disclosed in JP,A 63-238115.

(C-2) Fluorine-containing polymer compound disclosed in JP,A 3-129852.

The form of the polymer compound when it is used as a deposition source is not specially limited. The form may be powdery, particulate, bulk-like, disk-like or pellets-like. The form is properly selected depending upon the kind of the PVD method employed for forming the film.

When the polymer compound (B), (C-1) or (C-2) out of the above polymer compounds is used as a deposition source, there can be obtained, by a PVD method, a deposited film (protection layer) which is formed of the same polymer compound as the polymer compound used as a deposition source and is pin-hole free. Further, the decrease in the electric resistivity, breakdown strength and moisture resistance, entailed when the film is connected through a second capacitor 76 to a high voltage alternating current source 78.

In FIG. 4 a resonant 10 KHz, AC high voltage power source 100 capable of supplying power to the AMELD of the invention includes an input electrode 102 for receiving low voltage power at the desired pulse rate. A resistor 104 and an EL cell 106 are connected in series through a switch 108 between the electrode 102 and a node 110 which is all of the nodes A shown in FIG. 2. The EL cell 106 is shown as a variable capacitor because it behaves that way in the operation of the AMELD of the invention as discussed above. The input electrode 102 is also connected through an inductor 112 and a switch 114 to a source of reference potential 116. A comparator 118 is connected across the EL cell 106 to the reset input 120 of a set/reset latch 122. Set/reset latch 122 has a set input 124, an initial charge output 126, a bootstrap output 128 and an off output 130. The initial charge output 126, when activated, closes switches 108 and 114. The bootstrap output 128, when activated, opens switches 108 and 114 and closes switch 132 which is connected across the input electrode 102, the inductor 112, the switch 108 and the resistor 104; thereby providing a direct connection between the inductor 112 and the input of the EL cell 106. In operation, switches 108 and 114 are initially closed, current flows from input electrode through resistor 104, EL cell 106 and through inductor 112 to reference potential until comparator 118 senses that the preselected voltage on the variable capacitor load 106 has been reached. At this time comparator 118 resets the latch 122, opening switches 104 and 114 and closing switch 132. Inductor 112 then discharges through switch 132 and drives the voltage on the variable capacitor 106 to a fixed multiple of the preselected voltage. The values of the resistor 104 and the inductor 112 are chosen to provide a multiplication of the voltage applied to the input electrode 102. Preferably, the impedance of the resistor and inductor are such that a large fraction of the energy flows to the inductor. Approximately ninety-five percent of the current would flow into the inductor to achieve a voltage multiplication of twenty.

The AMELD of the invention can be formed using one of several semiconductor processes for the active matrix circuitry. The process which I believe will produce the best performance uses crystalline silicon (x-Si) as the material in which the high voltage transistors are formed. This process comprises forming the high voltage transistors, pixel electrodes and peripheral drive logic in/on the x-Si layer, and depositing the phosphors and other elements of the EL cell.

The key aspect of forming the x-Si layer is the use of the isolated silicon (Si) epitaxy process to produce a layer of high quality Si on a insulating layer as disclosed for example by Salerno et al in the Society For Information Display SID 92 Digest, pages 63-66. x-Si-on-insulator material (x-SOI) is formed by first growing a high quality thermal silicon oxide (SiO_x) of the desired thickness on a standard silicon wafer depositing a polycrystalline silicon (poly-Si) layer on the SiO_x and capping the poly-Si layer with an SiO_x layer. The wafer is then heated to near the melting point of Si and a thin movable strip heater is scanned above the surface of the wafer. The movable heater melts and recrystallizes the Si layer that is trapped between the oxide layers, producing single crystal Si layer. A particular advantage of the x-SOI process is the use of grown SiO_x, which can be made as thick as necessary, and much thicker and more dense than ion-implanted SiO_x layers.

The circuitry in/on the x-SOI is formed using a high voltage BiCMOS process for the fabrication of BiCMOS devices, such as transistors and peripheral scanners. Results indicate that high voltage (HV) transistors can be fabricated with breakdown voltages of over 100 V in/on 1 μm thick x-SOI. In FIG. 5(*a*) to (*f*), the high voltage BiCMOS process, shown schematically, starts with the etching of the N− conductivity type x-SOI layer 200, typically about 1 μm thick, on the dielectric layer 202 into discrete islands 204*a*, 204*b* and 204*c* isolated by oxide 205, forming both the P- and N-wells using masking and ion implantation steps; first of an N-type dopant, such as arsenic, then of a P-type dopant, such as boron, as shown, to form the N-type wells 204*a* and 204*c* and the P-type well 204*b*. Masks 206, typically formed of SiON, are shown in FIGS. 5(*a*) and (*d*). A channel oxide 208 and a thick field oxide 210 and are then grown over the surface of the Si islands to define the active regions, poly-Si is then deposited and defined to form the gate 212 of the high voltage DMOS transistor 214 and the gates 216 of the low voltage CMOS transistors 218. In FIG. 5(*f*), the gate 212 of the DMOS transistor extends from the active region over the field oxide, forming a field plate 220. The edge of the gate 212 that is over the active region is used as a diffusion edge for the P−-channel diffusion 222 while the portion of the gate that is over the field oxide is used to control the electric field in the N− type conductivity drift region 224 of the DMOS transistor 214. The N+-channel source/drain regions 226 are formed using arsenic ion implantation. The P+-channel source/drain regions 228 are then formed using boron ion implantation. The process is completed by depositing a borophosphosilicate glass (BPSG) layer 230 over the structure, flowing the BPSG layer 230, opening vias 232 down to the Si islands 204, and interconnecting the devices using aluminum metallization 234. The process has nine mask steps and permits the fabrication of both DMOS and CMOS transistors.

In operation, the N+-P− junction of the DMOS transistor 214 switches on at low voltage causing the transistor to conduct, while the N−-N+ junction holds off the voltage applied to the EL cell when the DMOS transistor is not conducting.

The high voltage characteristics of the DMOS transistors depend on several physical dimensions of the device as well as the doping concentrations of both the diffused P-channel and N-well drift region. The total channel length for a 300 V transistor is typically about 30 μm. The important physical dimensions are the length of the N-well drift region, typically about 30 μm, the spacing between the edge of the poly-Si gate in the active region and the edge of the underlying field oxide, typically about 4 μm, and the amount of overlap, typically about 6 μm, between the poly-Si gate over the field oxide and the edge of the field oxide. The degree of current handling in the DMOS transistor is also a function of some of these parameters as well as a function of the overall size of the transistor. Since a high density AMELD having about 400 pixels/cm is desirable, the pixel area (and hence the transistors) must be kept as small as possible. In some cases, however, the conditions that produce high voltage performance also reduce the overall current handling capability of the transistor and therefore require a larger transistor area for a given current specification. For example, the N-well doping concentration controls the maximum current and breakdown voltage inversely, usually making careful optimization necessary. However, this is much less of a factor in this approach, since the design eliminates the requirement for high current (only 1 μA/pixel needed).

The layer thicknesses can be adjusted to provide the required breakdown voltages and isolation levels for the transistors in the AMELD. High quality thermal SiO_x can be easily grown to the required thickness. This tailoring cannot be obtained easily or economically by other techniques. This x-SOI is characterized by high crystal quality and excellent transistors. A second advantage of the x-SOI process is the substrate removal process. Owing to the tailoring of the oxide layer beneath the Si layer, the substrate can be removed using lift-off techniques, and the resultant thin layer can be remounted on a variety of substrates such as glass, lexan, or other materials.

The process for forming the EL cell, whether monochrome or color, begins with the formation of the active matrix circuitry. The next steps are sequentially depositing the bottom electrode, which is preferably the source or drain metallization of the second transistor in the pixel circuit, the bottom insulating layer, the phosphor layer and the top insulating layer. The two insulating layers are then patterned to expose the connection points between the top electrodes and the active matrix, and also to remove material from the areas to which external connections will be made to the driver logic. The top transparent electrode, typically indium tin oxide, is then deposited and patterned. This step also serves to complete the circuit between the phosphors and the active matrix.

The process for forming a color phosphor layer comprises depositing and patterning the first phosphor, depositing an etch stop layer, depositing and patterning the second phosphor, depositing a second etch stop layer, and depositing and patterning the third phosphor. This array of patterned phosphors is then coated with the top insulator. Tuenge et al in U.S. Pat. No. 4,954,747 have disclosed a multicolor EL display including a blue $SrS:CeF_3$ or ZnS:Tm phosphor or a group II metal thiogallate doped with cerium, a green $ZnS:TbF_3$ phosphor and a red phosphor formed from the combination of ZnS:Mn phosphor and a filter. The filter is a red polyimide or CdSSe filter, preferably $CdS_{0.62}Se_{0.38}$, formed over the red pixels, or alternatively, incorporated on the seal cover plate if a cover is used. The red filter transmits the desired red portion of the ZnS:Mn phosphor (yellow) output to produce the desired red color. These phosphors and filters are formed sequentially using well known deposition, patterning and etching techniques.

The insulating layers may be Al_2O_3, SiO_2, SiON or $BaTa_2O_6$ or the like between about 10 and 80 nanometers (nm) thick. The dielectric layers may be Si_3N_4 or SiON. The presence of the insulating oxide layers improves the adhesion of the Si_3N_4 layers. The dielectric layers are formed by sputtering, plasma CVD or the like and the insulating oxide layers by electron beam evaporation, sputtering, CVD or the like. The processing temperature for the insulator deposition steps is about 500° C. The silicon wafer is exposed to a maximum temperature during processing would be 750° C. which is necessary to anneal the blue phosphor.

An alternative process to form the AMELD of the invention when a large area display is desired includes forming the transistors in amorphous silicon (a-Si) or poly-Si, although a-Si is preferred because better high voltage devices can presently be fabricated in a-Si as disclosed, for example, by Suzuki et al in the Society For Information Display SID 92 Digest, pages 344–347. In this case, whether a-Si or poly-Si is used, the process of forming the AMELD is reversed; the EL cell is first formed on a transparent substrate and the transistors are formed on the EL cell. In FIG. 6 an AMELD 300 incorporating a-Si transistors includes a transparent substrate 302, a transparent electrode 304, a first insulating layer 306, an EL phosphor layer 308 patterned as described above, a second insulating layer 310, a back electrode 312 and an isolation layer 314. The active matrix circuitry is formed on the isolation layer 314 in/on a a-Si island 316 deposited using standard glow discharge in silane techniques and isolated from adjacent islands using standard masking and etching techniques to define the pixels along with the segmentation of the back electrode 312. It is understood that the pixels can equally well be defined by segmenting the transparent electrode 304.

The first transistor 318 includes a gate 320 overlying a gate oxide 322 and connected to a select line 324, a source region 326 contacted by a data line bus 328, a drain region 330 connected by conductor 332 to a gate 334 overlying a gate oxide 336 of a second transistor 338. The second transistor 336 has a source region 340 contacted to the data line bus 328 and a drain region 342 connected by conductor 344 through opening 346 to the back electrode 312. The entire assembly is sealed by depositing a layer of an insulator 348 composed of a material such as BPSG.

It is to be understood that the apparatus and the method of operation taught herein are illustrative of the general principles of the invention. Modifications may readily be devised by those skilled in the art without departing from the spirit and scope of the invention. For example, different layouts of the components in a pixel are possible. Still further, the invention is not restricted to a particular type of high voltage excitation and pulse shape, to a particular type of power source or its capacity or to a particular transistor type. The system provided by the invention is not restricted to operation at a particular frequency.

I claim:

1. An electroluminescent display comprising an array of pixels, each pixel including

a first transistor having its gate connected to a select line, its source connected to a data line and its drain connected to the gate of a second transistor;

the second transistor having it source connected to the data line and its drain connected to a first electrode of an electroluminescent cell; and

said electroluminescent cell having a second electrode which is connected to means for providing an alternating voltage power source with the voltage power source means being connected between the second electrode and a source of reference potential.

2. The display of claim 1 wherein the means for providing an alternating voltage power source comprises a resonant alternating current high voltage power source.

3. The display of claim 2 wherein the power source includes:

first means for receiving an input voltage;

a resistor connected at one end and in series through a first switch to the first means and at another end to the second electrode of the electroluminescent cell;

an inductor connected to the first means and in series through a second switch to a source of reference potential;

a third switch connected across the first means, the inductor, the first switch and the resistor;

a comparator having an input connected to the second electrode of the electroluminescent cell and its output connected to an input of a set/reset latch, the latch having a second input, and first and second outputs;

wherein the first output of the latch, when activated, closes the first and second switches, the second output of the latch, when activated opens the first and second switches and closes the third switch;

wherein the values of the resistor and the inductor are chosen to provide a multiplication of the voltage applied to the first means.

4. The display of claim 1 wherein the second transistor is a drift type MOS transistor.

5. The display of claim 4 further comprising a capacitor connected between the gate of the second transistor and a source of reference potential.

6. The display of claim 4 further comprising a capacitor connected between said data line and the gate of the second transistor.

7. A method of operating an active matrix electroluminescent display, said display comprising a plurality of pixels, each pixel including a first transistor having its gate connected to a select line, its source connected to a data line and its drain connected to the gate of a second transistor; the second transistor having its source connected to the date line and its drain connected to a first electrode of an electroluminescent cell, the electroluminescent cell having a second electrode, the method comprising the steps of

applying voltages to the select and data lines to enable the second transistor of a given pixel;

applying a power source to the second electrode of the electroluminescent cell of the given pixel for a period of time; and

disabling the second transistor of the given pixel prior to the completion of said period of time.

* * * * *

US005847516A

United States Patent [19]

Kishita et al.

[11] Patent Number: 5,847,516
[45] Date of Patent: Dec. 8, 1998

[54] ELECTROLUMINESCENT DISPLAY DRIVER DEVICE

[75] Inventors: Hiroyuki Kishita, Kariya; Masahiko Osada, Hekinan; Hiroaki Himi, Nagoya; Nobuei Ito, Chiryu; Tadashi Hattori, Okazaki; Hideki Saito, Kariya, all of Japan

[73] Assignee: Nippondenso Co., Ltd., Kariya, Japan

[21] Appl. No.: 675,672

[22] Filed: Jul. 3, 1996

[30] Foreign Application Priority Data

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Aug. 11, 1995	[JP]	Japan	7-206344
Aug. 11, 1995	[JP]	Japan	7-206345

[51] Int. Cl.[6] G09G 3/12; G09G 3/30

[52] U.S. Cl. 315/169.3; 315/169.1; 345/204; 345/209; 345/76; 345/79

[58] Field of Search 315/169.1, 169.3; 345/76, 95, 210, 211, 79, 204, 209, 208

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5-333815	12/1993	Japan.	
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Primary Examiner—Arnold Kinkead
Attorney, Agent, or Firm—Pillsbury Madison & Sutro LLP

[57] ABSTRACT

A scan driver IC for an EL element in an EL display device supplies, in a positive field, a positive polarity scan voltage and an offset voltage which is higher than ground to scan side driver ICs from voltage supply circuits, and the scan side driver ICs set voltage of scan electrodes to be the offset voltage in the positive field, together with outputting the positive polarity scan voltage to the scan electrodes during electroluminescence timing. Consequently, a voltage of Vr–Vm is applied to the scan side driver ICs, and so the breakdown voltage can be lowered by an amount corresponding to the offset voltage Vm. Circuits for providing such voltages, for providing alternating current drive voltages, and for reducing power consumption of the drive circuits are also disclosed.

12 Claims, 11 Drawing Sheets

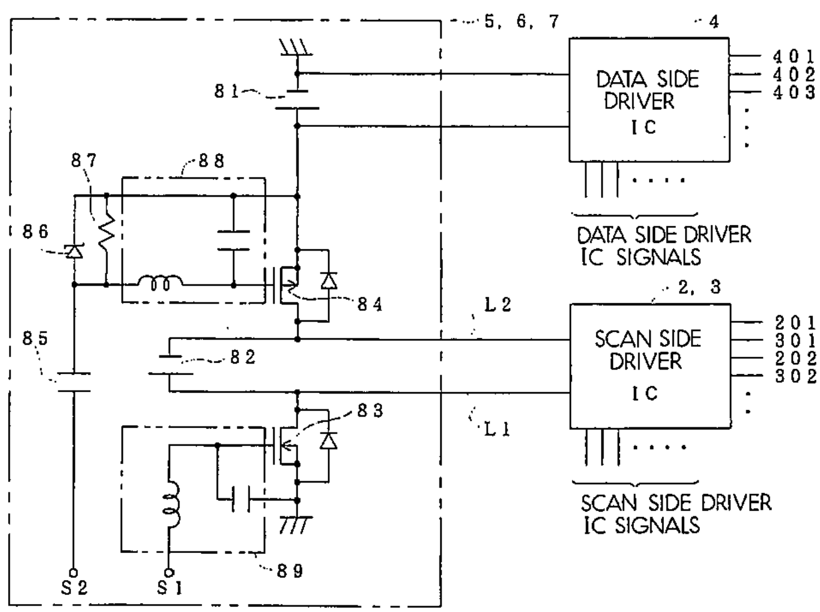


FIG.1

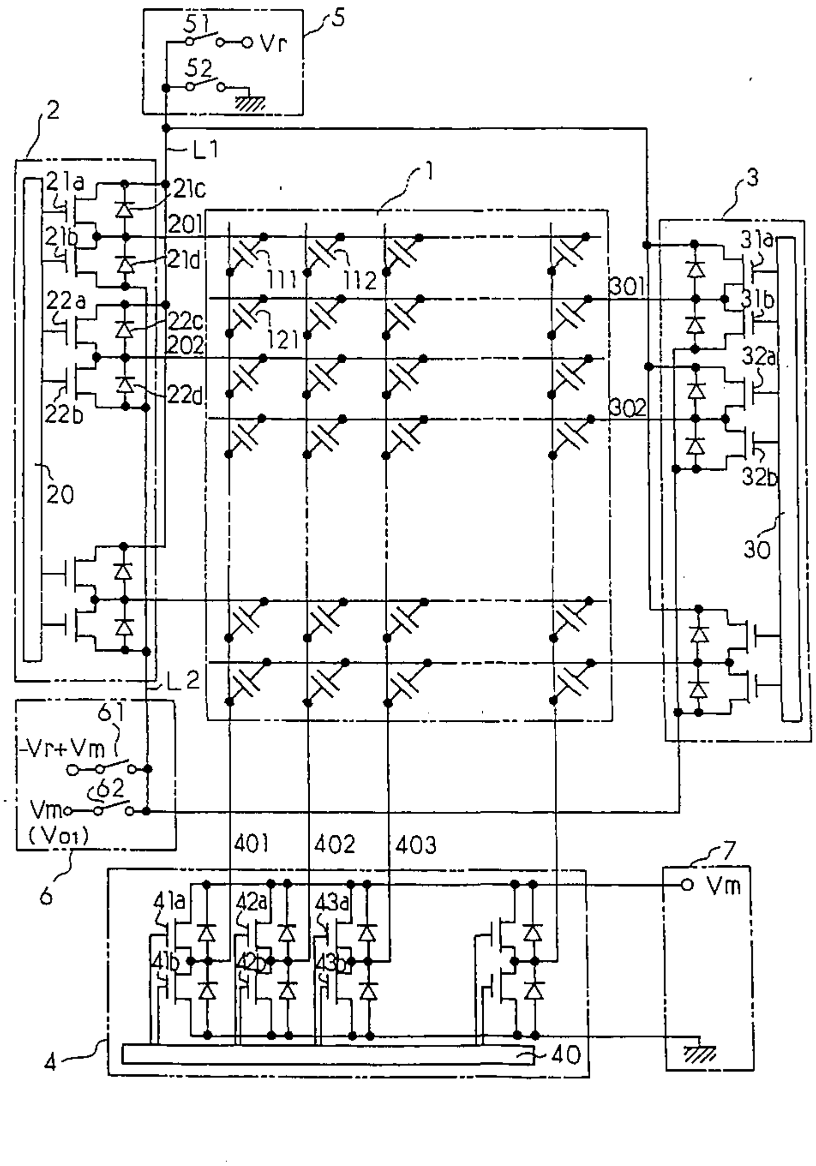

51
Vr
52
5
2
L1
21a
21c
1
3
201
21b
21d
111
112
301
31a
31b
22a
22c
121
202
32a
22d
22b
302
32b
20
30
L2
61
-Vr+Vm
62
Vm
(Vo1)
6
401
402
403
7
Vm
41a
42a
43a
41b
42b
43b
4
40

FIG. 2

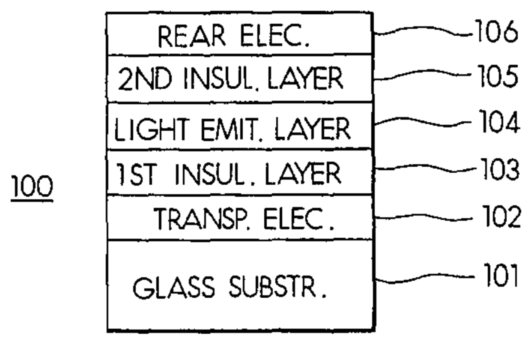


FIG. 8

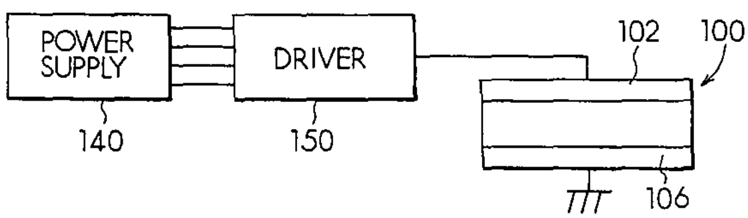
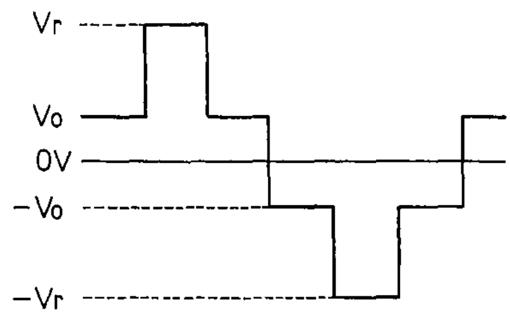


FIG. 9



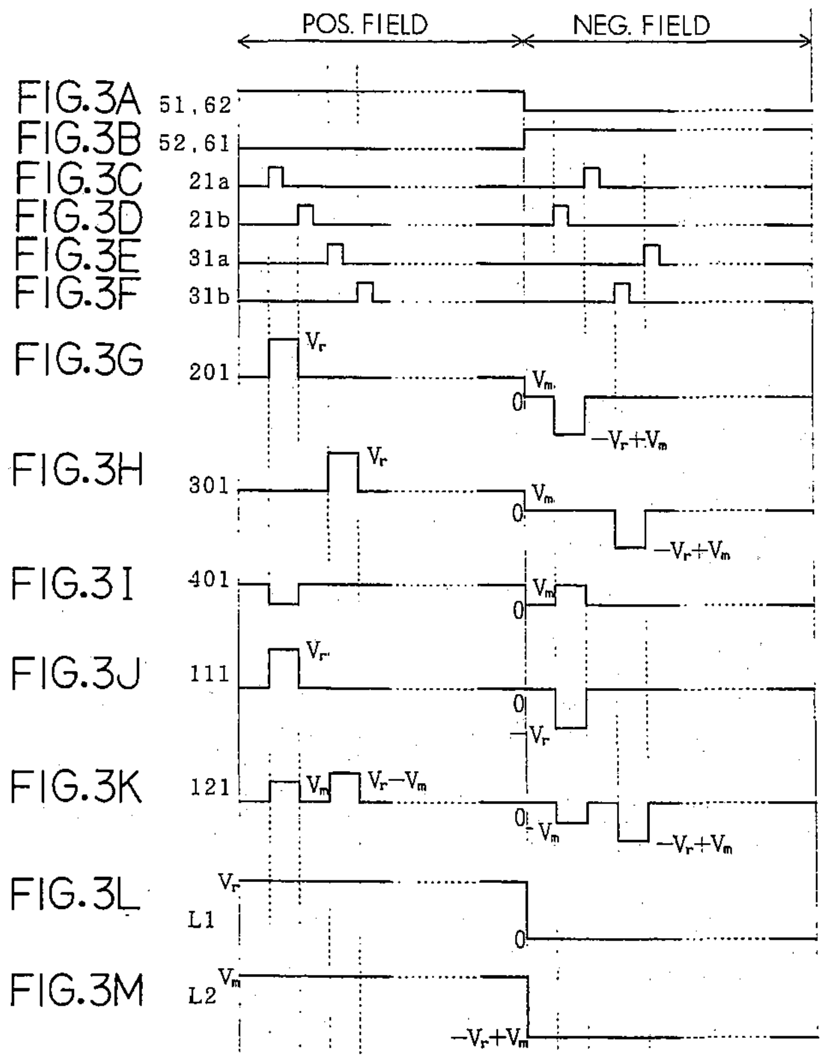

POS. FIELD
NEG. FIELD
FIG.3A 51,62
FIG.3B 52,61
FIG.3C 21a
FIG.3D 21b
FIG.3E 31a
FIG.3F 31b
FIG.3G 201
FIG.3H 301
FIG.3I 401
FIG.3J 111
FIG.3K 121
FIG.3L L1
FIG.3M L2
Vr
Vm
0
−Vr+Vm
−Vr
Vr−Vm

FIG. 4

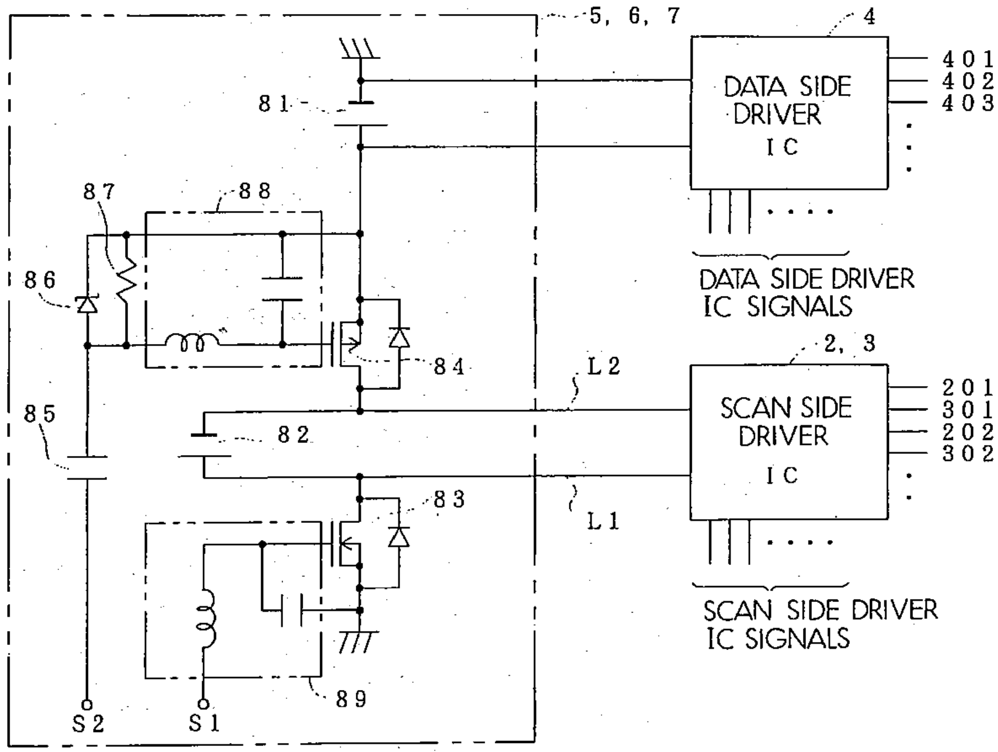
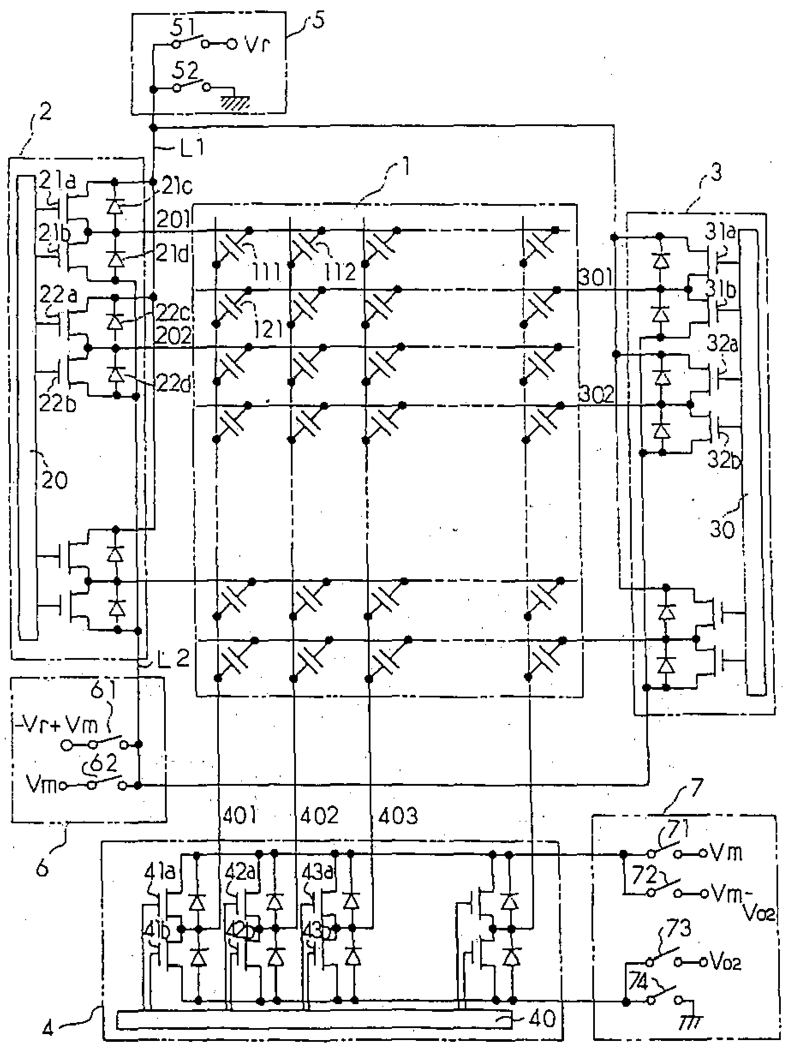

5, 6, 7
4
DATA SIDE DRIVER IC
401
402
403
81
87
88
86
84
85
82
83
89
S2
S1
L2
L1
DATA SIDE DRIVER IC SIGNALS
2, 3
SCAN SIDE DRIVER IC
201
301
202
302
SCAN SIDE DRIVER IC SIGNALS

FIG. 5


51
Vr
5
52
2
L1
1
3
21a
21c
21b
201
21d
111
112
301
31a
31b
22a
22c
202
121
32a
22d
302
22b
32b
20
30
L2
61
-Vr+Vm
62
Vm
401
402
403
7
71
Vm
6
41a
42a
43a
72
Vm-V02
41b
42b
43b
73
V02
74
4
40

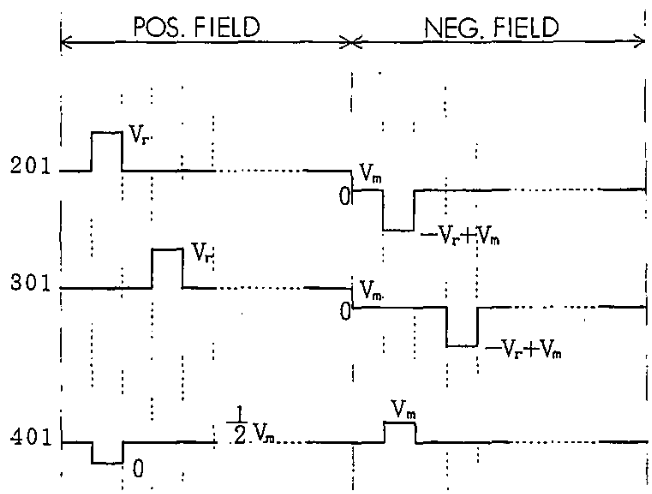


FIG.6A

FIG.6B

FIG.6C

FIG.7

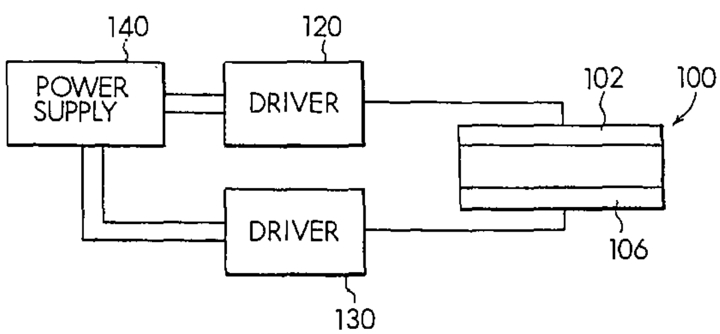
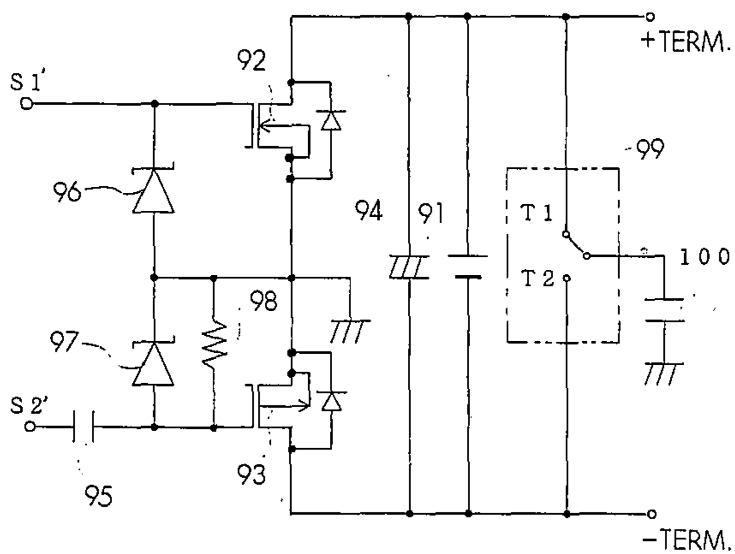


FIG.10


S1'
92
96
94
91
99
T1
T2
100
98
97
S2'
95
93
+TERM.
-TERM.

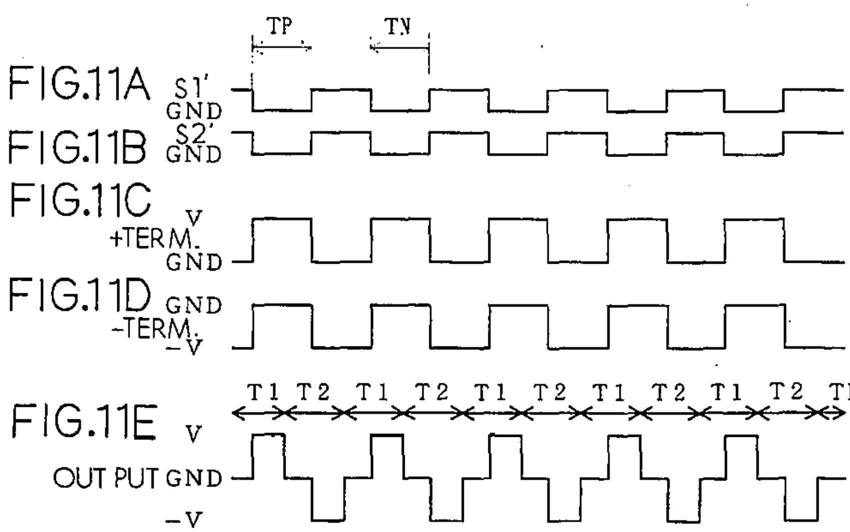

TP
TN
FIG.11A S1' GND
FIG.11B S2' GND
FIG.11C V +TERM. GND
FIG.11D GND -TERM. -V
T1 T2 T1 T2 T1 T2 T1 T2 T1 T2 T1
FIG.11E V OUT PUT GND -V

FIG.12

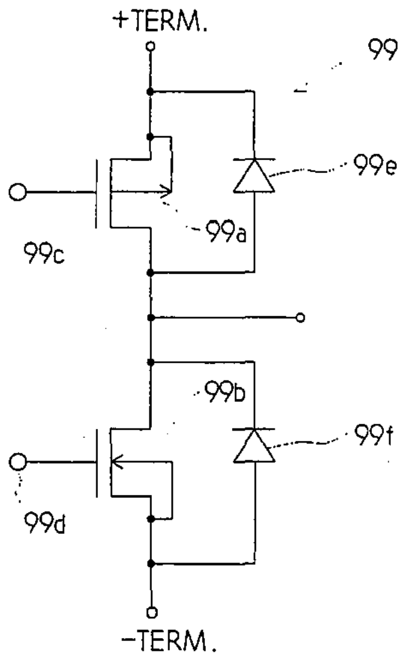


FIG.15 PRIOR ART

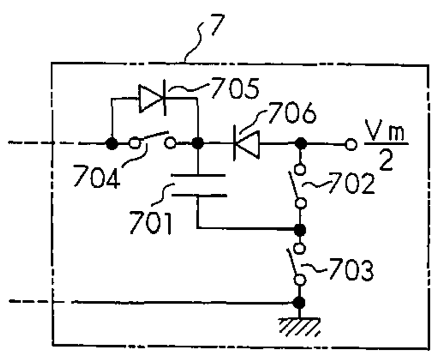
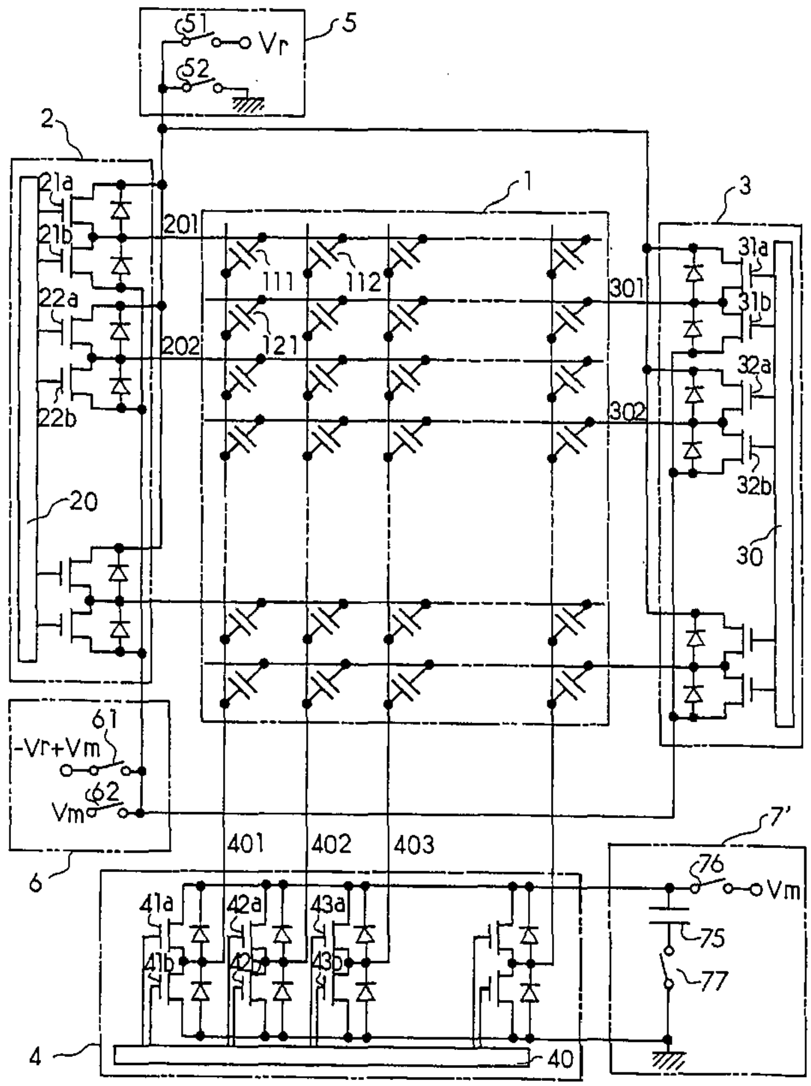
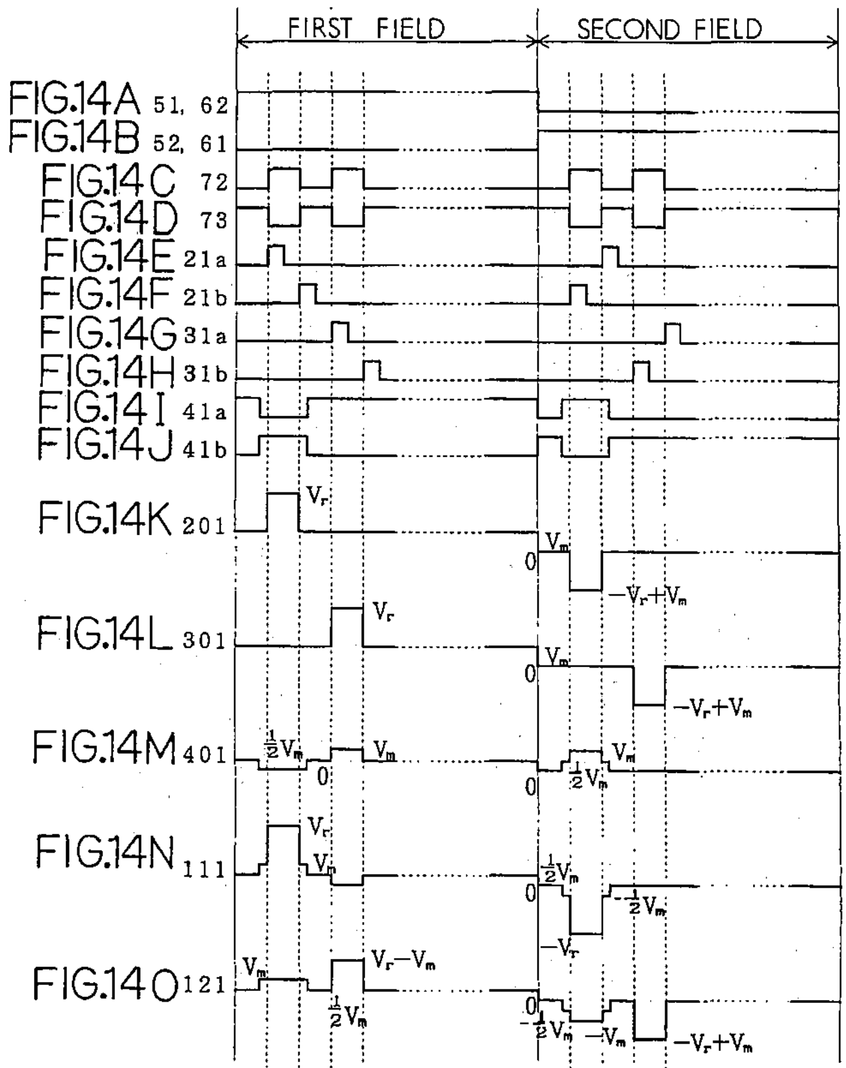


FIG.13


51
Vr
5
52
2
1
3
21a
21b
201
111
112
301
31a
31b
22a
121
202
32a
22b
302
32b
20
30
61
-Vr+Vm
62
Vm
401
402
403
7'
6
76
Vm
41a
42a
43a
75
41b
43b
77
4
40


FIRST FIELD
SECOND FIELD
FIG.14A 51, 62
FIG.14B 52, 61
FIG.14C 72
FIG.14D 73
FIG.14E 21a
FIG.14F 21b
FIG.14G 31a
FIG.14H 31b
FIG.14I 41a
FIG.14J 41b
FIG.14K 201
FIG.14L 301
FIG.14M 401
FIG.14N 111
FIG.14O 121
Vr
Vm
0
−Vr+Vm
1/2Vm
−1/2Vm
−Vr
Vr−Vm
−Vm

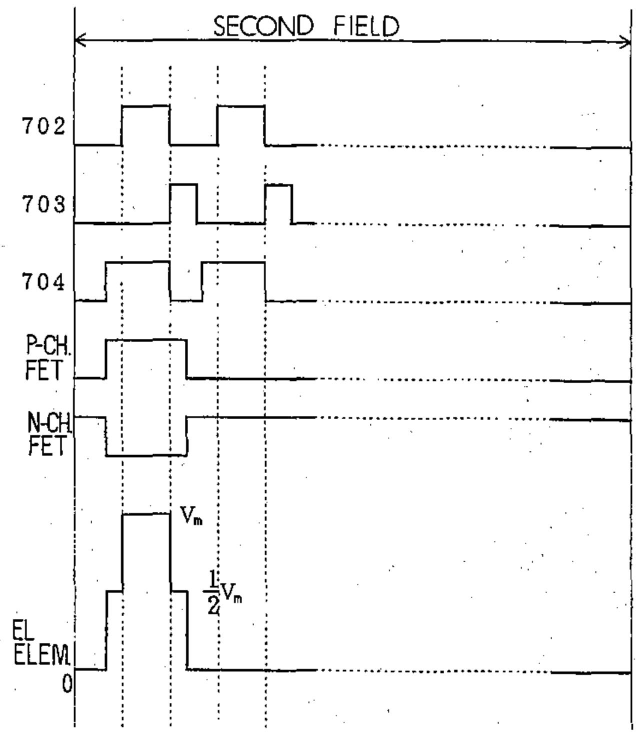


FIG.16A PRIOR ART
FIG.16B PRIOR ART
FIG.16C PRIOR ART
FIG.16D PRIOR ART
FIG.16E PRIOR ART
FIG.16F PRIOR ART

ELECTROLUMINESCENT DISPLAY DRIVER DEVICE

CROSS-REFERENCE TO RELATED APPLICATION

The present application is related to and claims priority from Japanese Patent Application Nos. Hei. 7-168822, 7206344 and 7-206345, incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a circuit for driving an electroluminescent (EL) display device.

2. Description of Related Art

A device disclosed in Japanese Patent Application Laid-Open Publication No. Hei 5-333815 is known as a circuit for driving an EL display.

According to this device, EL elements in the display are arranged in a matrix and a scan side driver IC and data side driver IC are respectively provided on a scan side and data side of the display elements. Accordingly, drive voltage pulses having a differing polarity with each positive and negative field are applied to the EL elements by the respective driver ICs and the EL elements emit light.

That is to say, in the positive field, a ground voltage (0 V) is taken to be a reference voltage and a voltage Vr corresponding to an EL drive voltage is output to a scan electrode of the EL display from the scan side driver IC, and from the data side driver IC, the ground voltage is output to the EL element so that it emits light, a modulation voltage Vm is output to a data electrode of an EL element to put it in a non-electroluminescent state, voltage of the data electrode is grounded with respect to the scan electrode to which the voltage Vr has been output, the Vr voltage is applied to the EL element, and the EL element emits light.

Additionally, in the negative field, ground voltage (0 V) is taken to be a reference voltage and a voltage of −Vr+Vm is output to the scan electrode from the scan side driver IC, and from the data side driver IC, the modulation voltage Vm is output to the EL element so that it emits light, the ground voltage is output to a data electrode of an EL element to put it in a non-electroluminescent state, voltage of the data electrode is set at the modulation voltage Vm with respect to the scan electrode to which voltage of −Vr+Vm has been output, −vr voltage is applied to the EL element, and the EL element emits light.

In a case wherein drive such as the foregoing is performed, the power source voltages of the scan side driver IC becomes Vr and ground voltage when driving in the positive field, and so the voltage Vr is applied to the scan side driver IC, and consequently the breakdown voltage thereof must be Vr or higher. Because the EL element is driven at a comparatively high voltage which becomes, for example, approximately 260 V, a device with high breakdown voltage as the scan side driver IC becomes necessary. Because a general purpose driver IC does not have such a high breakdown voltage, it is necessary to specially design a high breakdown voltage driver IC which has a high breakdown voltage to satisfy the above requirements, and this causes problems in terms of integration and cost. These considerations also apply to the data side driver side IC.

Further, when the rear electrode has been grounded and a positive and negative alternating current signal is applied to the transparent electrode, two types of positive and negative power sources normally become necessary, and power source circuitry becomes large.

Also, driving the above-described prior art device, electrical charging and discharging with respect to the EL display panel is performed at each scan line electroluminescence operation, and there exists a problem wherein drive power consumption per cycle becomes large.

The device disclosed in Japanese Patent Publication Laid-Open No. 63-168998 attempts to solve this problem. After an EL element has emitted light, accumulated charge is stored in a capacitor provided externally, and this accumulated charge is reused during subsequent electroluminescence, thereby reducing power consumption.

As shown in FIG. 15, this circuit includes a data voltage supply circuit 7 having a charge collection capacitor **701**, switching elements **702** through **704**, and diodes **705** and **706**, and Vm/2 is utilized as the power source voltage. The size of the charge collection capacitor **701** is sufficiently large in comparison with the charge capacity of the entirety of the EL display panel, and a charge equivalent to Vm/2 is charged therein as an initial state.

Operation of this device will be described hereinafter with reference to the graphs shown in FIGS. **16A–16F**.

In the second field, when performing drive for a predetermined scan line, firstly the switching element **704** is switched on as shown in FIG. 16C, a P-channel FET connected to a data electrode of an EL element to emit light is switched on and a corresponding N-channel FET is switched off as shown in FIGS. **16D** and **16E**, and voltage Vm/2 is applied to the data electrode as shown in FIG. **16F**.

Next, the switching element **702** is switched on as shown in FIG. **16A**, voltage Vm being power source voltage Vm/2 with Vm/2 corresponding to a capacitor charge added thereto is applied to the data electrode of the EL element to emit light, and the EL element emits light. Subsequent to this electroluminescence operation, the switching elements **702** and **704** are switched off, and approximately half of the charge output from the P-channel FET of the data side driver IC **4** is collected via the diode **705** in the charge collection capacitor **701**.

The collected charge is consumed when switching on the switching element **704** in the subsequent scan line selection period. This operation is repeated until the final line.

However, structure and operation of the charge collection capacitor **701** of the above-described device are complex, and there are problems where applied voltage at the time of the next scan line selection is affected by an amount of accumulated capacitor charge and is unstable, and so on.

SUMMARY OF THE INVENTION

In light of the foregoing problems, it is an object of the present invention to provide a drive circuit that is able to drive an EL element, where the drive circuit for the EL element has a low breakdown voltage.

To attain the above-described object, an EL display device according to a first aspect of the present invention applies a scan voltage having a differing polarity with each positive and negative field to drive an EL display where the scan voltage includes, in a positive field, a positive polarity scan voltage and a first offset voltage which is higher than ground level to a scan electrode drive circuit from a voltage supply circuit, and the scan electrode drive circuit sets the voltage of a scan electrode to be the first offset voltage in the positive field, together with outputting the positive polarity scan voltage to the scan electrode during electroluminescence timing.

Consequently, because voltage supplied to the scan electrode drive circuit can be lowered by an amount corresponding to the first offset voltage relative to prior art devices, the necessary breakdown voltage of the scan electrode drive circuit can be reduced.

Preferably, the circuit supplies a modulation voltage to set electroluminescence/non-electroluminescence of an EL element and a second offset voltage which is higher than ground level to a data electrode drive circuit, where the data electrode drive circuit, in the negative field, with respect to a data electrode of an EL element in an electroluminescent state, sets voltage thereof at the modulation voltage, and with respect to a data electrode of an EL element in a non-electroluminescent state, sets voltage thereof at the second offset voltage.

Consequently, because voltage supplied to the data electrode drive circuit can be lowered by an amount corresponding to the second offset voltage than in a device according to the prior art, the necessary breakdown voltage of the data electrode drive circuit can be reduced.

Such a circuit need not be limited to use with matrix-type EL displays and may also be used in EL display devices which perform segmented display, backlighting or the like.

It is another object of the present invention to provide an EL display drive circuit which uses a single power source to apply a positive and negative alternating current voltage to an EL element when outputting alternating current voltage to a load such as an EL element or the like, without employing two types of positive and negative power sources.

This object is attained according to another aspect of the invention by providing a first switching device to open and close a connection between a positive electrode of a power source and a first reference voltage and a second switching device to open and close a connection between a negative electrode of the power source and a second reference voltage to be alternatively actuated in accordance with a control signal, and further to select a voltage of the power source positive electrode and negative electrode and to perform output for driving a load.

Because of this, voltage of negative polarity with a magnitude of the first reference voltage is created by the negative electrode of the power source when the first switching device has been actuated, and voltage of positive polarity with a magnitude of the second reference voltage is created by the positive electrode of the power source when the second switching device has been actuated.

Consequently, by selecting and outputting the created voltage, an alternating current signal is output and a load such as an EL element or the like can be driven by the output.

It is another object of the present invention to provide a circuit to perform charge collection and rise in voltage to at least two stages, and moreover, to stabilize the applied voltage at a time of collected charge reuse without being affected by an amount of accumulated capacitor charge.

This object is attained according to another aspect of the present invention by providing a circuit in which charging of an EL display element by a charge collected by a charge collecting capacitor is performed and a predetermined voltage is applied to the EL display element prior to electroluminescence drive for the EL display element, and thereafter, during electroluminescence drive, power source voltage (modulation voltage) is applied directly to the EL display element and a voltage rise is performed, and electroluminescence drive of the EL display element is performed. Subsequently to electroluminescence drive, charge stored in the EL display element is collected in the capacitor for charge collecting use.

Consequently, by structuring the device so that power source voltage (modulation voltage) is applied directly to the EL display element and a voltage rise is performed during electroluminescence drive, no need exists to create voltage corresponding to a power source voltage positive capacitor charging, and so the structure of a circuit for this purpose can be simplified, and moreover, applied voltage at a time of collected charge reuse can be stabilized without being affected by an amount of accumulated capacitor charge by directly applying a power source voltage.

Other objects and features of the invention will appear in the course of the description thereof, which follows.

BRIEF DESCRIPTION OF THE DRAWINGS

Additional objects and advantages of the present invention will be more readily apparent from the following detailed description of preferred embodiments thereof when taken together with the accompanying drawings in which:

FIG. 1 is a schematic diagram of an EL display device drive circuit according to a first preferred embodiment of the present invention;

FIG. 2 is a cross-sectional view showing the structure of an EL element;

FIGS. 3A–3M are timing diagrams for the device shown in FIG. 1;

FIG. 4 is a schematic diagram showing a specific structure of a voltage supply circuit according to the first embodiment;

FIG. 5 is a schematic diagram of an EL display device according to a second preferred embodiment of the present invention;

FIGS. 6A–6C are timing diagrams showing the operation of the device shown in FIG. 5;

FIG. 7 is a block diagram of a third preferred embodiment of the present invention used for driving a segmented EL display;

FIG. 8 is a block diagram showing a fourth preferred embodiment of the present invention as used in a backlight EL display;

FIG. 9 is a drive waveform diagram of the embodiment shown in FIG. 8;

FIG. 10 is a schematic diagram of a data voltage supply circuit according to a fifth preferred embodiment of the present invention;

FIGS. 11A–11E are timing diagrams of drive signals in the fifth embodiment;

FIG. 12 is a schematic diagram of an output circuit in the fifth embodiment;

FIG. 13 is a schematic diagram of an EL display element drive circuit according to a sixth embodiment of the present invention;

FIGS. 14A–14O are timing diagrams of drive signals in the sixth embodiment;

FIG. 15 is a schematic diagram of a prior art drive circuit; and

FIGS. 16A–16F are timing diagrams of drive signals in the prior art circuit.

DETAILED DESCRIPTION OF THE PRESENTLY PREFERRED EXEMPLARY EMBODIMENTS

FIG. 2 shows a typical cross-sectional structure of an EL display. An EL element 100 is formed by laminating on a glass substrate **101** the following: a transparent electrode **102**, a first insulating layer **103**, a light emitting layer **104**, a second insulating layer **105**, and a rear electrode **106**, and emits light responsive to an alternating current pulse applied between the transparent electrode **102** and the rear electrode **106**. Accordingly, in FIG. 2, light is emitted through this glass substrate **101**. Further, light can be emitted in both the upper and lower directions in the drawing when the rear electrode **106** is transparent.

FIG. 1 shows an overall structure of an EL display device according to a first embodiment of the present invention. In this Figure, an EL display panel **1** has a plurality of transparent electrodes and back electrodes in columns and rows as scan electrodes and data electrodes, and is structured to perform matrix display.

In specific terms, as shown in FIG. 1, odd-numbered scan electrodes **201**, **202**, **203**, etc. and even-numbered scan electrodes **301**, **302**, etc. are formed along the column direction of the display, and data electrodes **401**, **402**, **403**, etc. are formed along the row direction of the display **1**.

EL elements **111**, **112**, etc. are formed as pixels at intersections of the scan electrodes **201**, **301**, **202**, **302**, etc. and the data electrodes **401**, **402**, **403**, etc. The EL elements are capacitive elements and are represented by capacitor symbols in the Figure.

Scan side driver ICs **2** and **3** and a data side driver IC **4** are provided to perform display drive for this EL display panel **1**.

The scan side driver IC **2** is a push-pull type drive circuit having P-channel FETs **21a**, **22a**, etc. and N-channel FETs **21b**, **22b**, etc. connected to the odd-numbered scan electrodes **201**, **202**, etc. and applies scan voltage to the odd-numbered scan electrodes **201**, **202**, etc. in accordance with output from a control circuit **20**.

Additionally, parasitic diodes **21c**, **21d**, **22c**, **22d**, etc. are formed in each of the FETs **21a**, **21b**, **22a**, **22b**, etc. to establish the voltage of the scan electrodes at a desired reference voltage.

The scan side driver IC **3** has a similar structure, having a control circuit **30**, P-channel FETs **31a**, **32a**, etc. and N-channel FETs **31b**, **32b**, etc. and supplies scanning voltage to the even-numbered scan electrodes **301**, **302**, etc.

The data side driver IC **4** also has a control circuit **40**, P-channel FETs **41a**, **42a**, etc. and N-channel FETs **41b**, **42b**, etc. and supplies data voltage to the data electrodes **401**, **402**, **403**, etc.

Scan voltage supply circuits **5** and **6** are provided to supply scan voltages to the scan side driver ICs **2** and **3**. The scan voltage supply circuit **5** has switching elements **51** and **52** and, in accordance with on/off states thereof, supplies a DC voltage Vr or ground to a P-channel FET source side common line L1 in the scan side driver ICs **2** and **3**.

The scan voltage supply circuit **6** has switching elements **61** and **62** and, in accordance with on/off states thereof, supplies a direct current voltage −Vr+Vm or an offset voltage V_{01} to an N-channel FET source side common line L2 in the scan side driver ICs **2** and **3**. According to this embodiment, V_{01} is taken to be a modulation voltage Vm, and so will be described as Vm hereinafter.

Additionally, a data voltage supply circuit **7** is provided with respect to the data side driver IC **4**. The data voltage supply circuit **7** supplies a direct current voltage Vm to a P-channel FET source side common line of the data side driver IC **4** and supplies a ground voltage to an N-channel FET source side common line of the data side driver IC **4**.

According to the above-described structure, it is necessary to apply an alternating current pulse voltage between the scan electrode and the data electrode so that the EL element emits light, and because of this, a pulse voltage whose polarity reverses in each field is provided at each of the several scan lines to drive the display. Operation in positive and negative fields will be described hereinafter with reference to the timing diagrams shown in FIGS. 3A–3M.

In the positive portion of the field, the switching elements **51** and **62** are switched on, and the switching elements **52** and **61** are switched off. At this time, the reference voltage of the scan electrodes **201**, **301**, **202**, **302**, etc. becomes offset voltage Vm due to operation of the parasitic diodes of the FETs of the scan side driver ICs **2** and **3**. Additionally, the FETs **41a**, **42a**, **43a**, etc. of the data side driver IC **4** are switched on, and voltage of the data electrodes is Vm. In this state, voltage applied to all EL elements becomes 0 V, and so the EL elements do not emit light.

Thereafter, electroluminescence operation in the positive field is started. Firstly, the P-channel FET **21a** of the scan side driver IC **20** connected to the scan electrode **201** of the first column is switched on, and voltage of the scan electrode **201** is set to Vr. Additionally, output stage FETs of the scan side driver ICs **2** and **3** connected to other scan electrodes are all switched off, and these scan electrodes enter a floating state.

Additionally, among the data electrodes **401**, **402**, **403**, etc., a P-channel FET of the data side driver IC **4** connected to a data electrode of an EL element to emit light is switched off and an N-channel FET thereof is switched on, and a P-channel FET of the data side driver IC **4** connected to a data electrode of an EL element to not emit light is switched on and an N-channel FET thereof is switched off.

Because of this, the data electrode of the EL element to emit light is grounded, and so the voltage vr being a threshold voltage or more is applied to the EL element and the EL element emits light. Additionally, the voltage Vm of the data electrode of the EL element to not emit light remains unchanged at Vm, and a voltage of Vr−Vm is applied to that EL element.

This voltage of Vr−Vm is lower than the threshold voltage; thus, that EL element does not emit light.

The timing diagram of FIG. 3I shows a state where the P-channel FET **41a** of the data side driver IC **4** is switched off and the N-channel FET **41b** thereof is switched on, and FIG. 3J shows a state wherein voltage Vr is applied to the EL element **111** and the EL element **111** emits light.

Thereafter, charge accumulated in the EL element on the scan electrode **201** is discharged by switching off the P-channel FET **21a** of the scan side driver IC **2** connected to the scan electrode **201** of the first column, and switching on the N-channel FET **21b** thereof as shown in FIGS. 3C and 3D.

Next, the P-channel FET **31a** of the scan side driver IC **3** connected to the scan electrode **301** is turned on, and the voltage of the scan electrode **301** is set to Vr as shown in FIG. 3H. Additionally, output stage FETs of the scan side driver ICs **2** and **3** connected to other scan electrodes are all switched off, and these scan electrodes enter a floating state.

Additionally, driving of the EL elements of the second column is performed similarly to the foregoing by setting the voltage levels of the data electrodes **401**, **402**, **403**, etc. to levels corresponding to an EL element to emit light and to an EL element to not emit light.

The timing diagram of FIG. 3I shows a state where the P-channel FET **41a** of the data side driver IC **4** is switched on, the N-channel FET **41**b thereof is switched off and the voltage of the data electrode **401** is Vm, and that of FIG. 3K shows that voltage Vr−Vm is applied to the EL element **121** and the EL element **121** does not emit light.

Thereafter, charge accumulated in the EL element on the scan electrode **301** is discharged by switching off the P-channel FET **31**a of the scan side driver IC **3** connected to the scan electrode **301** of the second column and switching on the N-channel FET **31**b thereof.

Thereafter, line-sequential scanning, wherein the above-described operation is repeated until the final scan line is reached, is performed similarly.

In the negative field portion, the switching elements **52** and **61** are switched on, the switching elements **51** and **62** are switched off, and operation similar to the operation in the positive field is performed with reversed polarity. At this time, reference voltage of the scan electrodes **201**, **301**, **202**, **302**, etc. goes to ground. Additionally, the FETs **41**b, **42**b, **43**b, etc. of the data side driver IC **4** are switched on, and voltage of the data electrodes is set to ground. In this state, the voltage applied to all EL elements becomes 0 V, and so the EL elements do not emit light.

Thereafter, line-sequential scanning similar to that done in the positive field is performed for the negative field as well. −Vr+Vm is applied to the scan electrode of the column where display selection is performed. On the data electrode side, oppositely to the positive field, voltage of a data electrode to emit light is set to Vm, and voltage of a data electrode which is to not emit light is remains at ground.

Consequently, when voltage Vm is applied to a data electrode with respect to a scan electrode to which a voltage of −Vr+Vm is applied, a voltage of −Vr is applied to an EL element corresponding thereto, and the EL element emits light. Furthermore, when voltage of a data electrode is ground voltage, a voltage of −Vr+Vm, which is lower than the threshold voltage, is applied to the EL element, and so the EL element does not emit light.

Accordingly, one cycle of display operation is completed by drive of the above-described positive and negative fields, and this is performed repeatedly.

As is understood from the above-described operation, a voltage of Vr−Vm is applied to the scan side driver ICs **2** and **3** in both the positive and negative fields. Consequently, the necessary breakdown voltage of the scan side driver ICs **2** and **3** can be lowered by an amount corresponding to the second offset voltage in comparison with prior art devices, and breakdown voltage of the scan side driver ICs **2** and **3** can be reduced.

Moreover, because a change from offset voltage Vm to voltage Vr for drive use is used in the positive field, the voltage change thereof can be smaller, peak current flowing to the EL element can be lowered, and reliability of the EL element can be improved.

Specific structures of the scan voltage supply circuit **6** and data voltage supply circuit **7** will be described below. A circuit where the switches **51** and **61** can be omitted due to utilization of a power source of (Vr−Vm) is shown in FIG. **4**.

In this Figure, voltage supply circuits **5** through **7** are provided with a first power source **81** having a voltage of Vm and a second power source **82** having a voltage of Vr−Vm, and the positive terminal of the first power source **81** and the negative terminal of the second power source **82** are connected via a P-channel FET **84** (i.e., a second switching device as recited in the appended claims). Additionally, the positive electrode of the second power source **82** is grounded via an N-channel FET **83** (i.e., a first switching device as recited in the appended claims).

A control signal is provided to the P-channel FET **84** from an input terminal S2 via a coupling capacitor **85**, input protection Zener diode **86**, resistor **87**, and filter circuit **88**. Additionally, a control signal is provided to the N-channel FET **83** from an input terminal S1 via a filter circuit **89**.

When in the positive field, low level control signals are provided to both input terminals S1 and S2, and the N-channel FET **83** is switched off and the P-channel FET **84** is switched on. At this time, a voltage Vm of the first power source **81** is output from the negative electrode of the second power source **82** to a negative electrode voltage supply line L2 as an offset voltage, and a voltage Vr (=Vr−Vm+Vm) is output to the positive electrode voltage supply line L1 from the positive electrode of the second power source **82**.

Additionally, voltages Vm and 0 V are respectively supplied to the data side driver IC **4** from the positive and negative electrodes of the first power source **81**.

Consequently, the drive voltage in the positive field is created by the above-described voltages.

Furthermore, according to the structure shown in FIG. **4**, a control signal for scan side driver IC drive use is provided to the scan side driver ICs **2** and **3** via an isolation circuit (not illustrated), and line sequential scanning of the scan side driver ICs is performed. The isolation circuit performs a level shift at a time of signal transmission between circuits having differing reference potentials, and functions to convey logic levels correctly.

Additionally, display data is output according to a control signal from the data side driver IC **4**.

In the foregoing first embodiment, lowering of breakdown voltage with respect to the scan side driver ICs **2** and **3** was provided, but according to a second preferred embodiment of the present invention, lowering of breakdown voltage with respect to the data side driver IC **4** as well is provided. The overall structure of this embodiment is shown in FIG. **5**.

In this Figure, the data voltage supply circuit **7** selectively outputs four voltages Vm, Vm−V_{02}, V_{02}, and 0 V in accordance with operation of switching elements **71** through **74**. That is to say, in the positive field, switching elements **72** and **74** are switched on and switching elements **71** and **73** are switched off, and voltages Vm−V_{02} and 0 V are supplied to the data side driver IC **4**.

Herein, the EL element emits light when a voltage Vr is applied to the scan electrode and a voltage of 0 V is applied to the data electrode during electroluminescence timing. Additionally, when a voltage of Vm−V_{02} is applied to the data electrode, the voltage on the EL element is Vr−Vm+V_{02}, which is not sufficient for it to emit light. The EL element can be set in a non-electroluminescent state by establishing a voltage thereof at a voltage which is lower than an electroluminescence threshold voltage of the EL element.

Moreover, in the negative field, the switching elements **71** and **73** are switched on and switching elements **72** and **74** are switched off, and voltages Vm and V_{02} are supplied to the data side driver IC **4**.

In this case, the EL element emits light when the voltage of the data electrode is Vm during electroluminescence timing when voltage of −Vr+Vm has been applied to the scan electrode. Additionally, voltage of −Vr+Vm−V_{02} is applied to the EL element when voltage of the data electrode is V_{02}, but because this voltage has been established at a voltage which is lower than the electroluminescence threshold voltage of the EL element, as was described above, the EL element is in a non-electroluminescent state.

Consequently, an EL element can selectively emit light in a positive field, similarly to the above-described first embodiment.

According to the foregoing structure, a voltage of $Vm-V_{02}$ is applied to the data side driver IC 4 in the positive field. Consequently, the breakdown voltage of the data side driver IC 4 can be reduced by an amount corresponding to offset voltage V_{02}.

Furthermore, according to this second embodiment, lowering of breakdown voltage with respect to both the scan side driver ICs 2 and 3 and the data side driver IC 4 was provided, but it is also acceptable to lower the breakdown voltage with respect to only the data side driver IC 4 if such is necessary.

Additionally, as shown in FIGS. 6A–6C, when ½ of modulation Vm is taken as the offset voltage V_{02}, a differential voltage applied to the EL element during electroluminescence and during non-electroluminescence can be optimized.

According to the above-described embodiments, a device to perform matrix display where a plurality of scan electrodes and a plurality of data electrodes are mutually perpendicular was described, but this invention can be applied also in a device to perform segmented display. In this case, it is sufficient to perform control so that positive and negative drive voltage pulses are applied to each segment with respect to the device shown by the timing diagrams of FIGS. 3A–3M without performing a shift in scan voltage. That is, in the positive field, an offset voltage Vm is applied as a reference voltage to one electrode, together with applying a voltage Vr during electroluminescence timing, and a ground voltage is applied to the other electrode for electroluminescence, or voltage Vm (or $Vm-V_{02}$ as in the second embodiment) is applied to the other electrode in a case of no electroluminescence. Additionally, in the negative field, ground voltage is applied as a reference voltage to one electrode, together with applying a voltage −Vr+Vm during electroluminescence timing, and a voltage Vm is applied to the other electrode in a case of electroluminescence, or a ground voltage (or voltage V_{02} as in the second embodiment) is applied to the other electrode in a case of no electroluminescence.

A block structure of this embodiment is shown in FIG. 7. In this Figure, a voltage supply circuit **140** supplies the foregoing voltages of Vr, Vm, and −Vr+Vm and ground voltage to a first drive circuit **120**, and supplies the foregoing voltages of Vm, ground voltage, and so on to a second drive circuit **130**. The first drive circuit **120** applies voltages which differ in the above-described positive and negative field to one electrode **102** of the EL element **100**, and the second drive circuit **130** applies the foregoing voltages to another electrode **106** thereof.

In another preferred embodiment, one electrode is grounded while positive and negative drive voltage pulses are applied to the other electrode. The structure of the latter case is shown in FIG. 8.

In this Figure, voltage supply circuit **140** outputs a voltage of ±Vr and an offset voltage of $\pm V_0$ to a drive circuit **150**. The drive circuit **150** applies an alternating current voltage having offset voltage V_0 to another electrode of the EL element **100**, as shown in FIG. 9. In this case, the breakdown voltage of the drive circuit **150** is established by $Vr-V_0$, and so the breakdown voltage can be lowered by an amount corresponding to offset voltage V_0.

Additionally, this invention can be applied also in a case wherein an EL element is utilized as a backlight (i.e., panel electroluminescence).

Furthermore, according to the above-described first and second embodiments, a device utilizing the FETs **21a**, **31a**, **41a**, etc. as switching elements to switch the voltage applied to the several electrodes in the several driver ICs **2** through **4** was described, but devices other than FETs, e.g. thyristors, bipolar transistors, and the like, can be employed as switching elements.

The data voltage supply circuit **7** shown in FIG. **5** is a variation on the power source circuit shown in FIG. **10**. This circuit has a single power source **91**, and is structured so that a positive electrode thereof is grounded via an N-channel FET **92** (a first switching device) and a negative electrode thereof is grounded via a P-channel FET **93** (a second switching device). Additionally, a smoothing capacitor **94** is provided in parallel with this power source **91**.

A control signal is input to the N-channel FET **92** from an input terminal S1', and a control signal is input to the P-channel FET **93** from an input terminal S2' via a coupling capacitor **95**. Zener diodes **96** and **97** and a resistor **98** are provided for input protection.

An output circuit **99** is provided in an output stage of the power source circuit, and output voltage thereof is applied to one electrode of an EL element **100**. The other electrode of the EL element **100** is grounded.

Operation of the above-described structure will be described hereinafter with reference to the graphs shown in FIGS. 11A–11E.

High level and low level control signals are input to the input terminals S1' and S2', as shown in FIGS. 11A and 11B. When the control signals are both low level, the N-channel FET **92** is switched off and the P-channel FET **93** is switched on. Consequently, voltage V of the power source **91** is output to the positive terminal and ground is output to the negative terminal.

Additionally, when the control signals are both high level, the N-channel FET **92** is switched on and the P-channel FET **93** is switched off. Consequently, ground voltage is output to the positive terminal and −V voltage is output to the negative terminal.

Meanwhile, the output circuit **99** is interlocked with the control signals and is alternatingly switched to a switch state of T1 or T2 at a timing shown in FIG. 11E. Accompanying this switching, the alternating current voltage of FIG. 11E according to ±V voltage and ground voltage is output. This alternating current voltage is applied to one side of the EL element **100**, and so the EL element **100** emits light.

When S1' and S2' are high level, the N-channel FET **92** is switched on, and so when T1 is on at this time, output is to GND. When S1' and S2' go low, the P-channel FET **93** is switched on, and so T1 remains unchanged and output goes to V. When switching on from T1 to T2 occurs with S1' and S2' remaining unchanged, output goes to ground and current from the EL element load flows from T2 through the parasitic diode of the FET **93** to GND. Output times (pulse widths) T_P and T_N for which voltage is output are determined according to switching timing of the switches T1 and T2 and change in the state of S1' and S2'.

A specific structure of the output circuit **99** is shown in FIG. 12, where the output circuit **99** has a P-channel FET **99a** and an N-channel FET **99b**, and is structured to switch on one FET or the other and output either a positive terminal or a negative terminal voltage in accordance with high level and low level signals (signals interlocked with control signals input to input terminals S1' and S2') from input terminals **99c** and **99d**. Further, **99e** and **99f** in the drawing are parasitic diodes.

The above-described embodiment is a device to output ±V as an alternating current signal, taking ground voltage as a reference, but when voltage connected to the power source **91** via the FETs **92** and **93** is a second power source to generate a predetermined reference voltage rather than ground voltage, alternating current voltage centering on this reference voltage can be output. In this case, the EL element **100** can emit light similarly to the above-described embodiment when voltage identical to the foregoing reference voltage is applied to the other electrode of the EL element.

The circuit described above is used as an EL element drive circuit, but it can be applied to drive any load, including a load other than an EL element, which is actuated by receiving positive and negative alternating current voltage from a single output line. In this case, it is acceptable for the device to selectively output a created positive and negative voltage by push-pull operation and drive a load.

Additionally, the driver circuit described above is a push-pull device connecting a P-channel FET and an N-channel FET, but a push-pull driver of solely N-channel FETs is also acceptable. It is also acceptable to utilize NPN and PNP bipolar transistors respectively in place of the N-channel FET **92** and P-channel FET **93**.

FIG. 13 shows another embodiment of the present invention in which a data voltage supply circuit **7'** includes a charge collecting capacitor **75** and switching elements **76** and **77**, and Vm is utilized as a power source voltage. The charge capacity of the charge collecting capacitor **75** is sufficiently large in comparison with charge capacity of the entirety of the EL display panel **1**.

Operation in first and second fields according to this embodiment will be described hereinafter with reference to the timing diagrams of FIGS. 14A–14O.

The charge collecting capacitor **75** is charged with a charge of Vm/2 , i.e., half of modulation voltage Vm, as an initial state. This is because an amount of capacitor charge accumulation converges to an equivalent of Vm/2 due to repeatedly performing drive which will be described hereinafter.

Initialization is performed at a start of operation of this first field. That is to say, switching elements **51** and **62** are switched on, switching elements **52** and **61** are switched off, and voltages on all scan electrodes are set to Vm. Additionally, switching element **76** is switched off and switching element **77** is switched on, and along with this, all P-channel FETs of a data side driver IC **4** are switched on and voltages on all data electrodes are Vm/2.

Subsequent to this initialization, source voltage of the P-channel FETs of the data side driver IC **4** becomes Vm/2. Herein, the N-channel FET of the data side driver IC **4** connected to the data electrode of an EL element to emit light is switched on, the P-channel FET thereof is switched off, the P-channel FET of the data side driver IC **4** connected to the data electrode of an EL element not to emit light is switched on, and the N-channel FET thereof is switched off. At this time, voltage of the data electrode of an EL element to emit light becomes Vm/2, and voltage of the data electrode of an EL element to emit light becomes 0.

Next, the P-channel FET **21a** of the scan side driver IC **2** connected to the scan electrode **201** of the first column is switched on, and voltage of the scan electrode **201** is set to Vr. Simultaneously thereto, the switching element **76** is switched on and the switching element **77** is switched off, and power source voltage Vm is applied to the data electrode of the P-channel FET of the data side driver IC **4** which was switched on, i.e., to the data electrode of the EL element not to emit light.

At this time, a voltage of Vm−Vr is applied to the EL element not to emit light, and so the EL element does not emit light, but voltage Vr is applied to the EL element to emit light and the EL element emits light.

The timing diagram of FIG. 14I shows a state wherein the P-channel FET **41a** of the data-side driver IC **4** is switched off; FIG. 14J shows that the N-channel FET **41b** thereof is switched on; FIG. 14M shows that the voltage of the data electrode **401** is 0; FIG. 14N shows that voltage Vr is applied to the EL element **111**, and the EL element **111** therefore emits light.

Thereafter, charge accumulated in the EL element on the scan electrode **201** is discharged by switching off the P-channel FET **21a** of the scan side driver IC **2** connected to the scan electrode **201** of the first column as shown in FIGS. 14E and 14K, and switching on the N-channel FET **21b** thereof as shown in FIG. 14F.

At this time, half of the charge with which the entirety of the EL display panel **1** has been charged between the data electrodes for which the P-channel FETs of the data side driver IC **4** were switched on and the data electrodes for which the N-channel FETs thereof were switched on by switching off the switching element **76** and switching on the switching element **77** is collected by the capacitor for charge collecting use **75** via the P-channel FETs of the data side driver IC **4**.

Charge capacity of the capacitor for charge collecting use **75** is sufficiently large in comparison with charge capacity of the EL elements, and the voltage Vm/2 between terminals remains substantially unchanged.

Finally, voltages on all data side electrodes are set to Vm/2 by switching on all P-channel FETs of the data side driver IC **4**.

Operation for the scan lines of the second and following columns is similar to the foregoing. According to the timing diagram of FIG. 14I, at the scan line of the second column, the P-channel FET **41a** of the data side driver IC **4** is switched on; as shown in FIG. 14J, the N-channel FET **41b** thereof is switched off; as shown in FIG. 14M, the voltage on the data electrode **401** is set to Vm; voltage Vr−Vm is applied to the EL element **121** as shown in FIG. 14O; and the EL element **121** does not emit light.

In the second field, initialization is first performed. That is, after electroluminescence operation for all columns in the first field has been performed, switching elements **51** and **62** are switched off, switching elements **52** and **61** are switched on, voltages on all scan electrodes are set to ground, and along with this, all N-channel FETs of the data side driver IC **4** are switched on, all data electrodes are set to ground, and charge which is the equivalent of approximately Vm/2 accumulated in all elements is discharged. Thus, the voltage on all data electrodes goes to zero.

Additionally, switching element **72** is switched off and switching element **73** is switched on, and the source voltage of the P-channel FETs of the data side driver IC **4** becomes Vm/2.

Herein, the N-channel FET of the data side driver IC **4** connected to the data electrode of an EL element to emit light is switched off, the P-channel FET thereof is switched on, the P-channel FET of the data side driver IC 4 connected to the data electrode of an EL element not to emit light is switched off, and the N-channel FET thereof is switched on.

According to the example in FIG. 13, voltage on the data electrode **401** is Vm/2 by switching on the P-channel FET of the data side driver IC 4 connected to the data electrode **401** as shown in FIG. 14M.

Next, the N-channel FET **21b** of the scan side driver IC **2** connected to the scan electrode **201** of the first column is switched on as shown in FIG. 14F, and voltage of the scan electrode **201** becomes −Vr+Vm. Simultaneously thereto, the switching element **76** is switched on and the switching element **77** is switched off, and power source voltage Vm is applied to the data electrode (data electrode **401** or the like) of the P-channel FET of the data side driver IC **4** which was switched on as shown in FIG. 14M.

At this time, voltage Vr is applied to an EL element to emit light and the EL element emits light, and voltage of Vm−Vr is applied to an EL element not to emit light and the EL element does not emit light.

Thereafter, charge accumulated in the EL element on the scan electrode **201** is discharged by switching on the P-channel FET **21a** and switching off the N-channel FET **21b** as shown in FIGS. 14E and 14F.

At this time, half of the charge with which the entirety of the EL display panel **1** has been charged between the data electrodes for which the P-channel FETs of the data side driver IC **4** were switched on and the data electrodes for which the N-channel FETs thereof were switched on by switching off the switching element **76** and switching on the switching element **77** is collected by the charge collecting capacitor **75** via the P-channel FETs of the data side driver IC **4**. The charge capacity of the charge collecting capacitor is sufficiently large in comparison with the charge capacity of the EL elements, and the voltage Vm/2 between terminals remains substantially unchanged.

Finally, voltages on all data side electrodes are set to Vm/2 by switching on all N-channel FETs of the data side driver IC **4**.

Operation for the scan lines of the second column and after is similar to the foregoing.

By performing drive as was described above, charge collected in the charge collecting capacitor **75** is used to set the voltage of the data electrode **401** to be Vm/2 prior to an electroluminescence operation at the subsequent scan line. Consequently, power consumption occurs only when the switching element **72** has been switched on, and an amount of output required from the power source Vm is 50% compared with the prior art; that is to say, power consumption becomes 50% in comparison with the prior art.

According to this embodiment, power source voltage at the data voltage supply circuit **7** is the same voltage as modulation voltage Vm, and so there is no need to create voltage of Vm/2 as with the device according to the prior art shown in FIG. 15, and the power source system can be simplified.

The voltage applied to the scan electrodes in the above embodiment was Vr, −Vr+Vm, or 0, and the voltage applied to the data electrodes was Vm or 0, but this invention is not exclusively limited to such voltages, and it is acceptable, for example, to set the voltage applied to the scan electrodes to be Vr−Vm/2 or −Vr+Vm/2, and to set the voltage applied to the data electrodes to be Vm/2 or −Vm/2.

Additionally, data side applied voltage rose in two stages, but it is also acceptable to provide a plurality of capacitors for charge collecting use and to increase the number of stages. In this case, the effect of reduction of power consumption becomes greater as the number of stages is increased.

Furthermore, the above-described method of EL drive is not exclusively limited to a field reversing drive method, and a field refreshing drive method may alternatively be used.

Still further, a device wherein charge collection is performed from a data electrode side was described, but charge collection from a scan electrode side is also acceptable.

Yet further, this invention is not exclusively limited to a device to drive a matrix-type EL display device, but can be applied also to an EL display device to perform pattern display.

Yet still further, a device utilizing FETs in the output stages of the scan side driver ICs **2**, **3**, and **4** was described, but output stages utilizing thyristors or bipolar transistors is also acceptable.

Although the present invention has been fully described in connection with the preferred embodiment thereof with reference to the accompanying drawings, it is to be noted that various changes and modifications will become apparent to those skilled in the art. Such changes and modifications are to be understood as being included within the scope of the present invention as defined by the appended claims.

We claim:

1. An EL display device comprising:

an EL display panel having a plurality of scan electrodes, a plurality of data electrodes, and a plurality of EL elements formed at intersections of said scan electrodes and said data electrodes;

a scan electrode drive circuit to sequentially output a scan voltage having a differing polarity with each positive and negative field to said plurality of scan electrodes; and

a data electrode drive circuit to output data voltage to said plurality of data electrodes; and

a voltage supply circuit for generating said scan voltage and said data voltage by supplying to said scan electrode drive circuit, in said positive field, a positive polarity scan voltage and a first offset voltage which is higher than ground level; wherein

said scan electrode drive circuit is further for setting voltages of said plurality of scan electrodes to be said first offset voltage in said positive field, together with outputting said positive polarity scan voltage to said plurality of scan electrodes during electroluminescence operation;

said data voltage has a modulation voltage to determine electroluminescence of said plurality of EL elements;

said first offset voltage is established at a voltage level identical to said modulation voltage;

said voltage supply circuit has a first power source and a second power source; and

said voltage supply circuit includes first switching means for connecting a positive electrode of said first power source and a negative electrode of said second power source so that when said modulation voltage is supplied from said first power source positive electrode to said data electrode drive circuit and said first means for switching has been switched on, said first offset voltage equal to said modulation voltage and said positive polarity scan voltage are respectively supplied to said scan electrode drive circuit from said second power source negative electrode and said first power source positive electrode.

2. An EL display device as recited in claim 1, said voltage supply circuit further comprising second switching means for connecting said second power source positive electrode to a predetermined reference voltage;

wherein when said first means for switching has been switched off and said second means for switching has been switched on, negative scan voltage of negative polarity in said negative field is supplied to said scan electrode drive circuit from said second power source negative electrode.

3. An EL display device as recited in claim 2, wherein:

said predetermined reference voltage is ground voltage; and

said negative polarity scan voltage is established at a voltage obtained by subtracting said positive polarity scan voltage from said modulation voltage.

4. An EL display device comprising:

an EL display panel having a plurality of scan electrodes, a plurality of data electrodes, and a plurality of EL elements formed at intersections of said scan electrodes and said data electrodes;

a scan electrode drive circuit to sequentially output a scan voltage having a differing polarity with each positive and negative field to said plurality of scan electrodes; and

a data electrode drive circuit to output data voltage to said plurality of data electrodes; and

a voltage supply circuit for generating said scan voltage and said data voltage by supplying to said scan electrode drive circuit, in said positive field, a positive polarity scan voltage and a first offset voltage which is higher than ground level; wherein

said scan electrode drive circuit is further for setting voltages of said plurality of scan electrodes to be said first offset voltage in said positive field, together with outputting said positive polarity scan voltage to said plurality of scan electrodes during electroluminescence operation;

said data voltage has a modulation voltage to determine electroluminescence of said plurality of EL elements: and

said voltage supply circuit is for supplying said modulation voltage and a second offset voltage which is higher than ground level to said data electrode drive circuit as said data voltage in said negative field.

5. An EL display device as recited in claim 4, wherein said voltage supply circuit is for supplying a voltage lower than said modulation voltage by an amount corresponding to said second offset voltage and ground voltage to said data electrode drive circuit as said data voltage.

6. An EL display device comprising:

an EL display panel having a plurality of scan electrodes, a plurality of data electrodes, and a plurality of EL elements formed at intersections of said scan electrodes and said data electrodes;

a scan electrode drive circuit to sequentially output a scan voltage having a differing polarity with each positive and negative field to said plurality of scan electrodes; and

a data electrode drive circuit to output data voltage to said plurality of data electrodes;

a voltage supply circuit for generating said scan voltage and said data voltage by supplying to said scan electrode drive circuit, in said positive field, a positive polarity scan voltage and a first offset voltage which is higher than ground level;

first switching means for setting a power source voltage to be applied to an EL element of said EL elements during electroluminescence drive of said EL element;

a charge collecting capacitor for collecting a charge charged in said EL element by application of said power source voltage; and

second switching means for charging said EL element by a charge collected by said charge collecting capacitor prior to electroluminescence drive of said EL element, and for causing said capacitor to collect a charge charged in said EL element subsequent to electroluminescence drive of said EL element;

wherein said scan electrode drive circuit is further for setting voltages of said plurality of scan electrodes to be said first offset voltage in said positive field, together with outputting said positive polarity scan voltage to said plurality of scan electrodes during electroluminescence operation.

7. An EL display device as recited in claim 6, wherein:

said first switching means is disposed in a power source line to supply said power source voltage; and

said charge collecting capacitor and said second switching means are disposed in series between said power source line and ground.

8. An EL display device comprising:

an EL display panel having a plurality of scan electrodes, a plurality of data electrodes, and a plurality of EL elements formed at intersections of said scan electrodes and said data electrodes;

a scan electrode drive circuit to sequentially output a scan voltage having a polarity alternating in correspondence with an alternation in positive and negative field of operational cycles of said device to said plurality of scan electrodes: and

a data electrode drive circuit to output a data voltage to said plurality of data electrodes; and

a voltage supply circuit for generating said scan voltage and said data voltage by supplying to said scan electrode drive circuit, in said positive field, a positive polarity scan voltage and a first offset voltage which is higher than ground level; wherein

said scan electrode drive circuit is further for setting voltages of said plurality of scan electrodes to be said first offset voltage in said positive field, together with outputting said positive polarity scan voltage to said plurality of scan electrodes doing electroluminescence operation:

said data electrode drive circuit is for outputting, as one of said data voltages and in a relationship with said scan voltage, a modulation voltage to cause one of said EL elements to selectively emit light; and

said voltage supply circuit supplying said modulation voltage to said data electrode drive circuit, said voltage supply circuit including first switching means for supplying said modulation voltage during electroluminescence drive of said EL element, a charge collecting capacitor, and a second switching means for charging of said EL element via said data electrode drive circuit by a charge collected by said capacitor for charge collecting use prior to electroluminescence drive of said EL element, and for charging said charge collecting capacitor to collect via said data electrode drive circuit a charge charged in said EL element subsequently to electroluminescence drive of said EL element.

9. An EL display device comprising:

an EL display panel having a plurality of scan electrodes, a plurality of data electrodes, and a plurality of EL elements are formed at intersections of said scan electrodes and said data electrodes;

a scan electrode drive circuit to sequentially output a scan voltage having a differing polarity with each positive and negative field to said plurality of scan electrodes; and

a data electrode drive circuit to output data voltage to said plurality of data electrodes; and

a voltage supply circuit for generating said scan voltage and said data voltage by supplying a modulation voltage to determine electroluminescence of said plurality of EL elements and an offset voltage which is higher than ground level to said data electrode drive circuit;

wherein said data electrode drive circuit, in said negative field, with respect to a data electrode of an EL element caused to be in an electroluminescent state, is further for setting a voltage thereof to be said modulation voltage, and with respect to a data electrode of an EL element caused to be in a non-electroluminescent state, is further for setting a voltage thereof to be said offset voltage;

said voltage supply circuit is for supplying a voltage lower than said modulation voltage by an amount corresponding to said offset voltage and ground voltage to said data electrode drive circuit as said data voltage; and

said data electrode drive circuit, in said positive field, with respect to a data electrode of an EL element caused to be in an electroluminescent state, is for setting a voltage thereof to be said ground voltage, and with respect to a data electrode of an EL element caused to be in a non-electroluminescent state, is for setting a voltage thereof to be a voltage lower than said modulation voltage by an amount corresponding to said offset voltage.

10. An EL display device having an EL element, said device comprising:

a first drive circuit to output a first drive voltage to a first electrode of said EL element and a second drive circuit to output a second drive voltage to a second electrode of said EL element so that a drive voltage pulse with an alternating positive and negative polarity is applied between said first and second electrodes, said first and second electrodes forming a pair of electrodes;

wherein said device further comprises a voltage supply circuit for generating a voltage required to generate said alternating positive and negative polarity drive voltage pulse in said first and second drive circuits by supplying a first main voltage to generate said positive polarity drive voltage pulse and a first offset voltage which is higher than ground level to a first one of said first and second drive circuits,

said first main voltage is such that, in a relationship with said second drive voltage, voltage applied between said pair of electrodes becomes at least a threshold voltage for causing said EL element to emit light,

said first off set voltage is such that, in a relationship with said second drive voltage, voltage applied between said pair of electrodes becomes lower than a threshold voltage,

said voltage supply circuit is further for supplying a modulation voltage to generate said negative polarity drive voltage pulse and a second offset voltage which is higher than ground level to a second one of said first and second drive circuits, and

said second offset voltage is such that, in a relationship with a drive voltage of said first one of said first and second drive circuits, voltage applied between said pair of electrodes becomes lower than said threshold voltage.

11. A display device comprising:

a display panel having a plurality of scan electrodes, a plurality of data electrodes, and a plurality of display elements formed at intersections of said scan electrodes and said data electrodes;

a scan electrode drive circuit to input a first power voltage from a first power supply through a pair of power supply lines and sequentially output a scan voltage; and

a data electrode drive circuit to input a second power voltage from a second power supply through a pair of power supply lines and sequentially output a data voltage;

wherein a positive terminal of said first power supply is connected to a negative terminal of said second power supply with a first switch interposed therebetween,

a negative terminal of said first power supply is connected to a positive terminal of said second power supply with a second switch interposed therebetween,

an operational cycle of said display device includes a positive field and a negative field, one of said first and second switches being turned on alternately in each of said positive and negative fields.

12. An EL display device comprising:

an EL display panel having a plurality of scan electrodes, a plurality of data electrodes, and a plurality of EL elements formed at intersections of said scan electrodes and said data electrodes;

a scan electrode drive circuit to sequentially output a scan voltage having a polarity alternating in correspondence with an alternation in positive and negative fields of an operational cycle of said device to said plurality of scan electrodes;

a data electrode drive circuit to output a data voltage to said plurality of data electrodes; and

a voltage supply circuit for generating said scan voltage and said data voltage by supplying to said scan electrode drive circuit, in a pre-determined field, a scan voltage with predetermined polarity scan voltage and a first offset voltage which has a pre-determined voltage which is different from ground level;

wherein said scan electrode drive circuit is further for setting voltages of said plurality of scan electrodes to be said first offset voltage in said pre-determined field, together with outputting said pre-determined polarity scan voltage to said plurality of scan electrodes during electroluminescence operation,

said data voltage has a modulation voltage to determine electroluminescence of said plurality of EL elements,

said first offset voltage is established at a voltage level identical to said modulation voltage,

said voltage supply circuit has a first power source and a second power source, and

said voltage supply circuit includes first switching means for connecting a positive electrode of said first power source and a negative electrode of said second power source so that when said modulation voltage is supplied from said first power source positive electrode to said data electrode drive circuit and said first switching means has been switched on, said first offset voltage equal to said modulation voltage and said predetermined polarity scan voltage are respectively supplied to said scan electrode drive circuit from said second power source negative electrode of said second power source and positive electrode of said first power source.

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United States Patent [19]

Okuda

[11] **Patent Number: 5,828,181**

[45] **Date of Patent: Oct. 27, 1998**

[54] **DRIVING CIRCUIT FOR AN ORGANIC ELECTROLUMINESCENT ELEMENT USED IN A DISPLAY**

[75] Inventor: **Yoshiyuki Okuda**, Tsurugashima, Japan

[73] Assignee: **Pioneer Electronic Corporation**, Tokyo, Japan

[21] Appl. No.: **653,160**

[22] Filed: **May 24, 1996**

[30] **Foreign Application Priority Data**

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[51] **Int. Cl.**^{6} **H05B 33/00**; G09G 3/00; G09G 3/12

[52] **U.S. Cl.** .... **315/169.3**; 315/200 R; 345/76; 345/77

[58] **Field of Search** .... 315/169.3, 169.1, 315/200 R; 345/211, 212, 82, 76, 77; 362/84, 800

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Primary Examiner—Arnold Kinkead
Attorney, Agent, or Firm—Fish & Richardson P.C.

[57] **ABSTRACT**

An emitting element driving circuit for driving an organic emitting element comprises at least one emitting element, and a rectifier directly connected in series to the emitting element. The driving circuit for driving an emitting element having a capacitor in parallel to an emission part in its electrical equivalent circuit capable of achieving a sufficient luminance even at a low voltage of the power supply during a high speed scanning driving.

5 Claims, 6 Drawing Sheets

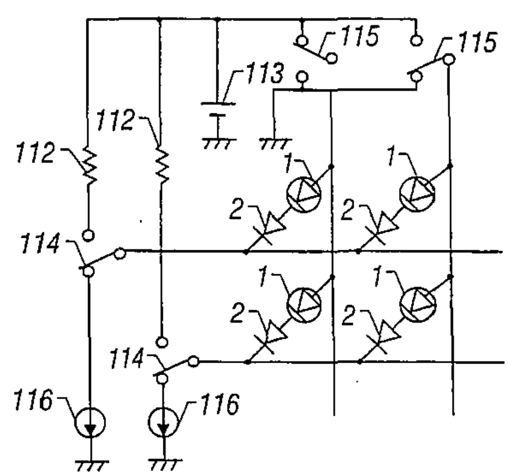


FIG.1

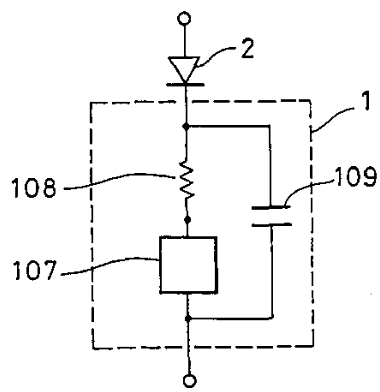


FIG.2

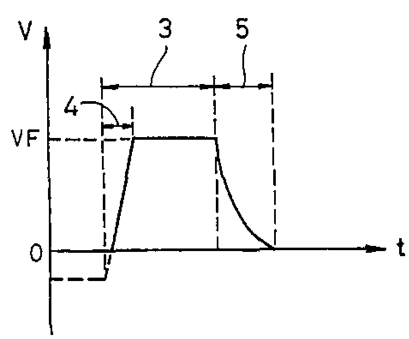


FIG.3

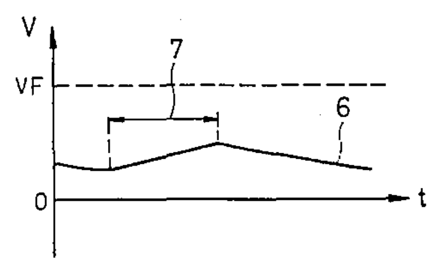
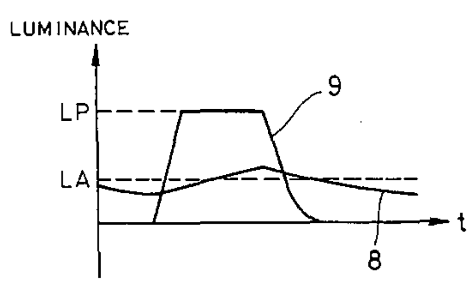


FIG.4



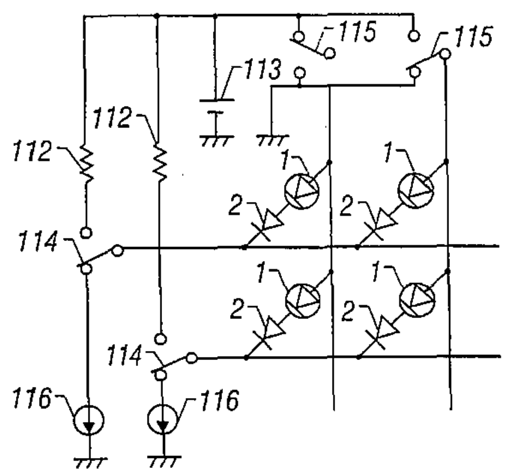


Figure 5

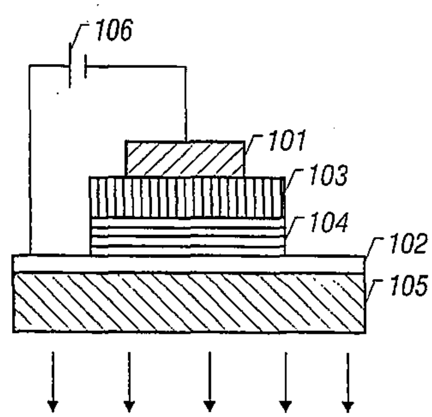


Figure 6
(Prior art)

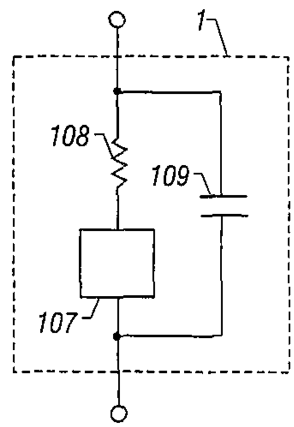


Figure 7
(Prior Art)

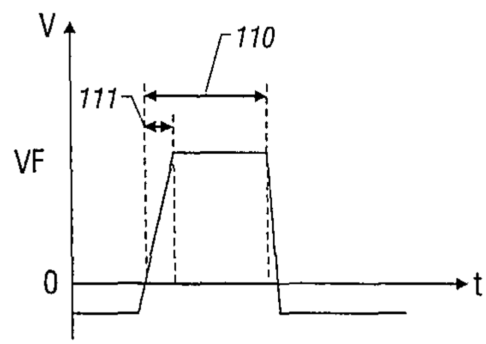


Figure 8
(Prior Art)

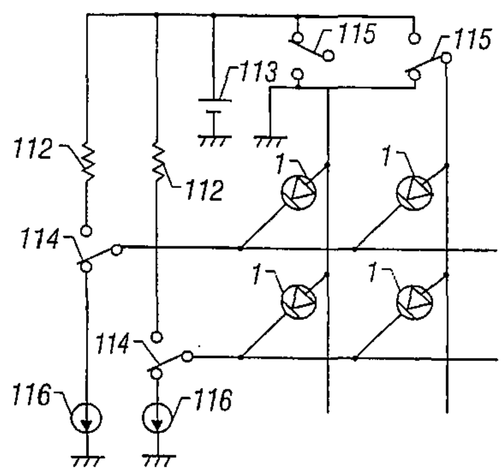


Figure 9
(Prior Art)

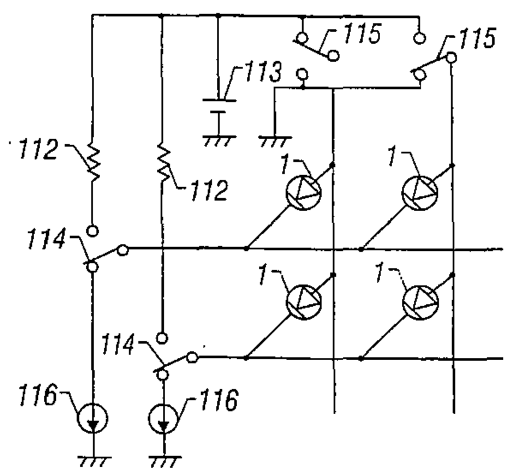


Figure 9
(Prior Art)

DRIVING CIRCUIT FOR AN ORGANIC ELECTROLUMINESCENT ELEMENT USED IN A DISPLAY

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an emitting element driving circuit for driving an emitting element, and particularly to an emitting element driving circuit for driving an emitting element having a capacitor in parallel to an emission part represented by an electrical equivalent circuit thereof.

2. Description of the Related Art

In the emitting elements, there is an electric field emitting element such as an organic electroluminescent (EL) emitting element. FIG. 6 shows a cross-sectional view of the EL element. This organic EL element consists of a cathode of a metallic electrode 101, an anode of a transparent electrode 102, and an organic fluorescent thin film 103 of an organic compound layer or more and an organic positive-hole transport layer 104 which are layered between the cathode and the anode.

In the organic EL emitting device, a glass substrate 105 is furnished outside the transparent anode 102. A power supply 106 provides electrons and positive-hole to the organic EL emitting device. The recombination of electrons injected from the metal cathode 101 and the holes injected from the transparent anode 102 to the emitting layer 103 generates excitons. The excitons emit light when they are deactivated through radiation. This light radiates toward outside through the transparent anode 102 and the glass substrate 105. An electrical equivalent circuit of this organic EL element has a capacitance because of the lamination structure of electrodes and organic fluorescent substance layers and so on.

FIG. 7 shows the electrical equivalent circuit of the organic EL emitting element where numeral 107 denotes an emission part of constant-voltage element, numeral 108 denotes an internal resistor, and 109 denotes a capacitor. As seen from the figure, the capacitor 109 is connected to the emission part 107 and the internal resistor 108 in parallel.

Assuming that a matrix array of the organic EL emitting elements is driven through the AC driving method with a pulse current in the form of scanning, a voltage-waveform generated from the emitting element will be described.

FIG. 8 shows a voltage-waveform before and after scanning the emitting element through the AC driving method.

The ordinate of FIG. 8 denotes a voltage value across the electrodes of the emitting element and the abscissa denotes time. In FIG. 8, numeral 110 denotes a scanning duration, and numeral 111 denotes a charging duration for the capacitor 109 of the EL element. In addition, VF denotes a forward voltage at a peak emission decided by the static characteristic.

As seen from the figure, the current injected to the emitting element during the scanning is consumed by the electric charging of the capacitor 109 at the beginning, so that the emitting element does not emit light. After the scanning, an inverse voltage is applied across the emitting element to prevent an erroneous emission due to the crosstalk, thereby to extract the electric charge charged in the capacitor 109 during the emission to the outside, so that the charged electric charge does not contribute any emission of the emission part 107. In addition, an instantaneous luminance of the emitting element is proportional to the level of the forward current injected to the emission part 107 thereof. An average luminance of the emitting element during the AC-driving is decided by the product between all of the amount of electric charge injected into the EL element during a period to be measured for the average and the quantum efficiency of the EL element. Therefore, when the quantum efficiency of the EL element is constant, the average luminance of the emitting element is proportional to all of the amount of electric charge injected into the EL element during one scanning of AC current.

FIG. 9 shows a portion of an equivalent circuit of a displaying device comprising organic EL emitting elements. In FIG. 9, numerals 1 denote organic EL emitting elements, therefore, the displaying device is constructed with a matrix arrangement of the number of N x N (only four elements appear in FIG. 9) in which the scanning line consists of the number of N of the EL elements. The cathodes of EL elements are connected at the same time by the switches 114 to power supplies 116 so that voltages are applied thereto, while the anodes are connected by the switches 115 so as to sequentially scan the number of N of the EL element row (vertical) thereby to emit light. In addition, numeral 112 denotes an external resistor used for applying an inverse voltage to the EL elements during the scanning in order to prevent an erroneous emission of the EL elements. The numeral 113 denotes a power supply for the whole driving circuit.

The conventional organic EL emitting element is constructed as mentioned above and used for a displaying device containing the organic EL emitting element.

However, such an emitting element driving circuit with the simple matrix arrangement for the organic EL emitting elements has a problem that the instantaneous emission luminance of each EL element during the scanning increases in proportion to the number of the scanning lines per one scanning in case that a predetermined desired luminance is given through the AC driving method, so that the EL emitting element is deteriorated or broken. In addition, the higher forward voltage increases, the higher the current flowing in the EL element increases in such a driving circuit. As a result, this causes the elevation of the power supply voltage for driving the emitting elements, and thus the number of the scanning lines are limited insufficient to achieve a high resolution for a displayed image.

SUMMARY OF THE INVENTION

Thus, the present invention has been made to solve such a problem in view of the forgoing status. An object of the invention is to provide a driving circuit for driving an emitting element having a capacitor in parallel to an emission part in its electrical equivalent circuit capable of achieving a sufficient luminance even at a constant voltage of the power supply during a high speed scanning driving and to prevent the emitting element from deteriorating or being broken by lowering instantaneous luminance of the emitting element.

The present invention set forth in claim 1 is an emitting element driving circuit for emitting an emitting element comprising a rectifier directly connected in series to the emitting element, per one emitting element.

According to the present invention, the rectifier connected in series to a capacitor, which is connected in parallel to an emission part in the electrical equivalent circuit of the emitting element, prevents from extracting the electric charge charged in the capacitor during the emission scanning to the outside. As a result, the remaining electric charge of the capacitor is used for the next emission scanning, so that the emission efficiency is improved. Therefore, the power supply voltage to be applied to the emitting element for a desired luminance is saved and the deterioration and destruction of the EL element are prevented.

In case that the emitting element driving circuit of the present invention is used in the displaying device with a simple matrix circuit driven with a short scanning period, the elevation of the instantaneous luminance of the EL element is suppressed regardless of the increase of the number of the scanning lines. Therefore, the number of the scanning lines may be increased for achieving a high resolution for a displayed image.

Other and further features, advantages and benefits of the invention will become apparent in the following description taken in conjunction with the following drawings. It is to be understood that the foregoing general description and following detailed description are exemplary and explanatory but are not to be restrictive of the invention. The accompanying drawings which are incorporated in and constitute a part of this invention and, together with the description, serve to explain the principles of the invention in general terms. Like numerals refer to like parts throughout the disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an electrical equivalent circuit diagram of the emitting element driving circuit in the present invention;

FIG. 2 is a graphical representation showing a voltage-waveform before and after scanning the emitting element through the AC driving method in accordance with the present invention;

FIG. 3 is a graphical representation showing a voltage-waveform generated across the EL element driven at a high speed by an emitting element driving circuit in accordance with the present invention;

FIG. 4 is a graphical representation showing instantaneous emission luminance characteristics of the EL element driven at high and low speeds by an emitting element driving circuit in accordance with the present invention;

FIG. 5 is an electrical equivalent circuit diagram of the displaying device using the emitting element driving circuit in accordance with the present invention;

FIG. 6 is a schematic cross sectional view of an organic EL emitting element;

FIG. 7 is an electrical equivalent circuit diagram of an organic EL emitting element driving circuit;

FIG. 8 is a graphical representation showing a voltage-waveform before and after scanning the emitting element through the AC driving method; and

FIG. 9 is an electrical equivalent circuit diagram of the displaying device using the emitting element driving circuit.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The embodiments according to the present invention will be described in more detail with reference to the accompanying drawings, particularly FIGS. 1 to 5.

FIG. 1 shows the electrical equivalent circuit of the organic EL emitting element driven by an emitting element driving circuit according to the present invention, where numeral 1 denotes an emitting element such as an organic EL emitting element, and numeral 107 denotes an emission part of constant-voltage element, and numeral 108 denotes an internal resistor, and 109 denotes a capacitor. As seen from the figure, the capacitor 109 is connected to the emission part 107 and the internal resistor 108 in parallel in the organic EL emitting element. In addition, numeral 2 denotes a rectifier such as a rectification diode or the like which is connected in series to the emitting element 1. Both the emitting element 1 and the rectifier 2 may be included in the emitting element driving circuit.

In case that the emitting element driving circuit with a matrix array of the organic EL emitting elements is driven through the AC driving method with a pulse current in the form of scanning driving, a voltage-waveform generated from the emitting element will be described.

FIG. 2 shows a voltage-waveform before and after scanning the emitting element through the AC driving method.

The ordinate of FIG. 2 denotes a voltage value appearing across the electrodes of the emitting element and the abscissa denotes time. In FIG. 2, numeral 3 denotes a scanning duration, and numeral 4 denotes a charging duration for the capacitor 109 of the EL emitting element 1. Numeral 5 denotes a discharging duration for the capacitor 109 of the EL emitting element 1. In addition, VF denotes a forward voltage at a peak emission decided by the static characteristic. As seen from the figure, the applied forward voltage injects the current to the emitting element during the scanning of the emitting element driving circuit. The injected current is consumed by the electric charging of the capacitor 109 at the beginning, so that the emitting element i.e., the emission part does not emit light. Next, upon the lapse of charging duration 4, the emission part 107 starts to emit light at the forward voltage level (VF shown in FIG. 2). After the scanning duration 3, an inverse voltage is applied across the emitting element 1, but the rectifier 2 functioning as a valve prohibits the injection of the inverse current. At this point, the emitting element driving circuit becomes a closed circuit, so that the electric charge remaining in the capacitor 109 flows through the internal resistor 108 into the emission part 107, so that the emission of the emitting element 1 continues during the discharging duration 5. As a result, the average luminance of the EL element per one scanning increases by the level of the remaining electric charge of the capacitor 109 in comparison with the conventional device at a low speed scanning.

Furthermore, in case that the number of scanning per a unit time in the emitting element driving circuit is increased i.e., the scanning speed is raised up, finally, the next scanning starts before all of the remaining electric charge of the capacitor 109 of the last scanning finishes flowing into the emission part. As a result, the EL element continues to emit light.

In this case of at a high speed scanning, since the switching interval of the current is shorter than the charging duration of EL element, one part of the current flowing into the EL element is consumed by the electric charging of the capacitor 109. Therefore, the voltage-waveform 6 appearing across the EL element is obtained as shown in FIG. 3 in which the peak of the voltage-waveform 6 does not reach at the forward voltage VF decided by the static characteristic of the EL element.

FIG. 4 shows variations of instantaneous emission luminance with respect to time in which the luminance curve 8 is at a high speed scanning of the EL element and the luminance curve 9 is at a low speed scanning of the EL element. The peak of the high speed luminance curve 8 does not reach at the peak level of the high speed instantaneous emission luminance (LP shown in FIG. 4). The average emission luminance of the high speed curve 8 is substantially maintained at a constant regardless of the scanning speed in the conditions that the scanning duty ratio is constant, because the average luminance of the emitting element during the AC-driving is decided by the product between all of the amount of electric charge injected into the EL element during a period to be measured for the average and the quantum efficiency of the EL element.

Next, an operation of a displaying device comprising organic EL emitting elements according to the present invention will be described with reference to FIG. 5. FIG. 5 shows a portion of an equivalent circuit of the displaying device comprising organic EL emitting elements driven by the emitting element driving circuit according to the present invention. In the figure, numerals 1 denote organic EL emitting elements, and numerals 2 denote rectifiers each is connected in series to each organic EL emitting element. This displaying device is constructed with a simple matrix arrangement of the number of N x N (only four elements appear in FIG. 5) in which the scanning line consists of the number of N of the EL elements. The cathodes of EL elements are connected at the same time by the switches **114** to power supplies **116** so that voltages are applied thereto, while the anodes are connected by the switches **115** so as to sequentially scan the number of N of the EL element row (vertical) thereby to emit light. In addition, numeral **112** denotes an external resistor used for applying an inverse voltage to the EL elements during the scanning in order to prevent an erroneous emission of the EL elements. The numeral **113** denotes a power supply for the whole driving circuit.

The higher scanning speed of the displaying device is raised gradually, finally, the next scanning starts before all of the remaining electric charge of the capacitor **109** of the last scanning finishes flowing into the emission part. As a result, the EL element continues to emit light. Therefore, any electric charge charged in the capacitor of each EL element during the emission is not extracted to the outside. In contrast the remaining electric charge in the capacitor is used for emission of the EL element, so that the emission efficiency is improved. In addition, since the peak luminance of each EL element becomes close to the average luminance, the electric load to the emitting element is reduced, so that the life of the EL element increases greatly. Furthermore, the peak voltage to applied to the EL element is managed to the average voltage required for the average luminance. Therefore, the displaying device comprising organic EL emitting elements according to the present invention can be provided with a low power supply voltage lower than that of sufficient to maintain the average luminance emitted by the conventional organic EL emitting element having the power supply **113** as shown in FIG. 9, i.e., the consumption power is saved and the destruction of the EL element due to overvoltage is prevented.

In addition to the above embodiment in which the emitting element driving circuit drives the organic EL emitting elements, the present invention may be adopted to any emitting element other than the organic EL emitting element in the electrical equivalent circuit such as a light emitting diode, a self-emission type EL element, as far as the emitting element has a capacitor in parallel to an emission part in its electrical equivalent circuit.

According to the present invention set forth in claim 1, the rectifier connected in series to a capacitor in parallel to an emission part in the electrical equivalent circuit of the emitting element prevents extracting the electric charge charged in the capacitor during the scanning to the outside. As a result, the remaining electric charge of the capacitor is used for the next emission scanning, so that the emission efficiency is improved. Therefore, the power supply voltage to be applied to the emitting element for a desired luminance is saved. Therefore, the present invention adapted into the displaying device secures a sufficient emission duration without using a circuit having a memory characteristic such as a thin film transistor (TFT). Moreover, the present invention adapted into the displaying device with a simple matrix construction of emitting elements may easily drive a display panel with a high duty ratio.

Since the peak luminance becomes near the average luminance in the present invention, the power supply voltage for a desired luminance of the emitting element is saved at a low level. Further, the deterioration and destruction of the EL element are prevented.

In the case that the present invention is used for the displaying device with a simple matrix circuit, the increase of the number of the scanning lines does not cause the instantaneous luminance of the EL element rising. Therefore, the number of the scanning lines may be increased to achieve a high resolution for a displayed image.

In addition, when that the present invention is used for the displaying device with a dot matrix circuit, the gray scale representation may be easily achieved by a pulse density moderation or the like because of a short scanning period.

It should thus be apparent that the scope of the teaching of this invention is not intended to be limited by only the embodiments that have been expressly disclosed and illustrated, but that instead the scope of the teaching of this invention should be read as being commensurate with the scope of the claims that follow.

What is claimed is:

1. An emitting element driving circuit for driving an emitting element comprising:
   at least one organic electroluminescent emitting element, and
   a rectifier directly connected in series to said emitting element, wherein said emitting element has a capacitor in parallel to an emission part in its electrical equivalent circuit,
   wherein, immediately after a scanning duration with a forward bias to the emitting element and the rectifier, an inverse voltage is applied across the emitting element, and said rectifier prohibits injection of an inverse current to the emitting element so that emission of the emitting element continues during a discharge period.

2. An emitting element driving circuit according to claim 1 wherein a plurality of the emitting elements are used for a displaying device so as to be constructed with a matrix arrangement array having a number of scanning lines and vertical row lines to form plural crossover points at which the emitting elements are connected to the scanning lines and vertical row lines respectively.

3. An emitting element driving circuit according to claim 2 wherein said matrix arrangement array of the emitting elements is driven through an AC driving method.

4. An emitting element driving circuit according to claim 1 wherein, each of said emitting elements is an organic electroluminescent element comprising a cathode of a metallic electrode, an anode of a transparent electrode, and an organic fluorescent thin film of an organic compound layer and an organic positive-hole transport layer, which are layered between the cathode and the anode, wherein said rectifier is directly connected in series and in a forward direction thereof to said organic electroluminescent element.

5. An emitting element driving circuit for emitting elements with a simple matrix arrangement comprising:

organic electroluminescent emitting element arranged in a simple matrix each having a cathode and an anode and a capacitor in parallel to an emission part in its electrical equivalent circuit;

vertical row lines connected to said emitting elements each connectable to a first power supply for applying a forward voltage thereto;

scanning lines crossing apart from said vertical row lines to form plural crossover points at which the emitting elements are disposed respectively and each connectable to a switch used for applying an inverse voltage to the emitting elements; and

at least one rectifier directly connected in series and in a forward direction thereof to each of said emitting elements between respective ones of said vertical row lines and scanning lines, wherein, immediately after a scanning duration with a forward bias to the emitting element and the rectifier, an inverse voltage is applied across the emitting element, and said rectifier prohibits injection of an inverse current to the emitting element so that emission of the emitting element continues during a discharge period.

* * * * *

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06/17/97 OR 5,640,067

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United States Patent [19]

Yamauchi et al.

[11] Patent Number: 5,640,067

[45] Date of Patent: Jun. 17, 1997

[54] **THIN FILM TRANSISTOR, ORGANIC ELECTROLUMINESCENCE DISPLAY DEVICE AND MANUFACTURING METHOD OF THE SAME**

[75] Inventors: **Yukio Yamauchi**, Kanagawa; **Michio Arai**, Tokyo, both of Japan

[73] Assignees: **TDK Corporation**, Tokyo; **Semiconductor Energy Laboratory Co., Ltd.**, Kanagawa, both of Japan

[21] Appl. No.: **617,121**

[22] Filed: **Mar. 18, 1996**

[30] **Foreign Application Priority Data**

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[51] **Int. Cl.**^{6} **H01J 1/62**; H01J 63/04; G09G 3/10

[52] **U.S. Cl.** **313/504**; 313/506; 313/509; 315/169.3; 315/169.1

[58] **Field of Search** 313/504–509, 313/511, 512; 315/169.1, 169.3; 428/917; 257/501, 506, 508

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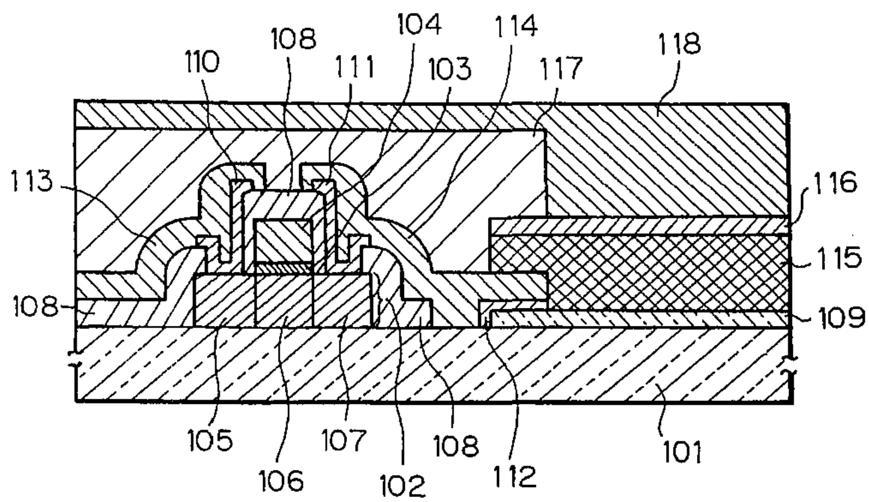
Primary Examiner—Richard Chilcot
Assistant Examiner—Mack Haynes

[57] **ABSTRACT**

An organic EL display device has a substrate, a plurality of organic EL elements formed on the substrate and a plurality of thin film transistors formed on the substrate. The transistors are connected to the respective EL elements for controlling current applied to the respective elements. Each of the transistors includes an active layer of semiconductor material, formed on the substrate, a source region and a drain region being formed in the active layer, a source electrode of aluminum material electrically coupled to the source region formed in the active layer, a drain electrode of aluminum material electrically coupled to the drain region formed in the active layer, an insulation layer formed on the active layer, a gate electrode formed on the insulation layer, a first barrier metal layer of titanium nitride containing equal to or less than 50 atm % of nitrogen or titanium, inserted between the source electrode and the source region of the active layer, and a second barrier metal layer of titanium nitride containing equal to or less than 50 atm % of nitrogen or titanium, inserted between the drain electrode and the drain region of the active layer.

14 Claims, 3 Drawing Sheets



IPR2020-01059

Fig. 1

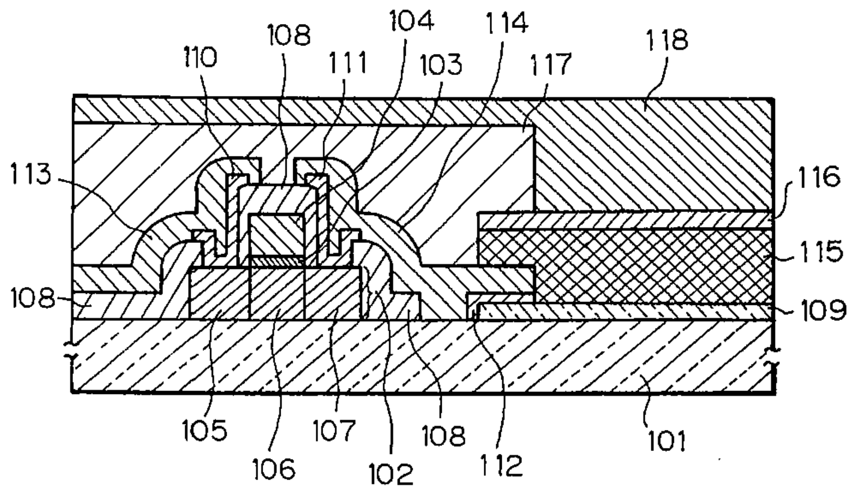

108
104
114
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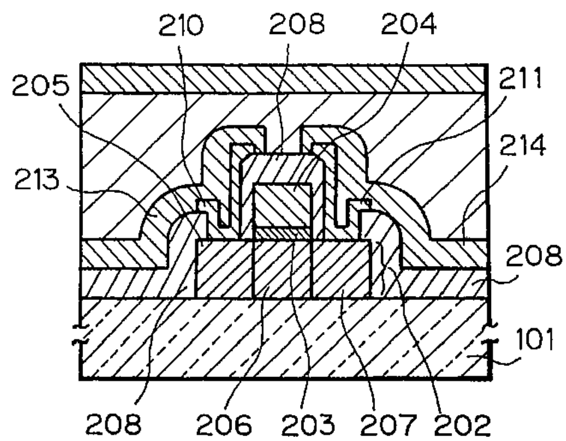
Fig. 2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203
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202

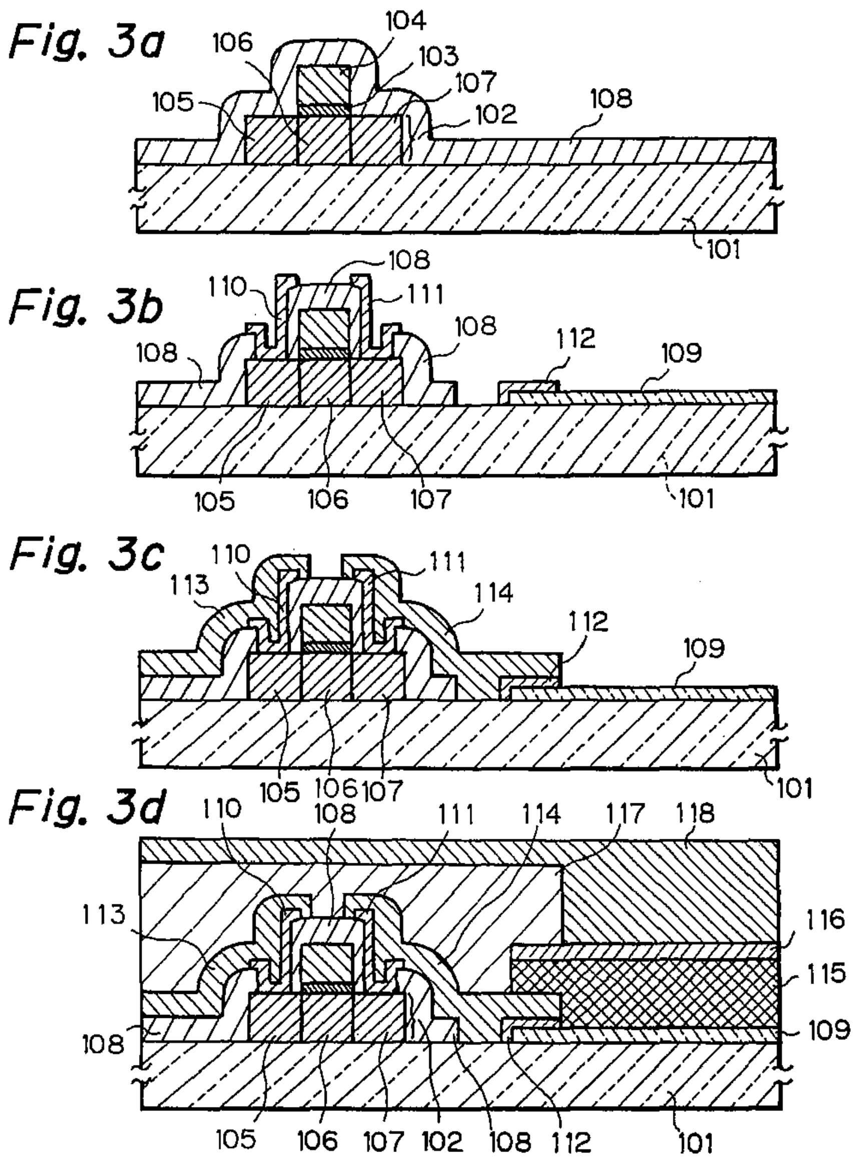
Fig. 3a
104
106
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102
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101
Fig. 3b
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110
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108
112
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106
107
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Fig. 3c
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111
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114
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107
101
Fig. 3d
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116
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102
108
112
101

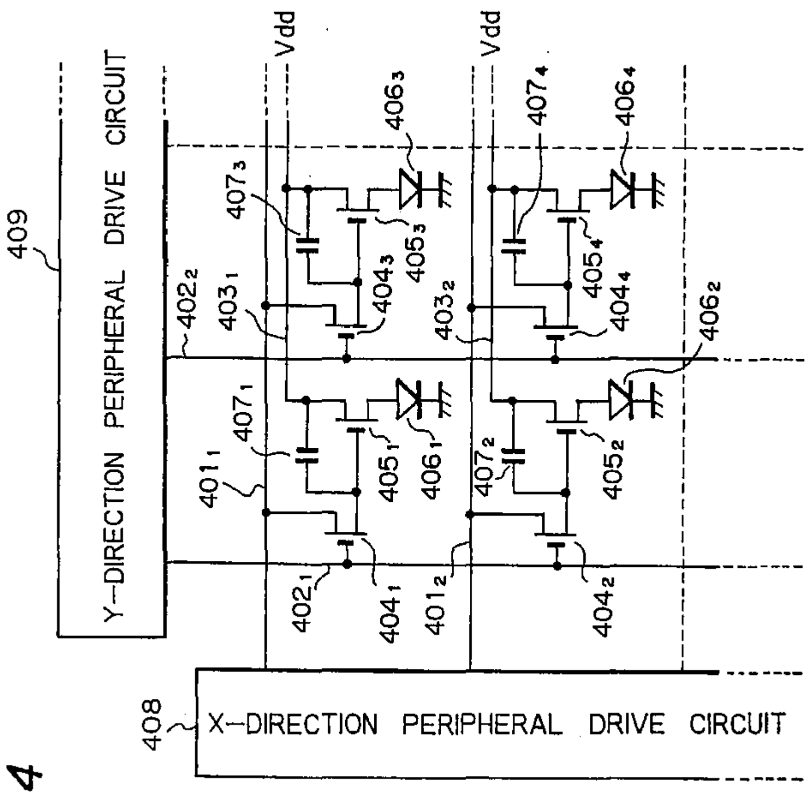
Y-DIRECTION PERIPHERAL DRIVE CIRCUIT
409
X-DIRECTION PERIPHERAL DRIVE CIRCUIT
408
Vdd
Vdd
401_1
401_2
402_1
402_2
403_1
403_2
404_1
404_2
404_3
404_4
405_1
405_2
405_3
405_4
406_1
406_2
406_3
406_4
407_1
407_2
407_3
407_4

Fig. 4

THIN FILM TRANSISTOR, ORGANIC ELECTROLUMINESCENCE DISPLAY DEVICE AND MANUFACTURING METHOD OF THE SAME

FIELD OF THE INVENTION

The present invention relates to a thin film transistor used in an organic electroluminescence (EL) display device, the organic EL display device and a method of manufacturing the organic EL display device.

DESCRIPTION OF THE RELATED ART

In an organic EL display device, many of organic EL elements are arranged in matrix on a substrate. Each of the EL elements, namely a pixel (picture element), consists of a transparent electrode layer, an organic EL layer and an upper electrode layer. At least one thin film transistor for controlling current applied to the EL element is electrically connected to this EL element.

In general, each of the thin film transistors has a silicon active layer with a source region and a drain region, and source and drain electrodes of aluminum material to be electrically connected to the source and drain regions, respectively. In the conventional thin film transistor, barrier metal layers made of chrome material are inserted between the silicon active layer and the source and drain electrodes so as to prevent silicon atoms in the silicon active layer from being diffused and disappeared into the source and drain electrodes of aluminum material.

However, according to the conventional organic EL display device, chrome used for material of the barrier metal layers of the thin film transistors often elutes into the upper electrode layers and the transparent electrode layers of the EL elements causing the thin film transistors to short-circuit with the upper electrode layers or the transparent electrode layers. Subsequently to this, all the chrome of the barrier metal layers may elute so that hollow spaces will be formed between the source and drain regions of the silicon active layers and the aluminum source and drain electrodes. This results disconnection of the source and drain regions and the respective electrodes. These short-circuit and disconnection will stop operations of the thin film transistors causing reliability of the organic EL display device to extremely lower.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide a thin film transistor used in an organic EL display device, the organic EL display device and a method of manufacturing the organic EL display device, whereby short-circuit and disconnection in the organic EL display device due to elusion of the barrier metal material of the thin film transistors can be prevented from occurring to keep high reliability of the organic EL display device.

According to careful study by the inventors of this application, it has come out that the aforementioned short-circuit and disconnection are caused by movement of ionized chrome to the organic EL elements. The ionization of the chrome and the movement of the ionized chrome will be occurred due to moisture provided from the organic EL layer made of high hydroscopic material and due to relatively high DC current (bias current) continuously flowing through the current control thin film transistors connected to the EL elements and through switching thin film transistors connected to and for driving the respective current control transistors.

Thus, according to the present invention, a thin film transistor which is formed in an organic EL display device having a substrate and a plurality of organic EL elements formed on the substrate is provided. This transistor used to drive one of the EL elements includes an active layer of semiconductor material, formed on the substrate, a source region and a drain region being formed in the active layer, a source electrode of aluminum material electrically coupled to the source region formed in the active layer, a drain electrode of aluminum material electrically coupled to the drain region formed in the active layer, an insulation layer formed on the active layer, a gate electrode formed on the insulation layer, a first barrier metal layer of titanium nitride containing equal to or less than 50 atm % of nitrogen or made of titanium, inserted between the source electrode and the source region of the active layer, and a second barrier metal layer of titanium nitride containing equal to or less than 50 atm % of nitrogen or made of titanium, inserted between the drain electrode and the drain region of the active layer.

According to the present invention, also, an organic EL display device having a substrate, a plurality of organic EL elements formed on the substrate and a plurality of thin film transistors formed on the substrate is provided. The transistors are connected to the respective EL elements for controlling current applied to the respective elements. Each of the transistors includes an active layer of semiconductor material, formed on the substrate, a source region and a drain region being formed in the active layer, a source electrode of aluminum material electrically coupled to the source region formed in the active layer, a drain electrode of aluminum material electrically coupled to the drain region formed in the active layer, an insulation layer formed on the active layer, a gate electrode formed on the insulation layer, a first barrier metal layer of titanium nitride containing equal to or less than 50 atm % of nitrogen or made of titanium, inserted between the source electrode and the source region of the active layer, and a second barrier metal layer of titanium nitride containing equal to or less than 50 atm % of nitrogen or made of titanium, inserted between the drain electrode and the drain region of the active layer.

Since the barrier metal layers in the current control thin film transistors arranged nearest to the respective organic EL elements are made of titanium nitride containing equal to or less than 50 atm % of nitrogen or made of titanium, no elusion of the barrier metal layers occurs resulting no short-circuit nor disconnection in the organic EL display device to keep high reliability of the organic EL display device.

It is preferred that each of the organic EL elements includes a transparent electrode layer formed on the substrate, an organic EL layer formed on the transparent electrode layer and an upper electrode layer formed on the organic EL layer, the transparent electrode being electrically coupled to a conductive lead of aluminum material, and that each of the organic EL elements further includes a contact metal layer of titanium nitride containing equal to or less than 50 atm % of nitrogen or made of titanium, inserted between the transparent electrode layer and the conductive lead. The above-mentioned conductive lead may be connected to the drain electrode.

Since both the barrier metal layers in the current control thin film transistors and the contact metal layer in the organic EL elements are simultaneously manufactured in the same process, manufacturing cost can be decreased. Of course, the contact metal layers made of titanium nitride containing equal to or less than 50 atm % of nitrogen or made of titanium will result tight and stable contact between the respective conductive leads of aluminum and the respective transparent electrode layers.

According to the present invention, furthermore, an organic EL display device of active matrix type having a substrate, a plurality of organic EL elements formed on the substrate and a plurality of first and second thin film transistors formed on the substrate is provided. The first transistors are connected to the respective EL elements for controlling current applied to the respective elements, and the second transistors are connected to the respective first transistors for switching the respective first transistors. Each of the first and second transistors includes an active layer of semiconductor material, formed on the substrate, a source region and a drain region being formed in the active layer, a source electrode of aluminum material electrically coupled to the source region formed in the active layer, a drain electrode of aluminum material electrically coupled to the drain region formed in the active layer, an insulation layer formed on the active layer, a gate electrode formed on the insulation layer, a first barrier metal layer of titanium nitride containing equal to or less than 50 atm % of nitrogen or made of titanium, inserted between the source electrode and the source region of the active layer, and a second barrier metal layer of titanium nitride containing equal to or less than 50 atm % of nitrogen or made of titanium, inserted between the drain electrode and the drain region of the active layer.

It is preferred that each of the organic EL elements includes a transparent electrode layer formed on the substrate, an organic EL layer formed on the transparent electrode layer and an upper electrode layer formed on the organic EL layer, the transparent electrode being electrically coupled to a conductive lead of aluminum material, and that each of the organic EL elements further includes a contact metal layer of titanium nitride containing equal to or less than 50 atm % of nitrogen or made of titanium, inserted between the transparent electrode layer and the conductive lead. The above-mentioned conductive lead may be connected to the drain electrode.

According to the present invention, also, a method for manufacturing an organic EL display device having a plurality of organic EL elements and a plurality of thin film transistors formed on a substrate is provided. Each of the organic EL elements and the thin film transistors is manufactured by the steps of depositing an active layer of semiconductor material on the substrate, forming a source region and a drain region in the active layer, forming a gate insulation layer on the active layer, forming a gate electrode on the gate insulation layer, depositing an insulation interlayer on the active layer and the substrate, removing a part of the insulation interlayer to form contact holes on the source and drain regions of the active layer and organic EL element forming region, forming a transparent electrode layer in the organic EL element forming region on the substrate, simultaneously forming first and second barrier metal layers and a contact metal layer of titanium nitride containing equal to or less than 50 atm % of nitrogen or made of titanium, the first and second barrier metal layers being formed in the contact holes on the source and drain regions of the active layer, the contact metal layer being formed on the transparent electrode layer, forming source and drain electrode and a conductive lead of aluminum material on the first and second barrier metal layers and the contact metal layer, respectively, forming an organic EL layer on the transparent electrode layer, and forming an upper electrode layer on the EL layer.

Further objects and advantages of the present invention will be apparent from the following description of the preferred embodiments of the invention as illustrated in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a sectional view of a part of a preferred embodiment of an organic EL display device according to the present invention;

FIG. 2 shows a sectional view of a part of the embodiment shown in FIG. 1;

FIGS. 3*a* to 3*d* show sectional views of a part of manufacturing steps of the EL display device according to the embodiment shown in FIG. 1; and

FIG. 4 shows a circuit diagram of the EL display device shown in FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 shows an organic electroluminescence (EL) element and a current control thin film transistor for controlling current applied to the EL element in a preferred embodiment of an organic EL display device according to the present invention.

In FIG. 1, a reference numeral **101** denotes a transparent substrate such as a quartz substrate. On the substrate **101**, many of the organic EL elements and their peripheral circuit elements such as current control thin film transistors, switching thin film transistors for switching the respective current control transistors, another thin film transistors which constitute peripheral driving circuits and capacitors are formed.

Each of the current control thin film transistors is substantially constituted by an active silicon layer **102** formed on the substrate **101**, a gate oxide layer of SiO_2 **103** formed on a central region of the active silicon layer **102**, a gate electrode of phosphorous doped polysilicon **104** laminated on the gate oxide layer **103**, a source electrode and conductive lead of aluminum material **113** and a drain electrode and conductive lead of aluminum material **114**. The gate electrode **104** can be made of aluminum material instead of the phosphorous doped polysilicon. In the active silicon layer **102**, a source region **105**, a channel region **106** and a drain region **107** are formed. To the source region **105** of the active silicon layer **102**, the source electrode and conductive lead **113** is electrically coupled via a barrier metal layer of titanium nitride which contains 10 atm % of nitrogen **110**. Also, to the drain region **107** of the active silicon layer **102**, the drain electrode and conductive lead **114** is electrically coupled via a barrier metal layer of titanium nitride which contains 10 atm % of nitrogen **111**. An insulation interlayer of SiO_2 **108** is formed between the active silicon layer **102** and the conductive leads **113** and **114** and between the gate electrode **104** and the barrier metal layers **110** and **111**.

Each of the organic EL elements is substantially constituted by a transparent electrode layer of ITO (Indium Tin Oxide) **109** formed on the substrate **101**, an organic EL layer **115** formed on the transparent electrode layer **109**, an upper electrode layer of a magnesium film including silver material **116** formed on the EL layer **115** and a common electrode of aluminum material **118** formed on the upper electrode layer **116**. The transparent electrode layer **109** is electrically coupled to the drain conductive lead **114** via a contact metal layer of titanium nitride which contains 10 atm % of nitrogen **112**. A protection layer of SiO_2 **117** is formed between the common electrode **118** and the conductive leads **113** and **114**.

FIG. 2 shows the switching thin film transistor in the preferred embodiment of the organic EL display device according to the present invention.

Each of the switching thin film transistors is substantially constituted by an active silicon layer **202** formed on the substrate **101**, a gate oxide layer of SiO_2 **203** formed on a central region of the active silicon layer **202**, a gate electrode of phosphorous doped polysilicon **204** laminated on the gate oxide layer **203**, a source electrode and conductive lead of aluminum material **213** and a drain electrode and conductive lead of aluminum material **214**. The gate electrode **204** can be made of aluminum material instead of the phosphorous doped polysilicon. In the active silicon layer **202**, a source region **205**, a channel region **206** and a drain region **207** are formed. To the source region **205** of the active silicon layer **202**, the source electrode and conductive lead **213** is electrically coupled via a barrier metal layer of titanium nitride which contains 10 atm % of nitrogen **210**. Also, to the drain region **207** of the active silicon layer **202**, the drain electrode and conductive lead **214** is electrically coupled via a barrier metal layer of titanium nitride which contains 10 atm % of nitrogen **211**. An insulation interlayer of SiO_2 **208** is formed between the active silicon layer **202** and the conductive leads **213** and **214** and between the gate electrode **204** and the barrier metal layers **210** and **211**.

Referring to FIGS. 3*a* to 3*d*, manufacturing processes of the current control thin film transistor and the organic EL element of this embodiment will be described in detail. It should be noted that manufacturing processes of the switching thin film transistor and another thin film transistors which constitute peripheral driving circuits of the EL element will be the same as following processes of the current control thin film transistor.

As shown in FIG. 3*a*, on a transparent substrate **101** such as a quartz substrate, a glass substrate or a ceramic substrate, an active silicon layer **102** with an island shape is formed by depositing an amorphous silicon layer by a CVD (Chemical Vapor Deposition) method, annealing the deposited amorphous silicon layer to form a polysilicon layer (solid-phase growth), and then performing patterning process of the polysilicon layer.

Then, on the active silicon layer **102**, a gate oxide layer of SiO_2 **103** and a gate electrode of phosphorous doped polysilicon **104** are formed in lamination. The gate electrode **104** can be made of aluminum material instead of the phosphorous doped polysilicon. Thereafter, a source region **105**, a channel region **106** and a drain region **107** are formed in the active silicon layer **102** by an ion doping method. In this embodiment, dopant is for example P and the gate electrode **104** is used as a mask for the doping process. Then, to cover all of these layers, an insulation interlayer of SiO_2 **108** is deposited.

Then, contact holes are formed by etching the insulation interlayer **108** at the source region **105** and at the drain region **107**. Also, by this etching process, the insulation interlayer **108** in a region for forming the EL element is removed.

Then, an transparent conductive film of ITO, ZnO or SnO is sputtered to form an transparent electrode layer **109** in the EL element forming region on the substrate **101**. Without removing the insulation interlayer **108** from the EL element forming region, the transparent electrode layer may be formed on this insulation interlayer **108** not directly on the substrate **101**. Thereafter, a titanium nitride film consisting nitrogen of 10 atm % with a thickness of 100 to 1000 Angstrom preferably 500 Angstrom is deposited on all of the

these layers. Then, this deposited titanium nitride film is etched to simultaneously form a barrier metal layer of titanium nitride **110** on the source region **105**, a barrier metal layer of titanium nitride **111** on the drain region **107** and a contact metal layer of titanium nitride **112** on the transparent electrode layer **109**, respectively.

It will be apparent that barrier metal layers of titanium nitride in the switching thin film transistor and in the another thin film transistors which constitute peripheral driving circuits of the EL element can be simultaneously formed in this process.

Then, as shown in FIG. 3*c*, an aluminum film with a thickness of 6000 Angstrom is deposited by for example sputtering to cover all of these layers and the deposited aluminum film is etched so as to form a source electrode and conductive lead **113** and a drain electrode and conductive lead **114**. Thus, the source electrode and conductive lead of aluminum **113** is electrically coupled to the source region **105** of the active silicon layer **102** via the barrier metal layer of titanium nitride **110**, and also, the drain electrode and conductive lead of aluminum **114** is electrically coupled to the drain region **107** of the active silicon layer **102** via the barrier metal layer of titanium nitride **111** and to the transparent electrode layer **109** via the contact metal layer of titanium nitride **112**.

Then, as shown in FIG. 3*d*, an organic EL layer **115** and an upper electrode layer of a magnesium film including silver material **116** are formed in the EL element forming region on the transparent electrode layer **109** by vapor deposition methods using a metal mask. Thereafter, on these layers, a protection layer of SiO_2 **117** is deposited and a contact hole is etched on the upper electrode layer **116**. Finally, a common electrode of aluminum material **118** is deposited on all of the matrix portion of the organic EL display device.

In the aforementioned embodiment, it is described that the barrier metal layers **110** and **111** and the contact metal layer **112** are made of titanium nitride containing 10 atm % of nitrogen. Higher containing amount of nitrogen in the titanium nitride material will increase degree of contact and stability but decrease electrical conductivity. Thus, according to the present invention, this containing amount of nitrogen in the titanium nitride material is selected to a value equal to or less than 50 atm %, preferably 5 to 15 atm % for obtaining both good stability and electrical conductivity.

According to the present invention, since the barrier metal layers in the current control thin film transistors arranged nearest to the respective organic EL elements are made of titanium nitride containing equal to or less than 50 atm % of nitrogen, no elusion of the barrier metal layers occurs resulting no short-circuit nor disconnection in the organic EL display device to keep high reliability of the organic EL display device. Furthermore, since both the barrier metal layers in the current control thin film transistors and the contact metal layer in the organic EL elements are simultaneously manufactured in the same process, manufacturing cost can be decreased. Of course, the contact metal layers of titanium nitride containing equal to or less than 50 atm % of nitrogen will result tight and stable contact between the respective conductive leads of aluminum and the respective transparent electrode layers.

According to the present invention, also, the barrier metal layers in the current control thin film transistors and the contact metal layers in the respective organic EL elements can be made of titanium. Thus, no elusion of the barrier metal layers occurs resulting no short-circuit nor disconnection in the organic EL display device to keep high reliability of the organic EL display device. Furthermore, if both the barrier metal layers in the current control thin film transistors and the contact metal layer in the organic EL elements can be simultaneously manufactured in the same process, manufacturing cost can be decreased. Of course, the contact metal layers of titanium will also result tight and stable contact between the respective conductive leads of aluminum and the respective transparent electrode layers.

As shown in FIG. 4, the organic EL display device according to the embodiment shown in FIG. 1 is constituted by X-direction signal lines 401_1, 401_2, . . . , Y-direction signal lines 402_1, 402_2, . . . , power supply lines (Vdd) 403_1, 403_2, . . . , switching thin film transistors 404_1, 404_2, 404_3, 404_4, . . . , current control thin film transistors 405_1, 405_2, 405_3, 405_4, . . . , organic EL elements 406_1, 406_2, 406_3, 406_4, . . . , capacitors 407_1, 407_2, 407_3, 407_4, . . . , a X-direction peripheral drive circuit 408 and a Y-direction peripheral drive circuit 409.

Each of the pixels of the EL display device is specified by one of the X-direction signal lines 401_1, 401_2, . . . and one of the Y-direction signal lines 402_1, 402_2, ... If a signal corresponding to picture data is applied to the X-direction signal line 401_2 and Y-direction scanning signal is applied to the Y-direction signal line 402_1, the switching transistor 404_2 in the specified pixel turns on. Thus, the current control transistor 405_2 controls current flowing from the power supply line 403_2 into the organic EL element 406_2 in accordance with the picture data causing corresponding light emission from this EL element 406_2.

According to the present invention, at least the barrier metal layers in the current control thin film transistors and preferably the barrier metal layers in the switching thin film transistors are made of titanium nitride containing equal to or less than 50 atm % of nitrogen or made of titanium. In manufacturing the EL display device, it is desired that the contact metal layers in the organic EL elements are simultaneously formed in the same process of the barrier metal layers with the same material, namely titanium nitride containing equal to or less than 50 atm % of nitrogen or titanium. Furthermore, according to the present invention, the barrier metal layers in the thin film transistors in the peripheral drive circuits are preferably made of titanium nitride containing equal to or less than 50 atm % of nitrogen or made of titanium.

Many widely different embodiments of the present invention may be constructed without departing from the spirit and scope of the present invention. It should be understood that the present invention is not limited to the specific embodiments described in the specification, except as defined in the appended claims.

What is claimed is:

1. A thin film transistor formed in an organic electroluminescence display device having a substrate and a plurality of organic electroluminescence elements formed on said substrate, said transistor being used to drive one of said electroluminescence elements, said transistor comprising:

an active layer of semiconductor material, formed on said substrate, a source region and a drain region being formed in said active layer;

a source electrode of aluminum material electrically coupled to said source region formed in said active layer;

a drain electrode of aluminum material electrically coupled to said drain region formed in said active layer;

an insulation layer formed on said active layer;

a gate electrode formed on said insulation layer;

a first barrier metal layer of titanium nitride containing equal to or less than 50 atm % of nitrogen, inserted between said source electrode and said source region of said active layer; and

a second barrier metal layer of titanium nitride containing equal to or less than 50 atm % of nitrogen, inserted between said drain electrode and said drain region of said active layer.

2. A thin film transistor formed in an organic electroluminescence display device having a substrate and a plurality of organic electroluminescence elements formed on said substrate, said transistor being used to drive one of said electroluminescence elements, said transistor comprising:

an active layer of semiconductor material, formed on said substrate, a source region and a drain region being formed in said active layer;

a source electrode of aluminum material electrically coupled to said source region formed in said active layer;

a drain electrode of aluminum material electrically coupled to said drain region formed in said active layer;

an insulation layer formed on said active layer;

a gate electrode formed on said insulation layer;

a first barrier metal layer of titanium inserted between said source electrode and said source region of said active layer; and

a second barrier metal layer of titanium, inserted between said drain electrode and said drain region of said active layer.

3. An organic electroluminescence display device having a substrate, a plurality of organic electroluminescence elements formed on said substrate and a plurality of thin film transistors formed on said substrate, said transistors being connected to said respective electroluminescence elements for controlling current applied to said respective elements, each of said transistors comprising:

an active layer of semiconductor material, formed on said substrate, a source region and a drain region being formed in said active layer;

a source electrode of aluminum material electrically coupled to said source region formed in said active layer;

a drain electrode of aluminum material electrically coupled to said drain region formed in said active layer;

an insulation layer formed on said active layer;

a gate electrode formed on said insulation layer;

a first barrier metal layer of titanium nitride containing equal to or less than 50 atm % of nitrogen, inserted between said source electrode and said source region of said active layer; and

a second barrier metal layer of titanium nitride containing equal to or less than 50 atm % of nitrogen, inserted between said drain electrode and said drain region of said active layer.

4. The device as claimed in claim 3, wherein each of said organic electroluminescence elements includes a transparent electrode layer formed on said substrate, an organic electroluminescence layer formed on said transparent electrode layer and an upper electrode layer formed on said organic electroluminescence layer, said transparent electrode being electrically coupled to a conductive lead of aluminum material, and wherein each of said organic electroluminescence elements further includes a contact metal layer of

titanium nitride containing equal to or less than 50 atm % of nitrogen, inserted between said transparent electrode layer and said conductive lead.

5. The device as claimed in claim 4, wherein said conductive lead is connected to said drain electrode.

6. An organic electroluminescence display device having a substrate, a plurality of organic electroluminescence elements formed on said substrate and a plurality of thin film transistors formed on said substrate, said transistors being connected to said respective electroluminescence elements for controlling current applied to said respective elements, each of said transistors comprising:

an active layer of semiconductor material, formed on said substrate, a source region and a drain region being formed in said active layer;

a source electrode of aluminum material electrically coupled to said source region formed in said active layer;

a drain electrode of aluminum material electrically coupled to said drain region formed in said active layer;

an insulation layer formed on said active layer;

a gate electrode formed on said insulation layer;

a first barrier metal layer of titanium inserted between said source electrode and said source region of said active layer; and

a second barrier metal layer of titanium inserted between said drain electrode and said drain region of said active layer.

7. The device as claimed in claim 6, wherein each of said organic electroluminescence elements includes a transparent electrode layer formed on said substrate, an organic electroluminescence layer formed on said transparent electrode layer and an upper electrode layer formed on said organic electroluminescence layer, said transparent electrode being electrically coupled to a conductive lead of aluminum material, and wherein each of said organic electroluminescence elements further includes a contact metal layer of titanium inserted between said transparent electrode layer and said conductive lead.

8. The device as claimed in claim 7, wherein said conductive lead is connected to said drain electrode.

9. An organic electroluminescence display device of active matrix type having a substrate, a plurality of organic electroluminescence elements formed on said substrate and a plurality of first and second thin film transistors formed on said substrate, said first transistors being connected to said respective electroluminescence elements for controlling current applied to said respective elements, said second transistors being connected to said respective first transistors for switching said respective first transistors, each of said first and second transistors comprising:

an active layer of semiconductor material, formed on said substrate, a source region and a drain region being formed in said active layer;

a source electrode of aluminum material electrically coupled to said source region formed in said active layer;

a drain electrode of aluminum material electrically coupled to said drain region formed in said active layer;

an insulation layer formed on said active layer;

a gate electrode formed on said insulation layer;

a first barrier metal layer of titanium nitride containing equal to or less than 50 atm % of nitrogen, inserted between said source electrode and said source region of said active layer; and

a second barrier metal layer of titanium nitride containing equal to or less than 50 atm % of nitrogen, inserted between said drain electrode and said drain region of said active layer.

10. The device as claimed in claim 9, wherein each of said organic electroluminescence elements includes a transparent electrode layer formed on said substrate, an organic electroluminescence layer formed on said transparent electrode layer and an upper electrode layer formed on said organic electroluminescence layer, said transparent electrode being electrically coupled to a conductive lead of aluminum material, and wherein each of said organic electroluminescence elements further includes a contact metal layer of titanium nitride containing equal to or less than 50 atm % of nitrogen, inserted between said transparent electrode layer and said conductive lead.

11. The device as claimed in claim 10, wherein said conductive lead is connected to said drain electrode.

12. An organic electroluminescence display device of active matrix type having a substrate, a plurality of organic electroluminescence elements formed on said substrate and a plurality of first and second thin film transistors formed on said substrate, said first transistors being connected to said respective electroluminescence elements for controlling current applied to said respective elements, said second transistors being connected to said respective first transistors for switching said respective first transistors, each of said first and second transistors comprising:

an active layer of semiconductor material, formed on said substrate a source region and a drain region being formed in said active layer;

a source electrode of aluminum material electrically coupled to said source region formed in said active layer;

a drain electrode of aluminum material electrically coupled to said drain region formed in said active layer;

an insulation layer formed on said active layer;

a gate electrode formed on said insulation layer;

a first barrier metal layer of titanium inserted between said source electrode and said source region of said active layer; and

a second barrier metal layer of titanium inserted between said drain electrode and said drain region of said active layer.

13. The device as claimed in claim 12, wherein each of said organic electroluminescence elements includes a transparent electrode layer formed on said substrate, an organic electroluminescence layer formed on said transparent electrode layer and an upper electrode layer formed on said organic electroluminescence layer, said transparent electrode being electrically coupled to a conductive lead of aluminum material, and wherein each of said organic electroluminescence elements further includes a contact metal layer of titanium inserted between said transparent electrode layer and said conductive lead.

14. The device as claimed in claim 13, wherein said conductive lead is connected to said drain electrode.

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United States Patent [19]

Namiki et al.

[11] Patent Number: 5,302,468

[45] Date of Patent: Apr. 12, 1994

[54] **ORGANIC ELECTROLUMINESCENT DISPLAY APPARATUS**

[75] Inventors: **Tohru Namiki; Hitoshi Sato; Kenichi Nagayama; Teruichi Watanabe**, all of Tsurugashima, Japan

[73] Assignee: **Pioneer Electronic Corporation**, Tokyo, Japan

[21] Appl. No.: **921,128**

[22] Filed: **Jul. 29, 1992**

[30] **Foreign Application Priority Data**

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[51] **Int. Cl.**[5] **F21K 2/00; H05B 33/06**

[52] **U.S. Cl.** **428/690**; 428/917; 313/500; 313/504; 313/505; 313/506

[58] **Field of Search** 428/690, 917, 620, 623, 428/621, 624, 58, 192; 313/500, 504, 506, 505, 509

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Primary Examiner—Alexander S. Thomas
Assistant Examiner—Charles R. Nold
Attorney, Agent, or Firm—Sughrue, Mion, Zinn, Macpeak & Seas

[57] **ABSTRACT**

Disclosed is an organic electroluminescent display apparatus that has small panels each constituted by forming light-emitting sections, each comprising an organic electroluminescent layer, a transparent electrode and a metal electrode, on one major surface of the substrate. The transparent electrode has an extending portion formed to continuously extend from one major surface of the substrate to one side surface. The associated transparent electrodes of adjoining small panels are electrically connected via an anisotropic conductive sheet which has a conductivity only in the thickness direction. This design can narrow the non-light emitting area of each joint of the small panels.

3 Claims, 2 Drawing Sheets

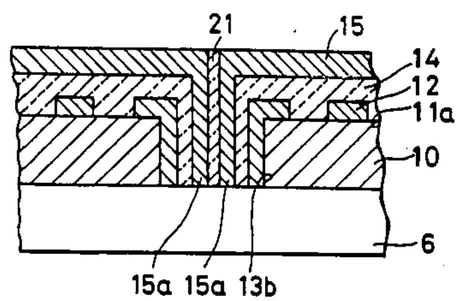


FIG. 1

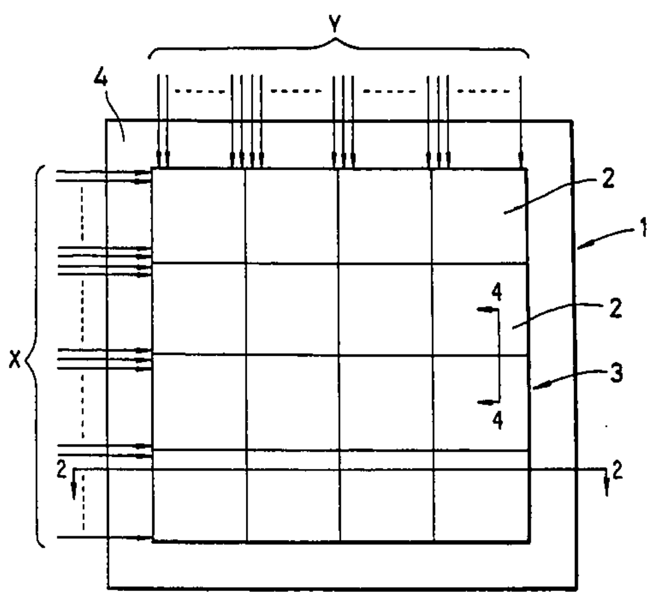


FIG. 2

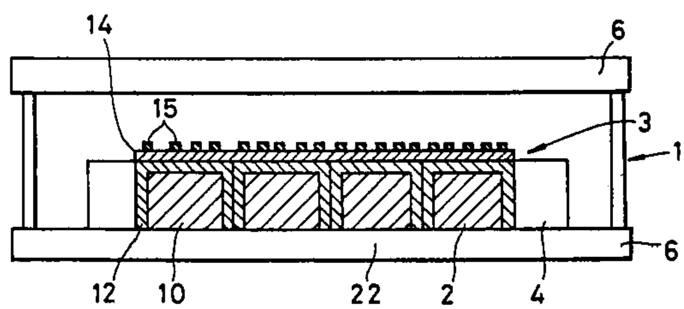


FIG. 3

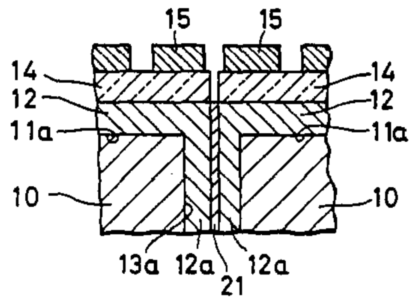


FIG. 4

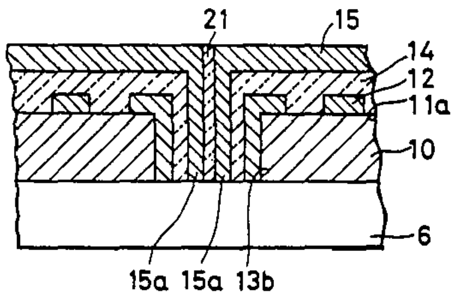
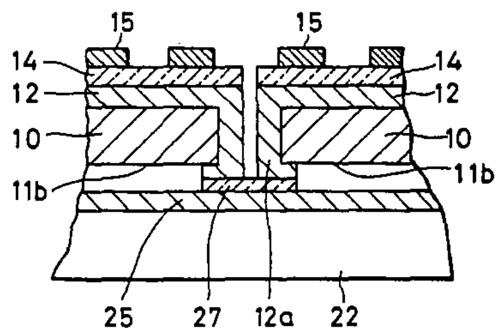


FIG. 5



ORGANIC ELECTROLUMINESCENT DISPLAY APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an organic electroluminescent (hereinafter referred to as EL) display apparatus comprising organic EL elements which emit light when applied with electric charges.

2. Description of the Related Art

Typically, large display apparatuses comprising organic EL elements have a plurality of organic EL elements. Each EL element has an organic EL layer and a pair of electrodes for applying electric charges to this organic EL layer. The quantity of EL elements is determined in accordance with the number of pixels. The EL elements are formed on a single large substrate of an element to constitute a large screen panel, or, alternatively a small panels each having a predetermined number of organic EL elements formed thereon are stacked together to form a large panel.

The organic EL layer should be formed uniformly over the entire panel surface. In the case where a plurality of organic EL elements are formed on a single large substrate, therefore, it is difficult to form the organic EL layer uniformly over the entire substrate surface. Further, a non-uniformly formed organic EL layer would result in uneven brightness on the screen. In addition to a non-uniformly formed organic EL layer, brightness may occur when a hole carrying layer, an electron carrying layer, or electrodes are formed unevenly.

In the case where a plurality of small panels are stacked together to form a large panel, the organic EL layer of each panel can be formed uniformly so that uneven brightness can be suppressed when the large panel is formed. Since the individual electrodes of the organic EL element are very thin, about 1000 angstroms, however, the electrodes to be connected have narrow connecting faces. This makes it difficult to connect the associated electrodes of the adjoining small panels at their end portions.

Conventionally, only the electrodes are led out from each panel to connect the electrodes to thereby facilitate the connection of the panels. This method inevitably increases the joint portions which do not emit light making the joints prominently darker.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide an organic EL display apparatus which does not have the above shortcoming and which suppresses the prominence of joints at the panel-connected portions created when a plurality of small panels are connected to form a large panel.

To achieve this object, according to the present invention, there is provided an organic EL display apparatus which comprises a plurality of organic EL element assemblies having light-emitting sections each including an organic EL layer and a pair of a transparent electrode and a metal electrode facing each other with the organic EL layer in between, and a substrate for supporting at least one of the light-emitting sections on one major surface, the plurality of organic EL element assemblies being arranged adjacent to one another in such a way that the associated transparent electrodes of the adjoining organic EL element assemblies are

electrically connected to one another and the associated metal electrodes thereof are electrically connected to one another, each of the transparent electrode and metal electrode having an extending portion continuously formed from the one major surface of the substrate to a side surface thereof, whereby the associated transparent electrodes and metal electrodes of the adjoining organic EL element assemblies are electrically connected together at the extending portions through a first anisotropic conductive adhesive layer having a conductivity only in a thickness direction.

In another embodiment, the organic EL display apparatus further comprises a transparent substrate for supporting the plurality of organic EL element assemblies arranged adjacent to one another, and the extending portion of the transparent electrode extends to the other major surface of the substrate, the transparent substrate having a conductive portion formed thereon for electrically connecting the extending portions of the associated transparent electrodes of the adjoining organic EL element assemblies and a second anisotropic conductive adhesive layer formed thereon for connecting the conductive portion with the extending portions of the associated transparent electrodes.

The organic EL display apparatus according to the present invention can allow the associated transparent electrodes and metal electrodes of the adjoining organic EL element assemblies to be surely and firmly connected to one another.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagram illustrating the structure of an organic EL display apparatus according to a first embodiment of the present invention;

FIG. 2 is a cross section taken along the line 2—2 in FIG. 1;

FIG. 3 is a cross section of a connecting portion of adjoining organic EL element assemblies in FIG. 2;

FIG. 4 is a cross section taken along the line 4—4 in FIG. 1; and

FIG. 5 is a cross section illustrating a connecting portion of adjoining organic EL element assemblies of an organic EL display apparatus according to a second embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Organic EL display apparatuses embodying the present invention will be described below referring to the accompanying drawings.

First, an organic EL display apparatus according to a first embodiment will be described referring to FIGS. 1 through 4.

Referring to FIGS. 1 and 2, an organic EL display apparatus 1 has a large panel 3 of the desired screen size, which is formed by arranging, for example, 16 small panels 2 as organic EL element assemblies in a 4 by 4 matrix form and electrically connecting them together. This large panel 3, with a drive device 4 attached to the periphery thereof, is housed in a casing 6 and is disposed on a transparent substrate 22 of transparent glass, which becomes a display surface.

Each small panel 2 has organic EL elements formed thereon for 20,000 pixels, for example. As shown in FIGS. 3 and 4, each small panel 2 has a plurality of belt-shaped transparent electrodes 12 of ITO (indium tin oxide) formed in parallel on one major surface 11*a* of a rectangular substrate 10, which is made of a transparent and insulating material, such as glass. The substrate 10 has a pair of facing major surfaces 11a and 11b, and four side surfaces 13a, 13b, 13a, and 13b which connect those major surfaces 11a and 11b. Of the four side surfaces, the side surfaces 13a and 13a face each other in parallel, and the side surfaces 13b and 13b face each other in parallel. Each transparent electrode 12 has an extending portion 12a which continuously extends in the lengthwise direction from the major surface 11a of the substrate 10 to the side surface 13a. An organic EL layer 14 made of an organic material is formed on the transparent electrodes 12 over the entire major surface 11a of the substrate 10.

As shown in FIGS. 3 and 4, a plurality of belt-shaped metal electrodes 15 are formed in parallel on this organic EL layer 14, each having a lengthwise direction defined as a direction crossing the lengthwise direction of the associated transparent electrode 12. Each metal electrode 15 has an extending portion 15a which continuously extends in the lengthwise direction from the major surface 11a of the substrate 10 to the side surface 13b.

In each small panel 2, therefore, the extending portions 12a of the transparent electrodes 12 are formed on one side surface pair 13a of the substrate 10, and the extending portions 15a of the metal electrodes 15 on the other side surface pair 13b.

The organic EL layer 14 and the transparent electrode 12 and metal electrode 15, which make a pair and face each other with the organic EL layer 14 in between, constitute a light-emitting section as an organic EL element. One pixel is formed with the light-emitting section in the vicinity of where each transparent electrode 12 crosses the associated metal electrode 15 while facing each other, taken as one unit.

On each metal electrode 15 may be formed a protective layer for protecting the metal electrode 15 and preventing the short-circuiting of the adjoining metal electrode 15.

The a plurality of small panels 2 are arranged in such a way that the extending portions 12a of the transparent electrodes 12 of the adjoining small panels 2 face each other at the opposite side surfaces 13a of the adjoining small panels 2, and the extending portions 15a of the metal electrodes 15 face each other at the opposite side surfaces 13b of the adjoining small panels 2. An anisotropic conductive sheet 21 as a first anisotropic conductive adhesive layer, which has a conductivity only in the thickness direction is sandwiched between the extending portions 12a and 15a to electrically and securely connect the extending portions 12a and 15a when heated or pressed, for example.

This anisotropic conductive sheet 21 is a film which has, for example, conductive particles almost uniformly dispersed in an adhesive and has, for example, a thin insulating film coated on the individual conductive particles so as to have a conductivity only in the direction of the film thickness while being insulative in the direction perpendicular to the thickness direction. Referring to FIGS. 3–4, the anisotropic layer 21 has conductivity in only the one direction, i.e., a horizontal direction. In other words, a current in the anisotropic layer cannot pass in any direction except the horizontal direction. Accordingly, the anisotropic layer in FIG. 3 prevents one extending portion 12a of the electrode 12 from connecting electrically to the adjoining extending portion 12a (not shown) on the same lateral surface 13a as the former. Similarly, in FIG. 4, one extending portion 15a of electrode 15 is electrically insulated from the adjoining extending portion 15a (not shown) on the same lateral surface 13b as the former.

In FIG. 3, however, the anisotropic layer 21 causes one extending portion 12a of one lateral side 13a of the left side to connect electrically to the extending portion 12a of the right side. In other words, the extending portions 12a and 12a facing each other through the anisotropic layer 21 are electrically connected together. In FIG. 4, similarly, the extending portion 15a and 15a facing each other through the anisotropic layer are electrically connected.

The large panel 3 is formed in the above manner, and the drive device 4 for controlling the individual transparent electrodes 12 and metal electrodes 15 in a matrix form is electrically connected to this large panel 3.

In the organic EL display apparatus 1 having the above structure, the associated electrodes 12 of the adjoining small panels 2 ar electrically connected to one another via the extending portions 12a of those electrodes 12 and the anisotropic conductive sheet 21, and the associated electrodes 15 of the adjoining small panels 2 are likewise electrically connected via their extending portions 15a and the anisotropic conductive sheet 21. This design can provide wider planar space for the connecting portion of the electrodes 12 or the electrodes 15. It is therefore possible to reduce the positioning accuracy at the time of connecting the associated electrodes 12 and 15 of the adjoining small panels 2 as compared with the prior art, thus facilitating the connection of the associated electrodes 12 or electrodes 15 to one another. In addition, the wider planar area of the connecting portion of the electrodes 12 or 15 can provide sure electric connection between the electrodes 12 or 15 and can make the electric connection stronger against the external force.

Further, the extending portions 12a or 15a of the electrodes 12 or 15 on the side surface 13a or 13b of the adjoining small panels 2 can be connected together via the thin anisotropic conductive sheet 21. The non-light emitting area of the joint of the small panels 2 can therefore be made narrower than the one in the prior art, suppressing the prominence of the joint of the small panels 2.

Furthermore, if, as shown in FIG. 4, the transparent electrode 12 at the edge portion of the substrate 10 is formed wide enough to extend to the side surface 13b of the substrate 10, and the extending portion 15a of the metal electrode 15 is formed to extend over the area where the organic EL layer 14 is formed on the transparent electrode 12 on the side surface 13b, the joint of the small panels 2 where the associated metal electrodes 15 face each other can also emit light.

A second embodiment of the present invention will now be described referring to FIG. 5.

In FIG. 5, the extending portions 12a of the transparent electrodes 12 of each small panel 2 are formed to extend from one major surface 11a of the substrate 10 to the other major surface 11b via the side surface 13a. The same reference numerals as used for the components of the first embodiment will be given to corresponding or identical components in the second embodiment to avoid repeating their description.

The small panels 2 are arranged in a matrix form in such a way that the associated transparent electrodes 12 of the adjoining small panels 2 face each other, the associated metal electrodes 15 facing each other, and the other major surface 11*b* of the substrate 10 is arranged to face the transparent substrate 22 that becomes the display surface of the casing 6.

On the transparent substrate 22 is formed a conductive portion 25 made of a transparent material, such as ITO. This conductive portion 25 simultaneously faces the extending portions 12*a* of the transparent electrodes 12 which are located on the other major surface 11*b* of each substrate 10 and are electrically connected.

An anisotropic conductive sheet 27 similar to the one used in the first embodiment is sandwiched as a second anisotropic conductive adhesive layer between the substrate 10 and the transparent substrate 22 to securely and electrically connect the extending portions 12*a* of the transparent electrodes 12 and the conductive portion 25 when heated or pressed.

The large panel 3 is formed in this manner.

In this organic EL display apparatus 1, at the time the associated electrodes 12 or 15 of the adjoining small panels 2 are electrically connected to one another, the extending portions 12*a* of the transparent electrodes 12 on the other major surface 11*b* of the substrates 10 of the small panels 2 are electrically connected to the conductive portion 25 of the transparent substrate 22 via the anisotropic conductive sheet 27. This design can provide wider planar space for the connecting portion of the adjoining small panels 2. The adjoining small panels 2 can thus be connected electrically by arranging the small panels 2 at given positions on the transparent substrate 22, connecting the associated transparent electrodes 12 together via this transparent substrate 22, and connecting the associated metal electrodes 15 together as shown in FIG. 4. It is therefore possible to reduce the positioning accuracy at the time of connecting the associated electrodes 12 and 15 of the adjoining small panels 2 as compared with the prior art, thus facilitating the connection of the associated electrodes 12 or electrodes 15 to one another. In addition, the electrical connection between the transparent electrodes 12 can be accomplished surely and firmly.

Because the anisotropic conductive sheets 21 and 27 show their conductivity only in the thickness direction, they may be formed in a tape shape whose lengthwise direction is the direction of the joint of the substrates 10.

Although the embodiments of the present invention have been illustrated to have the organic EL layer and electrodes in the foregoing description, they may have a hole carrying layer or an electron carrying layer.

In short, according to the organic EL display apparatus embodying the present invention, the electrodes of the light-emitting section each have an extending portion continuously extending from one major surface of the substrate to one side surface, so that the associated electrodes of the adjoining organic EL element assemblies are electrically connected at the extending portions via a first anisotropic conductive adhesive layer that has a conductivity only in the thickness direction. This design can provide wider planar space for the connecting portion of the electrodes. It is therefore possible to facilitate the electric connection between the associated electrodes of the adjoining organic EL element assemblies.

Further, according to a modification of the organic EL display apparatus of the present invention, a transparent substrate for supporting a plurality of organic EL element assemblies arranged adjacent to one another is provided and the extending portions of the transparent electrodes are formed to continuously extend to the other major surface of the substrate, and a conductive portion facing the extending portions of the associated transparent electrodes of the adjoining organic EL element assemblies and a second anisotropic conductive adhesive layer for connecting this conductive portion and the extending portions are formed on the transparent substrate. This design can facilitate the electric connection of the associated electrodes of the adjoining organic EL element assemblies. In addition, since the side surfaces of the adjoining organic EL element assemblies can be made to directly contact each other, it is possible to prevent the joint portions of the organic EL element assemblies from becoming darker, thus suppressing the prominence of the joint portions.

The above descriptions are intended by way of example only and is not intended to limit the present invention in any way except as set forth in the following claims.

What is claimed is:

1. An organic electroluminescent display apparatus comprising:

a plurality of organic electroluminescent element assemblies having light-emitting sections each including an organic electroluminescent layer, a transparent electrode and a metal electrode facing each other with said organic electroluminescent layer in between,

a substrate having a first major surface for supporting at least one of the light-emitting sections, said plurality of organic electroluminescent element assemblies being arranged adjacent to one another such that each said transparent electrode of said adjoining organic electroluminescent element assemblies is electrically connected to one another and each said metal electrode of said adjoining organic electroluminescent element assemblies is electrically connected to one another;

each said transparent electrode and said metal electrode having at least one extending portion continuously formed from said first major surface of said substrate to a side surface thereof; and,

a first anisotropic conductive adhesive layer electrically connecting said transparent electrodes of said adjoining organic electroluminescent element assemblies at the extending portions, said first anisotropic conductive adhesive layer electrically connecting said metal electrodes of said adjoining organic electroluminescent element assemblies at the extending portions, and said first anisotropic conductive adhesive layer having conductivity only in a direction substantially normal to the surface of the extending portions.

2. The organic electroluminescent display apparatus according to claim 1, further comprising:

a transparent substrate for supporting said plurality of organic electroluminescent element assemblies arranged adjacent to each other, wherein said extending portion of said transparent electrode extends to a second major surface of said substrate;

a conductive portion formed on said transparent substrate for electrically connecting said extending portions of each of said transparent electrodes of said adjoining organic electroluminescent element assemblies; and

a second anisotropic conductive adhesive layer formed on said conductive portion for connecting the conductive portion and said extending portions of said transparent electrodes.

3. An organic electroluminescent display apparatus comprising:

a plurality of organic electroluminescent element assemblies having light-emitting sections each including an organic electroluminescent layer, a transparent electrode and a metal electrode facing each other with said organic electroluminescent layer in between;

a substrate having a first major surface for supporting at least one of the light-emitting sections, said plurality of organic electroluminescent element assemblies being arranged adjacent to one another such that each said transparent electrode of said adjoining organic electroluminescent element assemblies is electrically connected to one another and each said metal electrode of said adjoining organic electroluminescent element assemblies is electrically connected to one another;

each said transparent electrode and said metal electrode having at least one extending portion continuously formed from said first major surface of said substrate to a side surface thereof;

a transparent substrate for supporting said plurality of organic electroluminescent element assemblies arranged adjacent to each other, wherein said extending portion of said transparent electrode extends to a second major surface of said substrate;

a conductive portion formed on said transparent substrate for electrically connecting said extending portions of each of said transparent electrodes of said adjoining organic electroluminescent element assemblies; and

an anisotropic conductive adhesive layer formed on said conductive portion for connecting the conductive portion and said extending portions of said transparent electrodes.

* * * * *

FORM PTO 948 (REV. 01-97) U.S. DEPARTMENT OF COMMERCE-Patent and Trademark Office Application No. 976217

NOTICE OF DRAFTPERSON'S PATENT DRAWING REVIEW

The drawing filed (insert date) 11/21/97 are:

A.______ not objected to by the Draftperson under 37 CFR 1.84 or 1.152.

B. ✓ objected to by the Draftperson under 37 CFR 1.84 or 1.152 as indicated below. The Examiner will require submission of new, corrected drawings when necessary. Corrected drawings must be submitted 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 drawing are not acceptable until petition is granted. Fig(s)____
   - ____ Pencil and non black ink is not permitted. Fig(s)____
2. PHOTOGRAPHS. 37 CFR 1.84(b)
   - ____ Photographs are not acceptable until petition is granted.
   - ____ 3 full-tone sets are required. Fig(s)____
   - ____ Photographs not properly mounted (must 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 acceptable. (too thin)
   - ____ Mylar, vellum 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 drawings sheets not the same size. Sheet(s)____
5. MARGINS. 37 CFR 18.4(g): Acceptable margins:
   - Top 2.5 cm Left 2.5 cm 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)____
   - ____ Top (T) ____ Left (L)
   - ____ Right (R) ____ Bottom (B)
6. VIEWS. CFR 1.84(h)
   REMINDER: Specification may require revision to correspond to drawing changes.
   - ____ Views connected by projection lines or lead lines. Fig.(s)____

   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 separately 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) 1, 17
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)____
   - ____ Views not on the same plane on drawing sheet. Fig.(s)____
9. SCALE. 37 CFR 1.84(k)
   - ____ Scale not large enough to show mechanism with 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)____
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 1.48(p)
    - ____ Numbers and reference characters not plain and legible. Fig.(s)____
    - ____ Figure legends are poor. Fig.(s)____
    - ____ Numbers and reference characters not oriented in the same direction as the view. 37 CFR 1.84(p)(3) Fig.(s)____
    - ____ English alphabet not used. 37 CFR 1.84(p)(3) Fig.(s)____
    - ____ Numbers, letters and reference characters must be at least .32 cm (1/8 inch) in height. 37 CFR 1.84(p)(3) Fig.(s)____
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 1.48(t)
    - ____ Sheets not numbered consecutively, and in Ababic numerals beginning with number 1. Fig.(s)____
15. NUMBERING OF VIEWS. 37 CFR 1.84(u)
    - ____ Views not numbered consecutively, and in Abrabic numerals, beginning with number 1. Fig.(s)____
16. CORRECTIONS. 37 CFR 1.84(w)
    - ____ Corrections not made from 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 9.D DATE 3/18/98 TELEPHONE NO. 7033058404

ATTACHMENT TO PAPER NO.____

PTO COPY

REMINDER

Drawing changes may also require changes in the specification, e.g., if Fig. I is changed to Fig. IA, Fig. IB, Fig. IC, etc., the specification, at the Brief Description of the Drawings, must likewise be changed. Please make such changes by 37 CFR 1.312 Amendment at the time of submitting drawing changes.

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 Review Branch.

2. Timing of 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 correction resubmitted within the original three-month period to avoid the necessity of obtaining as extension of time and paying the extension fee. Therefore, applicant should file corrected drawings as soon as 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.

Attorney Docket No. 970719/LH

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant(s): Hiroyasu YAMADA et al

Serial No. : 08/976,217

Filed : November 21, 1997

For : DISPLAY APPARATUS

Art Unit : 2778

Examiner : V. Kovalick

GAU 2778

RECEIVED DEC -3 1999 TC 2700

CERTIFICATE OF MAILING

I hereby certify that this correspondence is being deposited with the United States Postal Service as First Class mail in an envelope addressed to: Assistant Commissioner for Patents, Washington, D.C. 20231, on the date noted below.

Attorney: ROBERT MICHAL

Dated: November 30, 1999

In the event that this Paper is late filed, and the necessary petition for extension of time is not filed concurrently herewith, please consider this as a Petition for the requisite extension of time, and to the extent not tendered by check attached hereto, authorization to charge the extension fee, or any other fee required in connection with this Paper, to Account No. 06-1378.

A M E N D M E N T

Assistant Commissioner of Patents
Washington, D.C. 20231

S I R :

This is responsive to the Office Action mailed August 31, 1999, the term for response to which expires on November 30, 1999. Please amend the application as follows.

IN THE SPECIFICATION:

Page 7, line 1, change "A-A" to --2-2--.

Page 8, line 3, change "B-B" to --18-18;
line 4, change "C-C" to --19-19--;
line 17, change "K-K" to --2-2--.

Page 22, line 18, change "B-B" to --18-18--;
line 19, change "C-C" to --19-19--.

IN THE CLAIMS:

Please cancel claim 2 without prejudice, amend claims 1, 4, 5, 8, 10, 15 and 16, and add new claims 18-19 as follows:

1. (Amended) A display apparatus comprising:

a substrate;

active elements [which are] formed over said substrate and [which are] driven by an externally supplied signal;

an insulation film formed over said substrate so as to cover said active elements, [and] said insulation having at least one contact hole;

at least one first electrode formed on said [at least one] insulation film so as to cover said active elements, and connected to said active elements through said at least one contact hole, said at least one first electrode being made of a material which shields visible light;

an organic electroluminescent layer having an organic electroluminescent material formed on said at least one first electrode so as to cover said active elements and including at least one layer which emits light in accordance with a voltage applied to said at least one layer; and

at least one second electrode formed on said organic electroluminescent layer which covers said active elements.

Claim 4, line 2, between "said" and "electroluminescent layer" insert --organic--.

Claim 5, line 5, between "said" and "electroluminescent layer" insert --organic--.

Claim 8, line 7, between "said" and "electroluminescent layer" insert --organic--.

Claim 10, line 4, between "said" and "electroluminescent layer" insert --organic--.

Claim 15, line 1, between "said" and "electroluminescent layer" insert --organic--.

line 2, between "said" and "electroluminescent layer" insert --organic--.

---

16. (Amended) A display apparatus comprising:

a substrate;

selection transistors formed over said substrate and arranged in a matrix pattern;

drive transistors formed over said substrate and arranged in a matrix pattern, each of said drive transistors being connected to one of said selection transistors;

address lines connected to said selection transistors and through which a signal for turning on said selection transistors is supplied;

data lines connected to said selection transistors, a signal which corresponds to image data being supplied to said drive transistors through said data lines and said selection transistors while said selection transistors [is] are on;

an insulation film formed over said substrate so as to cover said drive transistors, said address lines and said data lines, said insulation film having contact holes formed in correspondence with said drive transistors;

first electrodes made of a material which shields visible light, and formed on said insulation film so as to cover said [election] selection transistors and said drive transistors, said first electrodes being arranged in a matrix pattern in areas surrounded by said address lines and said data lines, and being connected to said drive transistors through said contact holes;

a2 cncld

an organic electroluminescent layer formed on said first electrodes which covers said selection transistors and said drive transistors and including at least one layer which emits light in accordance with an applied voltage;

a second electrode formed on said organic electroluminescent layer which covers said selection transistors and said drive transistors;

a first driver circuit for selectively supplying said address signal to said address lines in sequence; and

a second driver circuit for supplying said image data to said data lines.

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~~Please~~ add the following new claims:

--~~18~~ 17. The display apparatus according to claim 1, wherein said display apparatus further comprises at least one filter, formed above said at least one second electrode, which selectively permits light rays in a first wavelength range to pass therethrough when incident light rays in a second wavelength range including said first wavelength range enter said at least one filter.

~~19~~ 18. The display apparatus according to claim ~~18~~ 17, wherein said at least one filter has a red filter which permits light in a red wavelength range to pass therethrough, a green filter which permits light in a green wavelength range to pass therethrough, and a blue filter which permits light in a blue wavelength range to pass therethrough.--

REMARKS

Reconsideration of this application, as amended, is respectfully requested.

The August 31, 1999 Office Action and the Examiner's comments have been carefully considered. In response, the specification and drawings are amended, claims are cancelled, amended and added, and remarks are set forth below in a sincere effort to place the present application in form for allowance. The amendments are supported by the application as originally filed. Therefore, no new matter is added.

Drawings

Attached to the August 31, 1999 Office Action is a Notice of Draftspersons Patent Drawing Review (Form PTO-948) wherein the Official Draftsperson objects to Figs. 1 and 17 as including sectional designations which are not Arabic or Roman numbers. In response, Figs. 1 and 17 are amended such that the sectional designations include Arabic numbers. Submitted concomitantly herewith is a Letter to the Official Draftsperson requesting approval of the proposed drawing changes to Figs. 1 and 17.

Specification

The specification is amended to coincide with the amendments to Figs. 1 and 17 of the drawings. No new matter is added.

The Present Claimed Invention

The present claimed invention as defined by claim 1 is directed to a display apparatus which includes at least one first electrode, an organic electroluminescent layer and at least one second electrode placed just above active elements. The active elements are being driven by an externally supplied signal. This configuration enables entrance of electrons and holes into the organic electroluminescent layer from the at least one first electrode and the at least one second electrode. Thus, the organic electroluminescent layer emits light even if it is placed just above the active elements. Since the organic electroluminescent layer is flexibly arrangeable regardless of the positional relationship with the active elements, the present claimed invention can enlarge a luminescent area of the electroluminescent layer. This is different than the conventional devices whose electroluminescent layer just above active elements does not emit light.

If the active elements comprise thin film transistors each having an amorphous silicon layer, such active elements may make errors when visible light enters. In the present claimed invention, however, the at least one first electrode prevents the visible light emitted by the electroluminescent layer from entering the active elements because the at least one first electrode includes a material that shields the visible light.

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Generally, the heat resistance of the organic electroluminescent material of the organic electroluminescent layer is poor. This characteristic may cause crystallization or the like when a temperature exceeds a glass transition temperature. Therefore, light emission capability of the organic electroluminescent layer may deteriorate easily. On the contrary, a substrate for the thin film transistors is heated up to several hundred degrees Celsius in a reactive chamber during the manufacturing process of the active elements (for example, thin film transistors). According to the present invention, the active elements are formed on the substrate, and the organic electroluminescent layer is formed on the active elements. Therefore, the organic electroluminescent layer is not exposed to high temperature heat during the manufacturing of the active elements. Accordingly, the present invention prevents the organic electroluminescent material from being deteriorated.

According to the present invention as defined by claim 16, since a set of first electrodes, an organic electroluminescent layer and a second electrode for one pixel cover a selection transistor and a drive transistor, light emission is realized at most of an area surrounded by address lines and data lines. This configuration provides a brighter display. Moreover, errors by the selection transistors and drive transistors are prevented from being made because the first electrodes are made of a material which shields visible light. Since the selection

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transistors and drive transistors are formed on the substrate and the organic electroluminescent layer is placed above them, the organic electroluminescent layer is prevented from being exposed to high temperature heat during the manufacturing process for the transistors. Thus, it prevents deterioration of the organic electroluminescent material.

Rejection under 35 U.S.C. 102(e)

In the Office Action claims 1, 2 and 6 are rejected under 35 USC 102(e) as being anticipated by USP 5,684,365 (Tang et al). In response, claim 1 is amended and claim 2 is cancelled.

Claim 1 is patentable over Tang et al because Tang et al do not disclose, teach or suggest, inter alia:

1. at least one first electrode formed on said insulation film so as to cover said active elements, and connected to said active elements through said at least one contact hole, said at least first electrode being made of a material which shields visible light (claim 1, lines 7-11);

2. an organic electroluminescent layer having an organic electroluminescent material formed on said at least one first electrode so as to cover said active elements and including at least one layer which emits light in

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accordance with a voltage applied to said at least one layer (claim 1, lines 12-16); and/or

3. at least one second electrode formed on said organic electroluminescent layer which covers said active elements (claim 1, lines 18-19).

FIG. 2 of Tang et al. teaches that the EL PAD does not cover TFT1 and TFT2. In the organic EL elements disclosed in Tang et al., only areas where an anode layer, an EL layer and a cathode layer are overlaid with each other emit light because of the light emission mechanism (see column 7, line 56 to column 8, line 4 of Tang et al). Each pixel's luminescent area depends on a transparent electrode material (ITO) 72 because an organic electroluminescent layer 82 and an EL cathode 84 are formed over a plurality of pixels as shown in FIG. 3. Since a transparent electrode material 72 does not cover the TFT1 and TFT2, the pixel resolution is defined by the feature size of the TFT (see column 5, lines 19 to 23 of Tang et al). Such restriction reduces the ratio of the luminescent area in each pixel.

In view of the foregoing amendments and remarks, claim 1 is patentable over Tang et al under 35 USC 102 as well as 35 USC 103. Claim 6 is patentable over Tang et al for the reasons set forth above, <u>inter alia</u>, in connection with claim 1.

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Rejection under 35 U.S.C. 103(a)

In the Office Action claims 5, 7-9 and 17 are rejected as being obvious and unpatentable over Tang et al in view of USP 5,302,966 (Stewart). Claim 3 is rejected as being obvious and unpatentable over Tang in view of USP 5,427,858 (Nakamura et al). Claim 4 is rejected because the Examiner contends that

> "at least one first electrode having a rough surface which is in contact with the electroluminescent layer is a design manufacturing choice".

Claims 10 and 12-14 are rejected as being obvious and unpatentable over Tang in view of USP 5,909,081 (Eida et al). Claim 16 is rejected as being obvious and unpatentable over Tang et al taken with Stewart, and further in view of USP 5,847,516 (Kishita et al).

Stewart discloses formation of a transparent electrode 304, a first insulating layer 306, an EL phosphor layer 308, a second insulating layer 310, a back electrode 312 and an insolation layer 314 in order on a transparent substrate 302 (see column 8, lines 9 to 14 and Fig. 6). According to this structure, the first insulating layer 306 is placed between the EL phosphor layer 308 and the electrode 304, and the second insulating layer 310 is placed between the EL phosphor layer 308 and the electrode 312. The first and second insulating layers prevent entrance of holes. This mechanism is embodied in <u>inorganic EL elements</u> made of an inorganic material (see column 7, lines 42 to 46).

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In contrast, organic EL elements emit light when electrons and holes enter the organic electroluminescent layer. Moreover, a manufacturing process for the active elements includes a heating process (see column 5, lines 57 to 67). Since Stewart utilizes inorganic EL elements, the disclosed formation order of the layers onto the substrate 302 occurs regardless of the specific formation order for preventing thermal deterioration caused during the manufacturing process for the organic EL elements.

Accordingly, Stewart does not disclose, teach or suggest the organic electroluminescent layer featured in the present invention and the specific layer formation order for preventing the organic electroluminescent layer from being deteriorated by heat.

Similarly, neither Nakamura et al. (USP 5,427,858) nor Eida et al. (USP 5,909,081) disclose the specific layer formation order for preventing thermal deterioration, and the arrangement of the first electrode, the organic electroluminescet layer and the second electrode which are placed above the active elements so as to cover the active elements in order to realize a larger luminescent area.

Kishita et al. (USP 5,847,516) disclose inorganic EL elements (see column 4, line 66 to column 5, line 9). Therefore, Kishita et al do not disclose the specific layer formation order and the characteristic arrangement featured in the organic EL elements.

In view of the foregoing, claims 3-5, 7-10, 12-14, 16 and 17 are patentable over the references cited by the Examiner taken either alone under 35 USC 102 or in any logical combination under 35 USC 103.

ALLOWABLE SUBJECT MATTER

The Examiner's indication that claims 11 and 15 would be allowable if rewritten in independent form to include all of the limitations of the base claim and any intervening claims is acknowledged and appreciated. Applicants have not placed claims 11 and 15 in independent form at this time because of applicants' belief that claim 1, upon which claims 11 and 15 depend, is patentable.

FORM PTO-892

Attached to the August 31, 1999 Office Action is a Form PTO-892 completed by the Examiner. The Form PTO-892 appears to improperly identify one of the cited references. Specifically, the patent identified as USP 6,640,067 (Yamaguchi et al) should have been identified as USP 5,640,067. It is respectfully requested that the Examiner send a new Form PTO-892 to applicants with the next Patent Office communication to indicate that the patent number of Yamaguchi has been corrected in the Patent Office records.

* * * *

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If the Examiner disagrees with any of the foregoing, the Examiner is respectfully requested to point out where in the references there is support for a contrary view.

Entry of the amendment, allowance of the claims, and the passing of the application to issue are respectfully solicited.

If the Examiner has any comments, questions, objections or recommendations, the Examiner is invited to telephone the undersigned at the telephone number given below for prompt action.

Respectfully submitted,

Robert P. Michal
Reg. No. 35,614

Frishauf, Holtz, Goodman, Langer & Chick, P.C.
767 Third Avenue - 25th Floor
New York, New York 10017-2023
Tel. No. (212) 319-4900
Fax Nos. (212) 319-5101
RPM:jh:ajj

Enc. - LETTER TO THE OFFICIAL DRAFTSPERSON

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Draftsmen
12/27/99
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OIPE JC82 DEC 0 2 1999 PATENT & TRADEMARK OFFICE

Attorney Docket No. 970719/LH

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant(s): Hiroyasu YAMADA et al

Serial No. : 08/976,217

Filed : November 21, 1997

For : DISPLAY APPARATUS

Art Unit : 2778

Examiner : V. Kovalick

CERTIFICATE OF MAILING

I hereby certify this correspondence is being deposited with the United States Postal Service as First Class mail in an envelope addressed to: Assistant Commissioner for Patents, Washington, D.C. 20231 on the date noted below.

Attorney: ROBERT P. MICHAL

Dated: November 30, 1999

In the event that this Paper is late filed, and the necessary petition for extension of time is not filed concurrently herewith, please consider this as a Petition for the requisite extension of time, and to the extent not tendered by check attached hereto, authorization to charge the extension fee, or any other fee required in connection with this Paper, to Account No. 06-1378.

RECEIVED DEC 1999 MAIL ROOM

LETTER TO THE OFFICIAL DRAFTSPERSON

ASSISTANT COMMISSIONER FOR PATENTS
Washington, D.C. 20231

S I R :

Attached hereto are Figs. 1 and 17 which have been marked in red to show the amendments being proposed thereto. The amendments are necessary to obviate the Official Draftsperson's objection set forth in Form PTO-948 attached to the August 31, 1999 Office Action wherein the sectional designations were not in Arabic or Roman numerals.

Upon approval of the drawing amendments and upon allowance of at least one claim, new formal drawings for Figs. 1 and 17 will be provided.

Respectfully submitted,

ROBERT P. MICHAL
REG. NO. 35,614

FRISHAUF, HOLTZ, GOODMAN, LANGER & CHICK, P.C.
767 THIRD AVENUE - 25TH FLOOR
NEW YORK, NEW YORK 10017-2023
Tel. No. (212) 319-4900
Fax No. Group 3: (212) 319-5101
RPM:ajj
Enc.- Figs. 1 and 17 marked in red

Approved
JCY
1/12/00

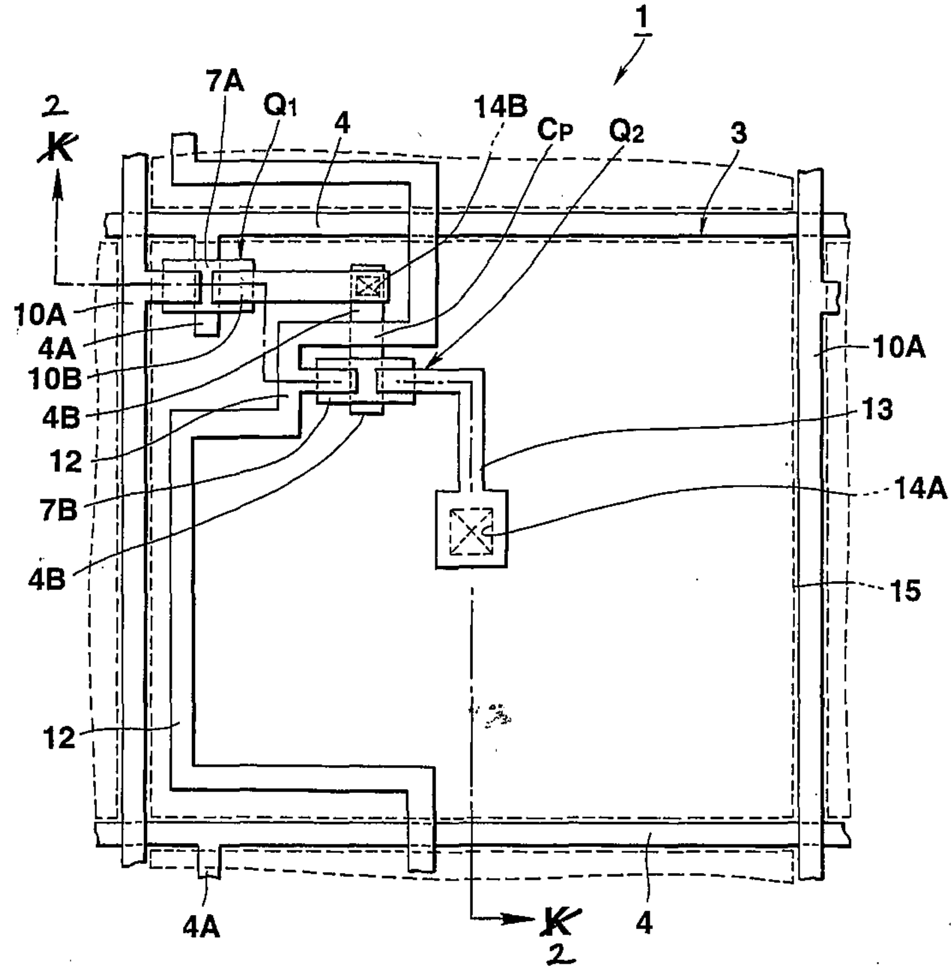
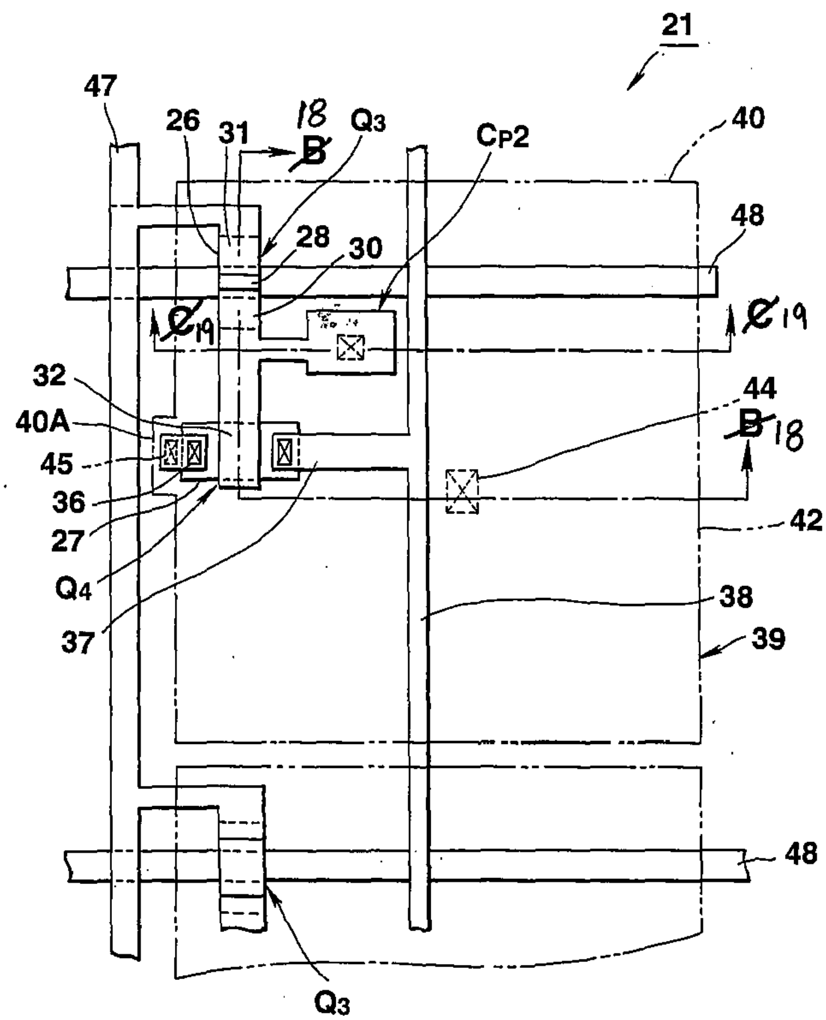


FIG.1


21
47
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Q3

FIG.17

08/976,217

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.
08/976,217	11/21/97	YAMADA	H	970719/LH

LM61/0114

FRISHAUF HOLTZ GOODMAN LANGER & CHICK
767 THIRD AVENUE 25TH FLOOR
NEW YORK NY 10017

EXAMINER	
KOVALICK,V	
ART UNIT	**PAPER NUMBER**
2778	7

DATE MAILED: 01/14/00

Please find below and/or attached an Office communication concerning this application or proceeding.

Commissioner of Patents and Trademarks

PTO-90C (Rev. 2/95)

1- File Copy

Notice of Allowability

Application No. 08/976,217	Applicant(s) Hiroyasu Yamada	
Examiner Vincent E. Kovalick	Group Art Unit 2778	

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance and Issue Fee Due or other appropriate communication will be mailed in due course.

☒ This communication is responsive to *applicant's ameandment dated 11/30/99*

☒ The allowed claim(s) is/are *1 and 3-19*

☐ The drawings filed on ____________ are acceptable.

☒ 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.

☐ received in Application No. (Series Code/Serial Number) ____________ .

☐ received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

*Certified copies not received: ____________

☐ Acknowledgement is made of a claim for domestic priority under 35 U.S.C. § 119(e).

A SHORTENED STATUTORY PERIOD FOR RESPONSE to comply with the requirements noted below is set to EXPIRE **THREE MONTHS** FROM THE "DATE MAILED" of this Office action. Failure to timely comply will result in ABANDONMENT of this application. Extensions of time may be obtained under the provisions of 37 CFR 1.136(a).

☐ Note the attached EXAMINER'S AMENDMENT or NOTICE OF INFORMAL APPLICATION, PTO-152, which discloses that the oath or declaration is deficient. A SUBSTITUTE OATH OR DECLARATION IS REQUIRED.

☒ Applicant MUST submit NEW FORMAL DRAWINGS

☐ because the originally filed drawings were declared by applicant to be informal.

☒ including changes required by the Notice of Draftsperson's Patent Drawing Review, PTO-948, attached hereto or to Paper No. *4 & 7*

☒ including changes required by the proposed drawing correction filed on *Nov 30, 1999* , which has been approved by the examiner.

☐ including changes required by the attached Examiner's Amendment/Comment.

Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the reverse side of the drawings. The drawings should be filed as a separate paper with a transmittal lettter addressed to the Official Draftsperson.

☐ Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Any response to this letter should include, in the upper right hand corner, the APPLICATION NUMBER (SERIES CODE/SERIAL NUMBER). If applicant has received a Notice of Allowance and Issue Fee Due, the ISSUE BATCH NUMBER and DATE of the NOTICE OF ALLOWANCE should also be included.

Attachment(s)

☒ Notice of References Cited, PTO-892

☐ Information Disclosure Statement(s), PTO-1449, Paper No(s). ____________

☒ Notice of Draftsperson's Patent Drawing Review, PTO-948

☐ Notice of Informal Patent Application, PTO-152

☐ Interview Summary, PTO-413

☐ Examiner's Amendment/Comment

☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material

☒ Examiner's Statement of Reasons for Allowance

DETAILED ACTION

Response to Amendment

1. This Office Action is in response to Applicant's Amendment dated November 30, 1999 in response to PTO Office Action dated August 31, 1999. The amendments to the specification; the cancellation of claim 2, the amendments to claims 1, 4, 5, 8, 10, 15 and 16; the addition of claims 18 and 19, and the consideration of Applicant's remarks are sufficient to overcome the rejections of the claims as set forth in said PTO Office Action.

2. The submitted proposed amendments to Figs. 1 and 17 have been reviewed and noted by the Official Draftsperson, Form PTO 948 is submitted herewith.

3. A substitute Form PTO-892 is herewith submitted changing the Patent No. that was identified as 6,640,067 to Patent No. 5,640,067 (Yamauchi et al.).

Allowable Subject Matter

4. Claims 1-19 are allowed.

5. The following is an examiner's statement of reasons for allowance:

Relative to claim 1, the prior art of record **does not teach** a display apparatus comprising: a substrate; active elements formed over said substrate and driven by an externally supplied signal; an insulation film formed over said substrate so as to cover said active elements, said insulation having at least one contact hole; at least one first electrode formed on said insulation film so as to cover said active elements, and connected to said active elements through said at least one contact hole, said at least one first electrode being made of a material which shields visible light; an organic electroluminescent layer having an organic electroluminescent material formed on said at least one first electrode so as to cover said active elements and including at least one layer which emits light in accordance with a voltage applied to said at least one layer; and at least one second electrode formed on said organic electroluminescent layer which covers said active elements.

Regarding claim 16, the prior art of record **does not teach** a display apparatus comprising: a substrate; selection transistors formed over said substrate and arranged in a matrix pattern; drive transistors formed over said substrate and arranged in a matrix pattern, each of said drive transistors being connected to one of said selection transistors; address lines connected to said selection transistors and through which a signal for turning on said selection transistors is supplied; data lines connected to said selection transistors, a signal which corresponds to image data being supplied to said drive transistors through said data lines and said selection transistors while said selection transistors are on; an insulation film formed over said substrate so as to cover said drive transistors, said address lines and said data lines, said insulation film having contact holes formed in correspondence with said drive transistors; first electrodes made of material which shields visible light, and formed on said insulation film so as to cover said selection transistors and said drive transistors, said first electrodes being arranged in a matrix pattern in areas surrounded by said address lines and said data lines, and being connected to said drive transistors through said contact holes; an organic electroluminescent layer formed on said first electrodes which covers said selection transistors and said drive transistors and including at least one layer which emits light in accordance with an applied voltage; a second electrode formed on said organic electroluminescent layer which covers said selection transistors and said drive transistors.

Any comments considered necessary by applicant must be submitted no later than the payment of the issue fee and, to avoid processing delays, should preferably accompany the issue fee. Such submissions should be clearly labeled "Comments on Statement of Reasons for Allowance."

Conclusion

6. The prior art made of record and not relied upon is considered pertinent to applicant's disclosure.

U. S. Patent No.	5,828,181	Okuda
U. S. Patent No.	5,640,067	Yamauchi et al.
U. S. Patent No.	5,302,468	Nimiki et al.

Responses

7. Responses to this action should be mailed to: Commissioner of Patents and Trademarks Washington, D.C. 20231. If applicant desires to fax a response, (703) 308-9051 may be used for formal communications or (703) 308-6606 for informal or draft communications. NOTE: a Request for Continuation (Rule 609 or 62) cannot be faxed.

Please label "PROPOSED" or "DRAFT" for informal facsimile communications. For after final responses, please label "AFTER FINAL" or "EXPEDITED PROCEDURE" on the document.

Hand-delivered responses should be brought to Crystal Part II, 2121 Crystal Drive, Arlington, VA., Sixth Floor (Receptionist)

Inquires

8. Any inquiry concerning this communication or earlier communications from the examiner should be directed to Vincent E. Kovalick whose telephone number is (703) 306-3020. The examiner can normally be reached on Monday-Thursday from 9:00 a.m. to 4:00 p.m.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Bipin Shalwala, can be reached on (703) 305-4938.

9. Any inquiry of a general nature or relating to the status of this application or proceeding should be directed to the Group receptionist whose telephone number is (703) 305-3900.

Vincent E Kovalick

Vincent E. Kovalick

BIPIN SHALWALA
SUPERVISORY PATENT EXAMINER
TECHNOLOGY CENTER 2700

Notice of References Cited	Application No. 08/976,217	Applicant(s) Hiroyasu Yamada et al.	
	Examiner Vincent E. Kovalick	Group Art Unit 2778	Page 1 of 1

U.S. PATENT DOCUMENTS

*		DOCUMENT NO.	DATE	NAME	CLASS	SUBCLASS
x	A	5,909,081	6/1999	Yamauchi et al.	313	504
x	B	5,684,365	11/1997	Tang et al.	345	76
x	C	5,427,858	6/1995	Nakamura et al.	428	421
x	D	5,302,966	4/1994	Stewart	315	169.3
x	E	5,847,516	12/1998	Kishita et al.	315	169.3
x	F	5,828,181	10/1998	Okuda	345	76
x	G	5,640,067	6/1999	Yamauchi et al.	313	504
x	H	5,302,468	4/1994	Nimike et al.	313	500
	I					
	J					
	K					
	L					
	M					

FOREIGN PATENT DOCUMENTS

*		DOCUMENT NO.	DATE	COUNTRY	NAME	CLASS	SUBCLASS
	N						
	O						
	P						
	Q						
	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 furnished with this Office action. (See Manual of Patent Examining Procedure, Section 707.05(a).)

Notice of References Cited	Application No. 08/976,217	Applicant(s) Hiroyasu Yamada et al.	
	Examiner Vincent E. Kovalick	Group Art Unit 2778	Page 1 of 1

U.S. PATENT DOCUMENTS

*		DOCUMENT NO.	DATE	NAME	CLASS	SUBCLASS
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X	D	5,302,966	4/1994	Stewart	315	169.3
X	E	5,847,516	12/1998	Kishita et al.	315	169.3
X	F	5,828,181	10/1998	Okuda	345	76
X	G	5,640,067	6/1999	Yamauchi et al.	313	504
X	H	5,302,468	4/1994	Nimike et al.	313	500
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	J					
	K					
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	M					

FOREIGN PATENT DOCUMENTS

*		DOCUMENT NO.	DATE	COUNTRY	NAME	CLASS	SUBCLASS
	N						
	O						
	P						
	Q						
	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 furnished with this Office action.
(See Manual of Patent Examining Procedure, Section 707.05(a).)

Form PTO 948 (Rev. 8-98) U.S. DEPARTMENT OF COMMERCE - Patent and Trademark Office Application No. 09/976,217

NOTICE OF DRAFTSPERSON'S PATENT DRAWING REVIEW

The drawing(s) filed (insert date) 12-2-99 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) ___
   - X Pencil and non black ink not permitted. Fig(s) 1-17
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) ___
   - ___ 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) ___
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) ___
    - ___ Figure legends are poor. Fig(s) ___
    - ___ 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) Fig(s) ___
    - ___ Numbers, letters and reference characters must be at least .32 cm (1/8 inch) in height. 37 CFR 1.84(p)(3) Fig(s) ___
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 [signature] DATE 1-12-00 TELEPHONE NO. ___

ATTACHMENT TO PAPER NO. ___

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 ALLOWANCE AND ISSUE FEE DUE

LM61/0114
FRISHAUF HOLTZ GOODMAN LANGER & CHICK
767 THIRD AVENUE 25TH FLOOR
NEW YORK NY 10017

APPLICATION NO.	FILING DATE	TOTAL CLAIMS	EXAMINER AND GROUP ART UNIT		DATE MAILED
08/976,217	11/21/97	018	KOVALICK, V	2778	01/14/00

First Named Applicant: YAMADA, 35 USC 154(b) term ext. = 0 Days.

LE OF ENTION: DISPLAY APPARATUS

ATTY'S DOCKET NO.	CLASS-SUBCLASS	BATCH NO.	APPLN. TYPE	SMALL ENTITY	FEE DUE	DATE DUE
2 970719/LH	345-076.000	G89	UTILITY	NO	$1210.00	04/14/00

IE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. 1OSECUTION ON THE MERITS IS CLOSED.

IE ISSUE FEE MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS 'PLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED.

OW TO RESPOND TO THIS NOTICE:

Review the SMALL ENTITY status shown above.
f the SMALL ENTITY is shown as YES, verify your current SMALL ENTITY status:

A. If the status is changed, pay twice the amount of the FEE DUE shown above and notify the Patent and Trademark Office of the change in status, or
B. If the status is the same, pay the FEE DUE shown above.

If the SMALL ENTITY is shown as NO:

A. Pay FEE DUE shown above, or

B. File verified statement of Small Entity Status before, or with, payment of 1/2 the FEE DUE shown above.

Part B-Issue Fee Transmittal should be completed and returned to the Patent and Trademark Office (PTO) with your ISSUE FEE. Even if the ISSUE FEE has already been paid by charge to deposit account, Part B Issue Fee Transmittal should be completed and returned. If you are charging the ISSUE FEE to your deposit account, section "4b" of Part B-Issue Fee Transmittal should be completed and an extra copy of the form should be submitted.

All communications regarding this application must give application number and batch number.
Please direct all communications prior to issuance to Box ISSUE FEE unless advised to the contrary.

IPORTANT REMINDER: ***Utility patents issuing on applications filed on or after Dec. 12, 1980 may require payment of maintenance fees. It is patentee's responsibility to ensure timely payment of maintenance fees when due.***

PATENT AND TRADEMARK OFFICE COPY

B

Attorney Docket No. 970719/LH

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

USSN: 08/976,217
Allowed: Jan. 14, 2000
Batch: G89

Applicant(s): H. YAMADA et al

Serial No. : 08/976,217

Filed : Nov. 21, 1997

For : DISPLAY APPARATUS

Art Unit : 2778

Examiner : V. Kovalick

CERTIFICATE OF MAILING

I hereby certify that this correspondence is being deposited with the United States Postal Service as First Class mail in an envelope addressed to: Assistant Commissioner for Patents, Washington, D.C. 20231 on the date noted below.

Attorney: Leonard Holtz

Dated: February 22, 2000

In the event that this Paper is late filed, and the necessary petition for extension of time is not filed concurrently herewith, please consider this as a Petition for the requisite extension of time, and to the extent not tendered by check attached hereto, authorization to charge the extension fee, or any other fee required in connection with this Paper, to Account No. 06-1378.

LETTER TO THE OFFICIAL DRAFTSPERSON
SUBMISSION OF CORRECTED FORMAL DRAWINGS

Asst. Commissioner for Patents
Washington, D.C. 20231

S I R : **ATTN: ISSUE BRANCH**

Submitted herewith are corrected sheets of formal drawings for Figs. 1 and 17, which include the proposed drawing correction filed on November 30, 1999, which has been approved by the Examiner. The amended sheets of formal drawings overcome the objections set forth in the PTO-948 attached to Papers Nos. 4 and 7.

It is respectfully requested that the corrected sheets of formal drawings for Figs. 1 and 17 be approved and entered in full compliance with all outstanding Patent Office drawing requirements.

Respectfully submitted,

Leonard Holtz
Reg. No. 22,974

February 22, 2000
Frishauf, Holtz, Goodman, Langer & Chick, P.C.
767 Third Avenue - 25th Floor
New York, New York 10017-2023
Tel. No. (212) 319-4900
Fax No. (212) 319-5101
LH:bv

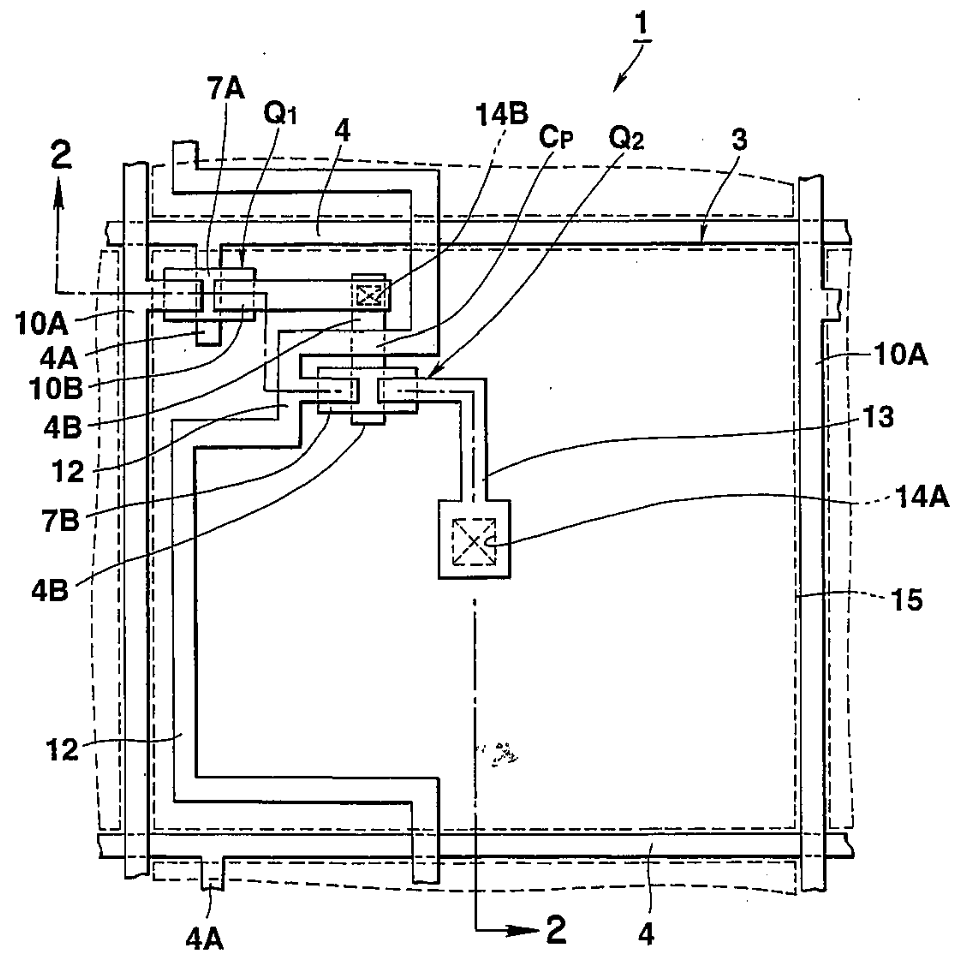

FIG.1

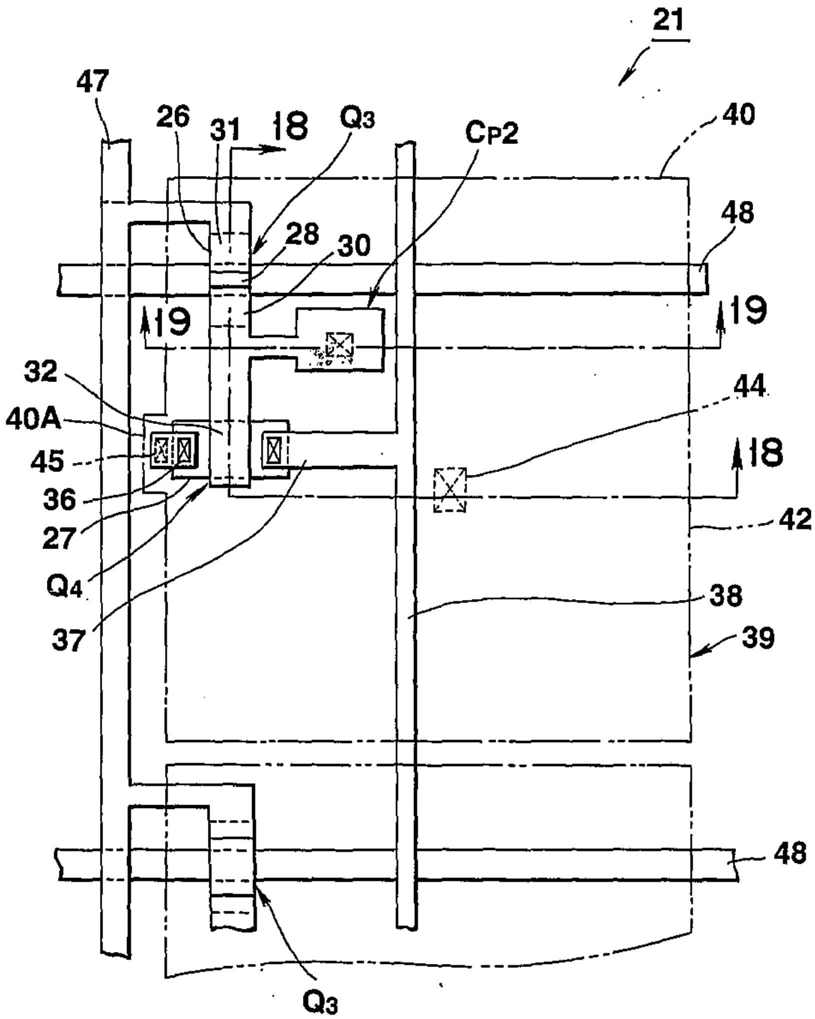
21
47
26
31
18
Q3
CP2
40
48
28
30
19
19
32
44
40A
18
45
36
42
27
Q4
38
37
39
48
Q3

FIG.17

PART B—ISSUE FEE TRANSMITTAL

Complete and mail this form, together with applicable fees, to: **Box ISSUE FEE**
Assistant Commissioner for Patents
Washington, D.C. 20231

B

OIPE APR 0 6 2000

MAILING INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE. Blocks 1 through 4 should be completed where appropriate. All further correspondence including the Issue Fee Receipt, the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Legibly mark-up with any corrections or use Block 1)

LM61/0114

FRISHAUF HOLTZ GOODMAN LANGER & CHICK
767 THIRD AVENUE 25TH FLOOR
NEW YORK NY 10017

Note: The certificate of mailing below can only be used for domestic mailings of the Issue Fee Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing.

Certificate of Mailing

I hereby certify that this Issue Fee Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Box Issue Fee address above on the date indicated below.

Sharon Portnoy (Depositor's name)

Sharon Portnoy (Signature)

April 3, 2000 (Date)

APPLICATION NO.	FILING DATE	TOTAL CLAIMS	EXAMINER AND GROUP ART UNIT		DATE MAILED
08/976,217	11/21/97	018	KOVALICK, V	2778	01/14/00

First Named Applicant: YAMADA, 35 USC 154(b) term ext. = 0 Days.

TITLE OF INVENTION: DISPLAY APPARATUS

ATTY'S DOCKET NO.	CLASS-SUBCLASS	BATCH NO.	APPLN. TYPE	SMALL ENTITY	FEE DUE	DATE DUE
2 970719/LH	345-076.000	G89	UTILITY	NO	$1210.00	04/14/00

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363). Use of PTO form(s) and Customer Number are recommended, but not required.

☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

☒ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47) attached.

2. For printing on the patent front page, list (1) the names of up to 3 registered patent attorneys or agents OR, alternatively, (2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 ~~FRISHAUF, HOLTZ,~~
2 GOODMAN, LANGER &
3 ~~CHICK, P.C.~~

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)
PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. Inclusion of assignee data is only appropriate when an assignment has been previously submitted to the PTO or is being submitted under separate cover. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE CASIO COMPUTER CO., LTD.

(B) RESIDENCE: (CITY & STATE OR COUNTRY) Tokyo, JAPAN

Please check the appropriate assignee category indicated below (will not be printed on the patent)
☐ individual ☒ corporation or other private group entity ☐ government

4a. The following fees are enclosed (make check payable to Commissioner of Patents and Trademarks):
☒ Issue Fee
☐ Advance Order - # of Copies ______

4b. The following fees or deficiency in these fees should be charged to:
DEPOSIT ACCOUNT NUMBER 06-1378
(ENCLOSE AN EXTRA COPY OF THIS FORM)
☒ Issue Fee
☐ Advance Order - # of Copies ______

The COMMISSIONER OF PATENTS AND TRADEMARKS IS requested to apply the Issue Fee to the application identified above.

(Authorized Signature) (Date)
Leonard Holtz, Reg. No. 22,974 4/3/00

NOTE: The Issue Fee will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the Patent and Trademark Office.

Burden Hour Statement: This form is estimated to take 0.2 hours to complete. Time will vary depending on the needs of the individual case. Any comments on the amount of time required to complete this form should be sent to the Chief Information Officer, Patent and Trademark Office, Washington, D.C. 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND FEES AND THIS FORM TO: Box Issue Fee, Assistant Commissioner for Patents, Washington D.C. 20231

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

04/07/2000 TTRAN2 00000136 08976217
01 FC:142 1210.00 OP

TRANSMIT THIS FORM WITH FEE

PTOL-85B (REV.10-96) Approved for use through 06/30/99. OMB 0651-0033

Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

11

PATENT APPLICATION FEE DETERMINATION RECORD

Effective October 1, 1997

Application or Docket Number

CLAIMS AS FILED - PART I

FOR	NUMBER FILED (Column 1)	NUMBER EXTRA (Column 2)	SMALL ENTITY TYPE ☐ RATE	FEE	OR	OTHER THAN SMALL ENTITY RATE	FEE
BASIC FEE				395.00	OR		790.00
TOTAL CLAIMS	17 minus 20 =	*	x$11=		OR	x$22=	
INDEPENDENT CLAIMS	2 minus 3 =	*	x41=		OR	x82=	
MULTIPLE DEPENDENT CLAIM PRESENT			+135=		OR	+270=	
			TOTAL		OR	TOTAL	790.00

* If the difference in column 1 is less than zero, enter "0" in column 2

CLAIMS AS AMENDED - PART II

AMENDMENT A

	CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	SMALL ENTITY RATE	ADDITIONAL FEE	OR	OTHER THAN SMALL ENTITY RATE	ADDITIONAL FEE
Total	*	Minus	**	=	x$11=		OR	x$22=	
Independent	*	Minus	***	=	x41=		OR	x82=	
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM					+135=		OR	+270=	
					TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

AMENDMENT B

	CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	SMALL ENTITY RATE	ADDITIONAL FEE	OR	OTHER THAN SMALL ENTITY RATE	ADDITIONAL FEE
Total	*	Minus	**	=	x$11=		OR	x$22=	
Independent	*	Minus	***	=	x41=		OR	x82=	
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM					+135=		OR	+270=	
					TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

AMENDMENT C

	CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	SMALL ENTITY RATE	ADDITIONAL FEE	OR	OTHER THAN SMALL ENTITY RATE	ADDITIONAL FEE
Total	*	Minus	**	=	x$11=		OR	x$22=	
Independent	*	Minus	***	=	x41=		OR	x82=	
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM					+135=		OR	+270=	
					TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20."
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3."
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

FORM PTO-875 (Rev. 8/97) *U.S. Government Printing Office: 1997 - 430-571/69194 Patent and Trademark Office, U.S. DEPARTMENT OF COMMERCE

Form PTO 1130
(REV 2/94)

U.S. DEPARTMENT OF COMMERCE
Patent and Trademark Office

PACE DATA ENTRY CODING SHEET

1ST EXAMINER	DATE
2ND EXAMINER	DATE

APPLICATION NUMBER	TYPE APPL	FILING DATE (MONTH DAY YEAR)	SPECIAL HANDLING	GROUP ART UNIT	CLASS	SHEETS OF DRAWING

TOTAL CLAIMS	INDEPENDENT CLAIMS	SMALL ENTITY?	FILING FEE	FOREIGN LICENSE	ATTORNEY DOCKET NUMBER

CONTINUITY DATA

CONT CODE	STATUS CODE	PARENT APPLICATION SERIAL NUMBER	PCT APPLICATION SERIAL NUMBER	PARENT PATENT NUMBER	PARENT FILING DATE (MONTH DAY YEAR)
			P C T / /		
			P C T / /		
			P C T / /		
			P C T / /		
			P C T / /		

PCT/FOREIGN APPLICATION DATA

FOREIGN PRIORITY CLAIMED	COUNTRY CODE	PCT/FOREIGN APPLICATION SERIAL NUMBER	FOREIGN FILING DATE (MONTH DAY YEAR)

TITLE OF INVENTION

ATTORNEY REGISTRATION NUMBERS

CORRESPONDENCE NAME AND ADDRESS

APPLICANT/INVENTOR DATA

AUTHORITY CODE

FAMILY NAME

NAME SUFFIX

GIVEN NAME

STATE/CTRY CODE

CITY

AUTHORITY CODE

FAMILY NAME

NAME SUFFIX

GIVEN NAME

STATE/CTRY CODE

CITY

MORE

☆U.S. GPO:1997-417-376/60324

US PAT NO: 5,923,308 [IMAGE AVAILABLE] L5: 12 of 13
TITLE: Array of leds with active pull down shadow canceling circuitry

ABSTRACT:
An array of OEDs is arranged in rows and columns with a plurality of row buses and a plurality of column buses. Each of the OEDs has a first terminal coupled to an associated row bus and a second terminal coupled to an associated column bus. A switching circuit is connected to a shadow canceling row bus of the plurality of row buses. The switching circuit is constructed to receive a shadow canceling signal on a terminal thereof and to connect the shadow canceling row bus to a pull down potential in response to the shadow canceling signal, whereby all of the OEDs in the array, other than those associated with the shadow canceling row bus, are coupled to the pull down potential and discharged.

US PAT NO: 5,319,491 [IMAGE AVAILABLE] L5: 13 of 13
TITLE: Optical display

ABSTRACT:
An optical display in which at least one pixel is selectively controlled to shutter light out of a light guidance substrate by violating the light guidance conditions of the medium, and in which a full color palette is provided by multiplexing the three additive primaries in relation to the inherent limitations of the human eye.

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d hist

   (FILE 'USPAT' ENTERED AT 11:23:40 ON 03 AUG 1999)
          SET PAGELENGTH 99
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L1     2296 S 345/CLAS AND DRIVE?(W)CIRCUIT?
L2      242 S L1 AND ELECTROLUMINESCENT?
L3      111 S L2 AND ADDRESS? AND DATA
L4       13 S L3 AND ORGANIC
L5       13 FOCUS L4 1-13

=>
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US006072450A

United States Patent [19]

Yamada et al.

[11] **Patent Number: 6,072,450**

[45] **Date of Patent: Jun. 6, 2000**

[54] **DISPLAY APPARATUS**

[75] Inventors: **Hiroyasu Yamada**, Hachioji; **Tomoyuki Shirasaki**, Higashiyamato; **Yoshihiro Kawamura**, Fussa, all of Japan

[73] Assignee: **Casio Computer Co., Ltd.**, Tokyo, Japan

[21] Appl. No.: **08/976,217**

[22] Filed: **Nov. 21, 1997**

[30] **Foreign Application Priority Data**

Nov. 28, 1996 [JP] Japan 8-331388
Nov. 28, 1996 [JP] Japan 8-331389

[51] **Int. Cl.**^{7} **H01L 27/12**

[52] **U.S. Cl.** **345/76**; 345/36; 345/45; 313/500; 313/504; 315/169.3

[58] **Field of Search** 345/36, 45, 76; 313/498–512; 315/169.3

[56] **References Cited**

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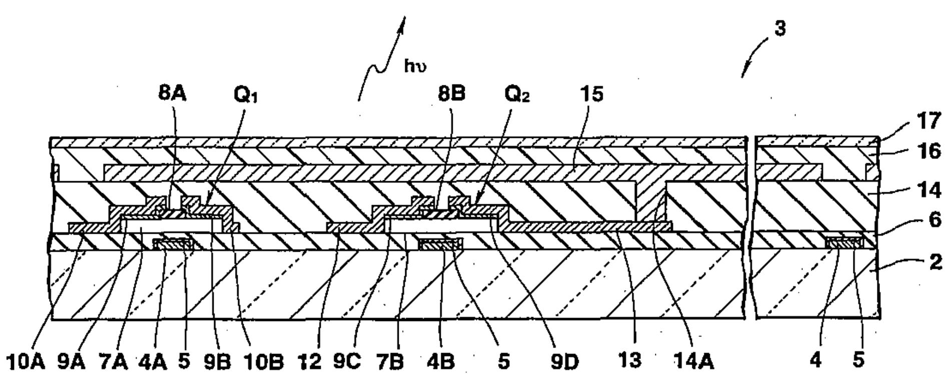
Primary Examiner—Bipin Shalwala
Assistant Examiner—Vincent E. Kovalick
Attorney, Agent, or Firm—Frishauf, Holtz, Goodman, Langer & Chick, P.C.

[57] **ABSTRACT**

Selection transistors and drive transistors are formed in individual pixel areas on a substrate. Cathode electrodes which reflect visible light are formed above the selection transistors and the drive transistors so as to cover the pixel areas, with flat insulation films between the cathode electrodes and the selection and drive transistors. An organic EL layer and an anode electrode are sequentially formed on the cathode electrodes.

18 Claims, 21 Drawing Sheets



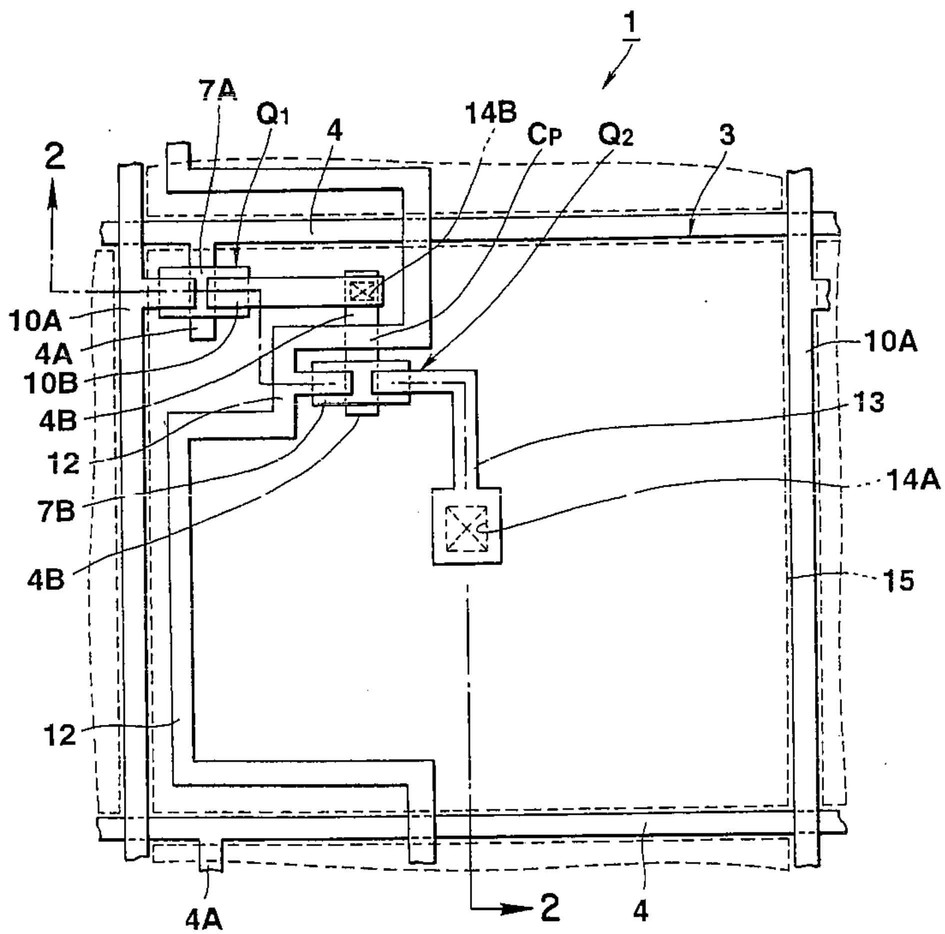


FIG.1

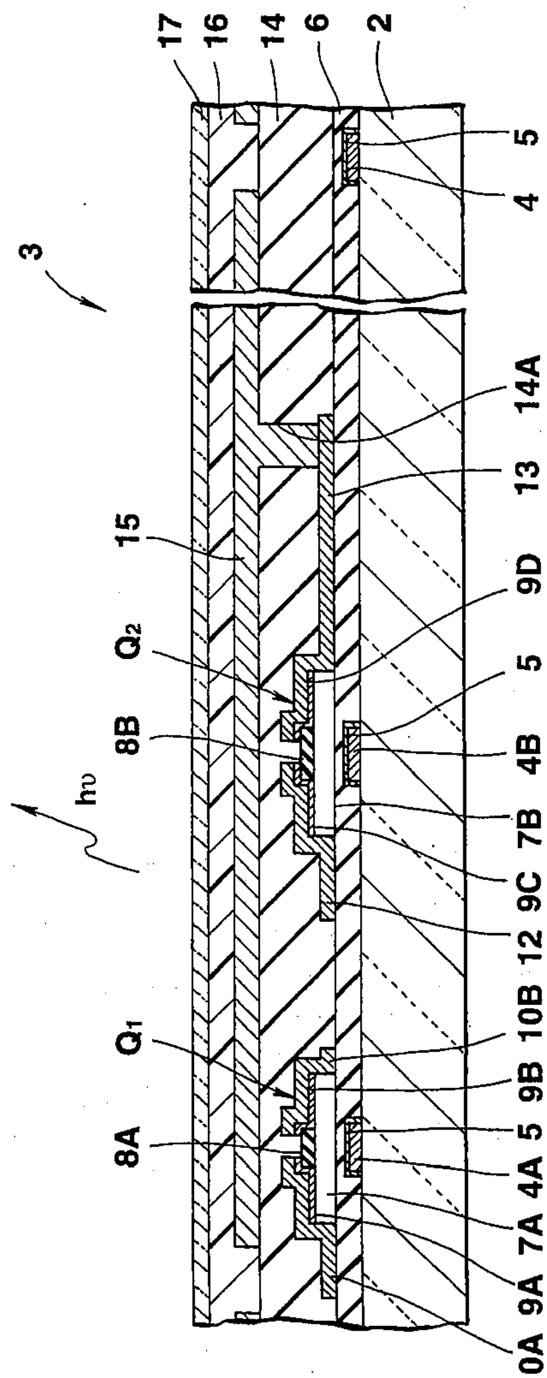

17
16
14
6
2
5
4
3
14A
13
15
9D
Q2
5
8B
4B
hυ
7B
9C
12
10B
Q1
9B
5
8A
4A
7A
9A
10A

FIG.2

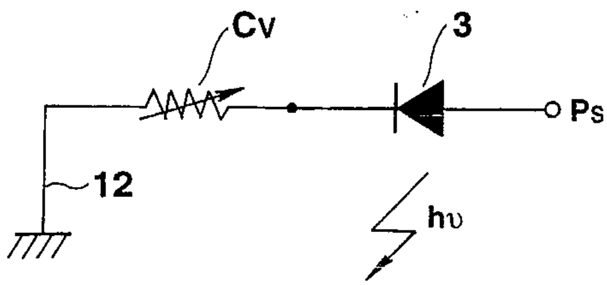


FIG.3

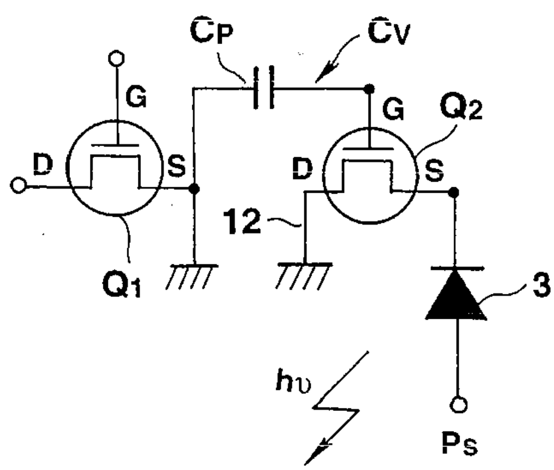
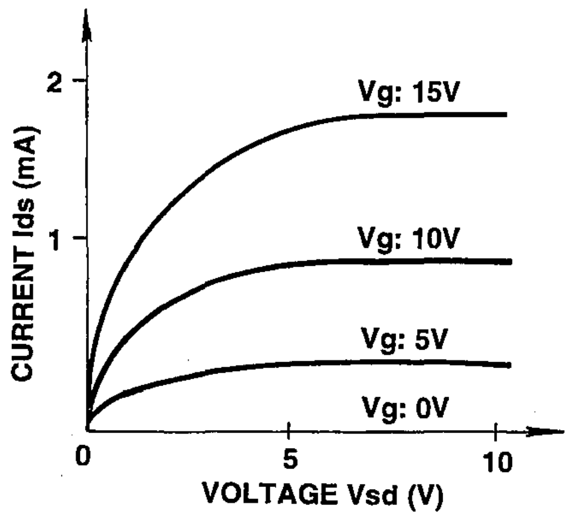
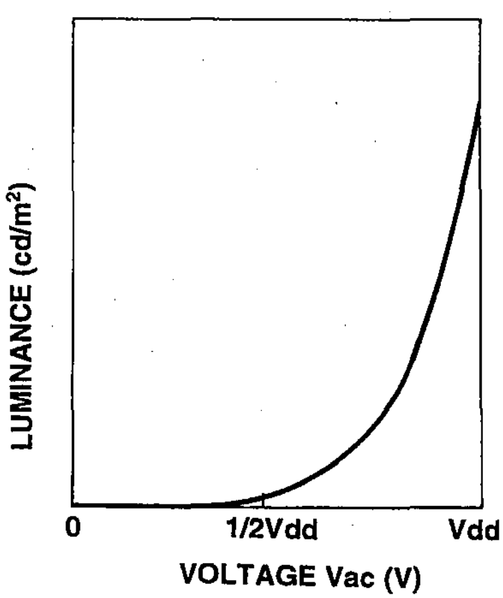


FIG.4



2
1
CURRENT Ids (mA)
Vg: 15V
Vg: 10V
Vg: 5V
Vg: 0V
0
5
10
VOLTAGE Vsd (V)

FIG.5



LUMINANCE (cd/m²)
0
1/2Vdd
Vdd
VOLTAGE Vac (V)

FIG.6

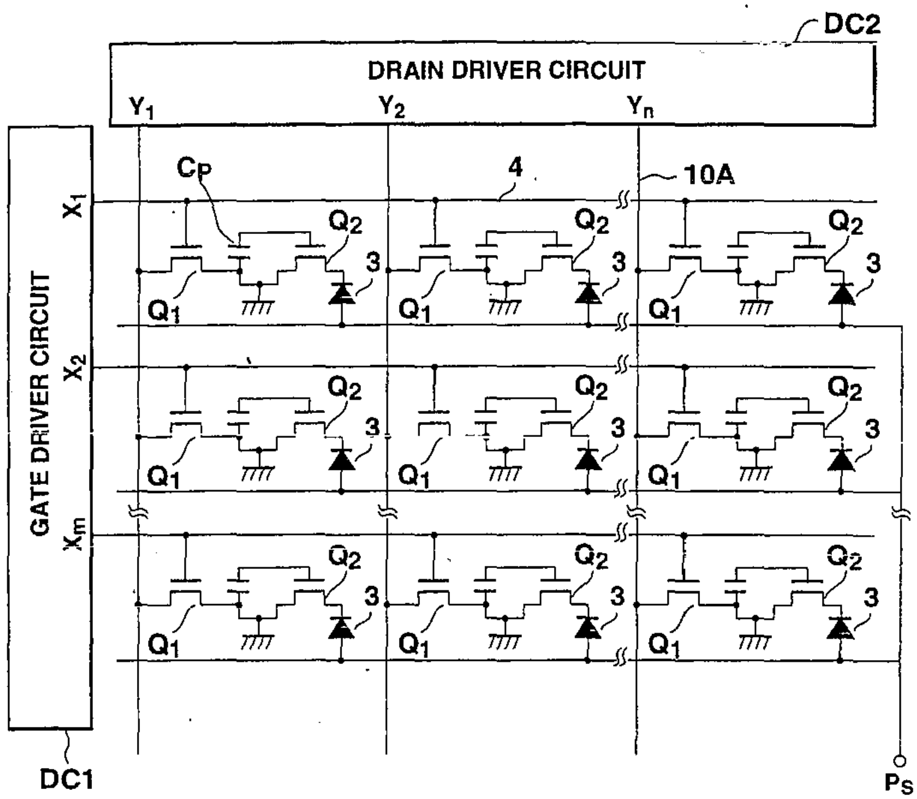

DC2
DRAIN DRIVER CIRCUIT
Y1
Y2
Yn
GATE DRIVER CIRCUIT
X1
X2
Xm
Cp
4
10A
Q1
Q2
3
DC1
Ps

FIG.7

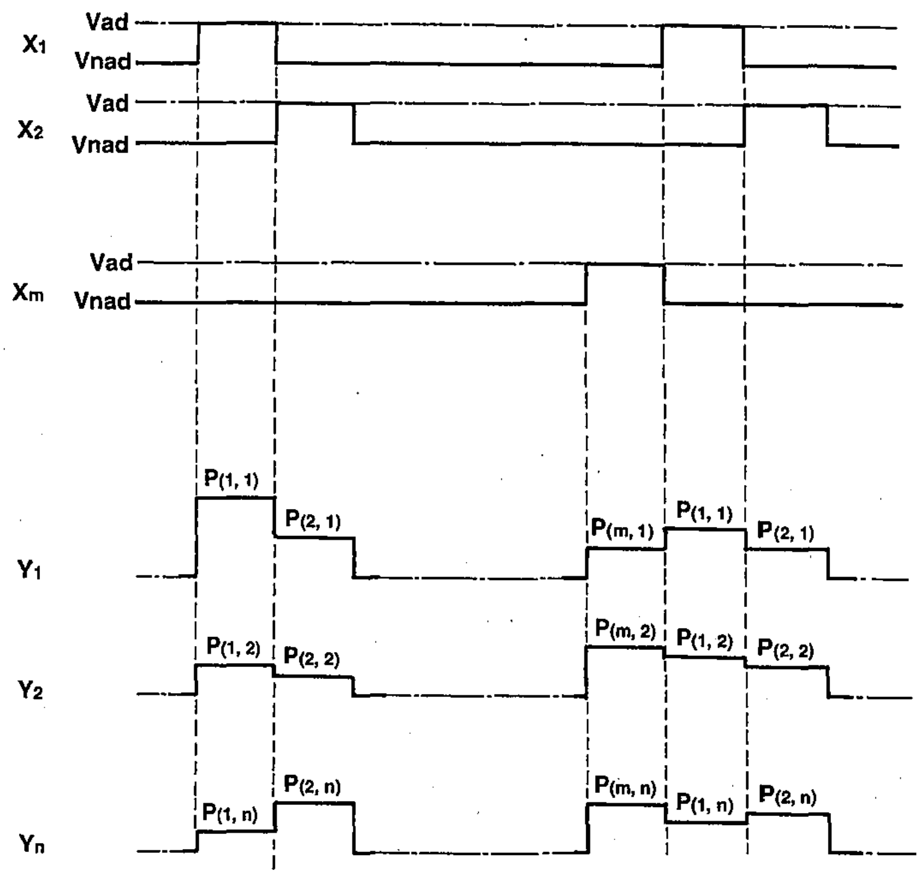

X1
Vad
Vnad
X2
Vad
Vnad
Xm
Vad
Vnad
Y1
P(1, 1)
P(2, 1)
P(m, 1)
P(1, 1)
P(2, 1)
Y2
P(1, 2)
P(2, 2)
P(m, 2)
P(1, 2)
P(2, 2)
Yn
P(1, n)
P(2, n)
P(m, n)
P(1, n)
P(2, n)

FIG.8

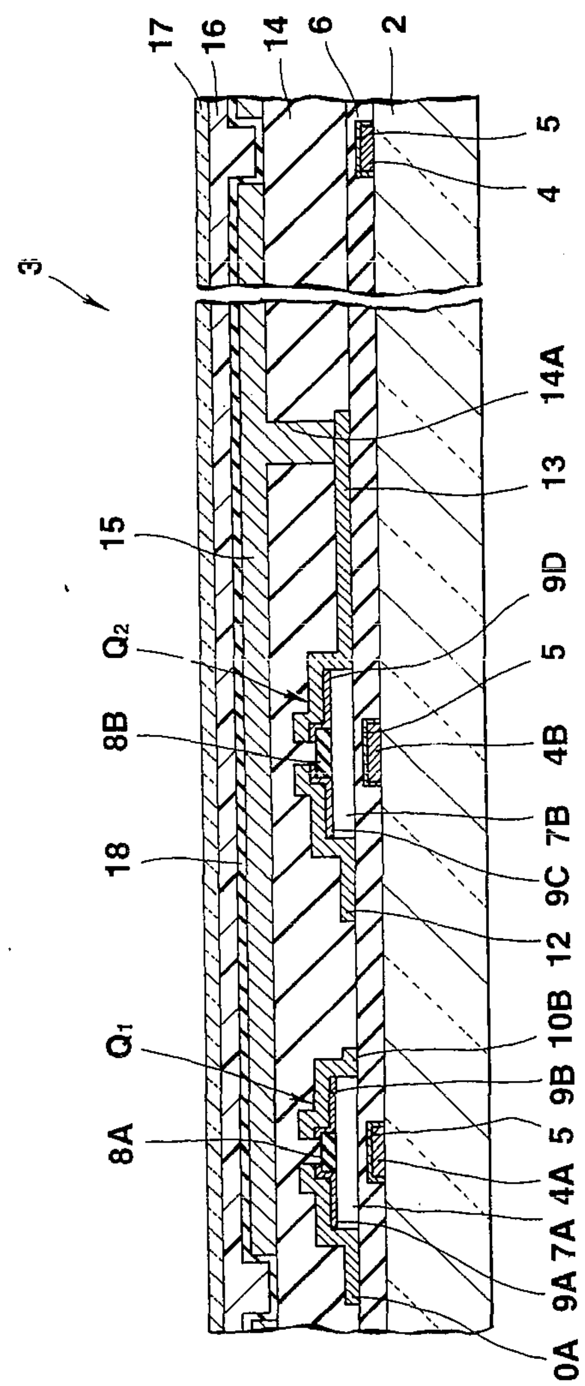

17
16
14
6
2
5
4
3
14A
13
15
9D
Q2
5
8B
4B
18
7B
9C
12
Q1
10B
9B
8A
5
4A
7A
9A
10A

FIG.9

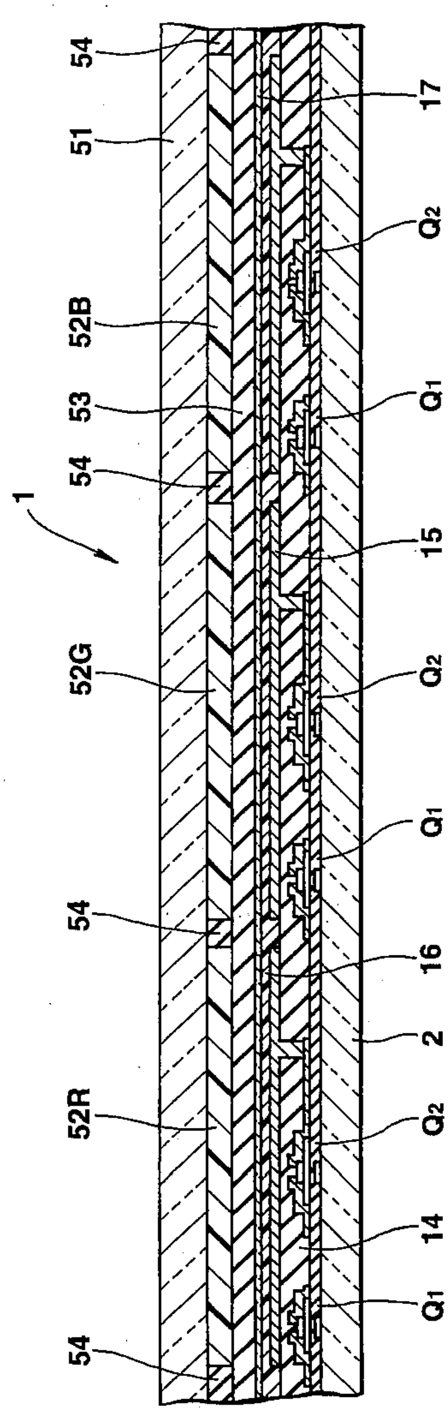


FIG.10

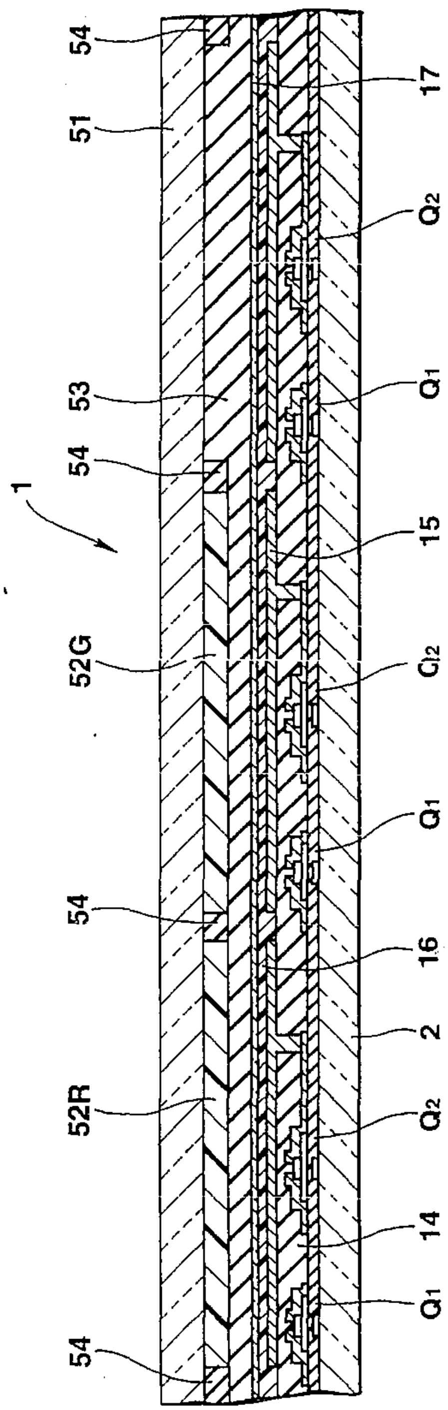


FIG.11

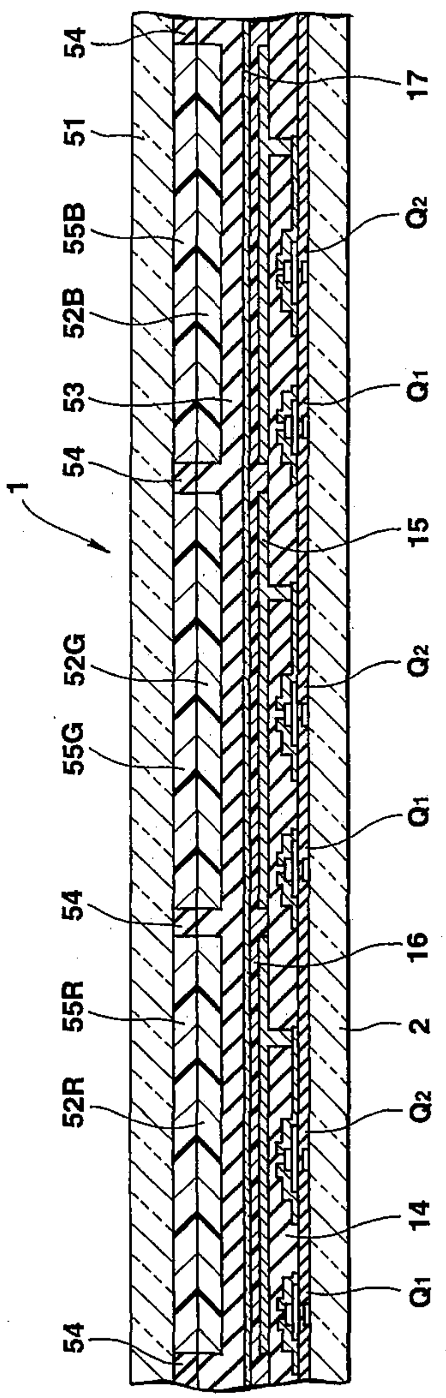

54
51
55B
52B
53
54
1
52G
55G
54
55R
52R
54
17
Q_2
Q_1
15
Q_2
Q_1
16
2
Q_2
14
Q_1

FIG.12

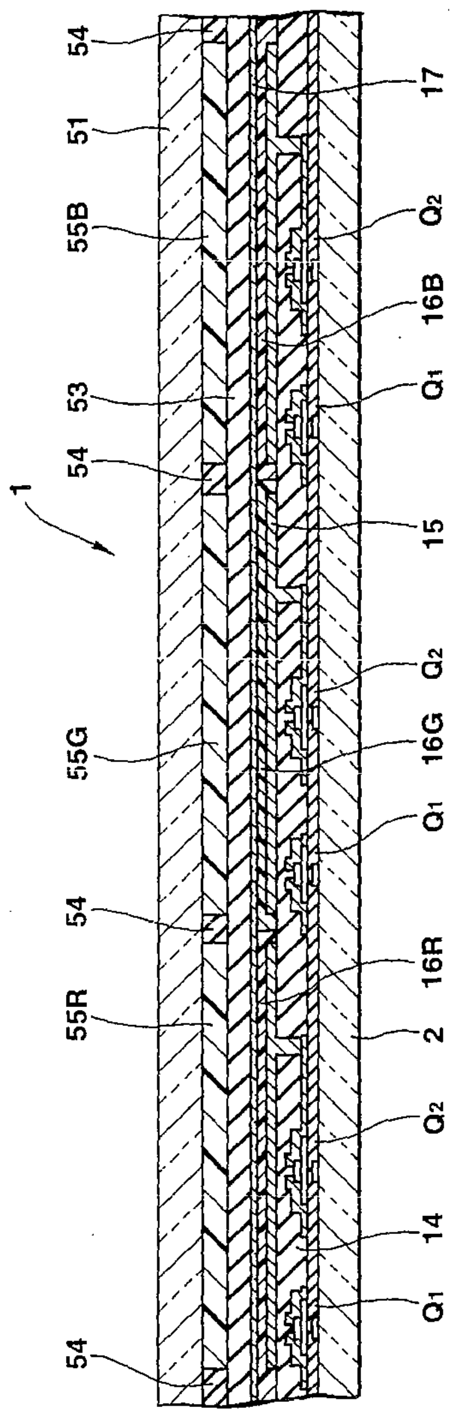

54
51
55B
53
54
1
55G
54
55R
54
17
Q2
16B
Q1
15
Q2
16G
Q1
16R
2
Q2
14
Q1

FIG.13

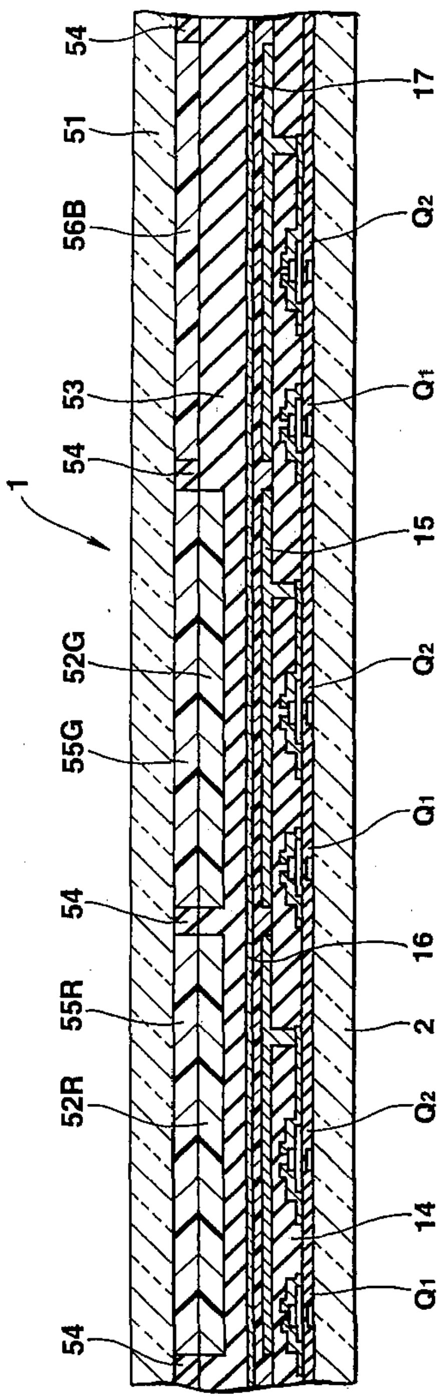


FIG.14

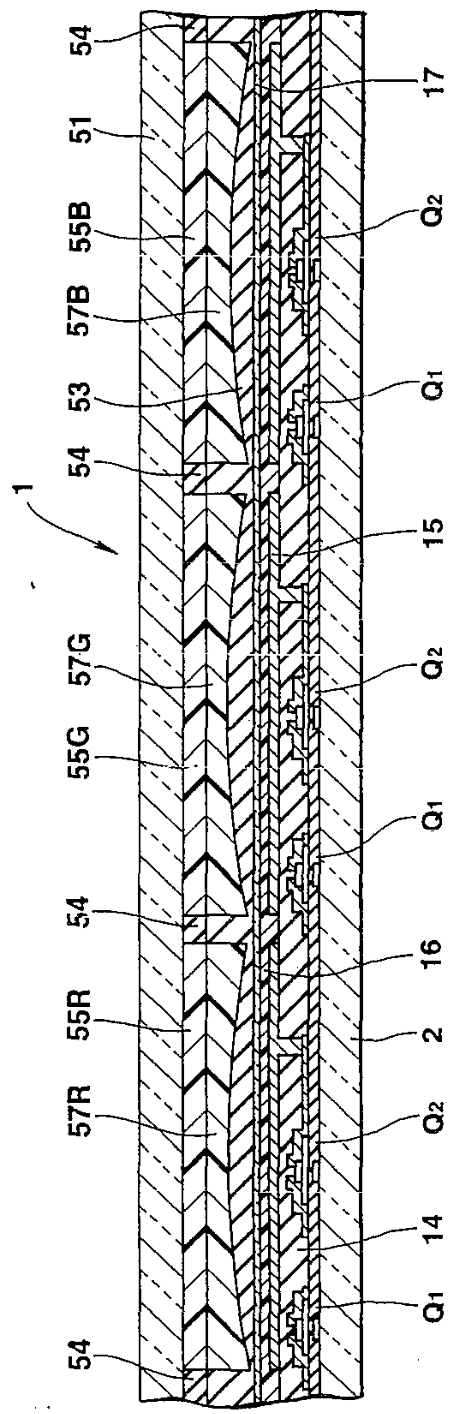

54
51
55B
57B
53
54
1
57G
55G
54
55R
57R
54
17
Q2
Q1
15
Q2
Q1
16
2
Q2
14
Q1

FIG.15

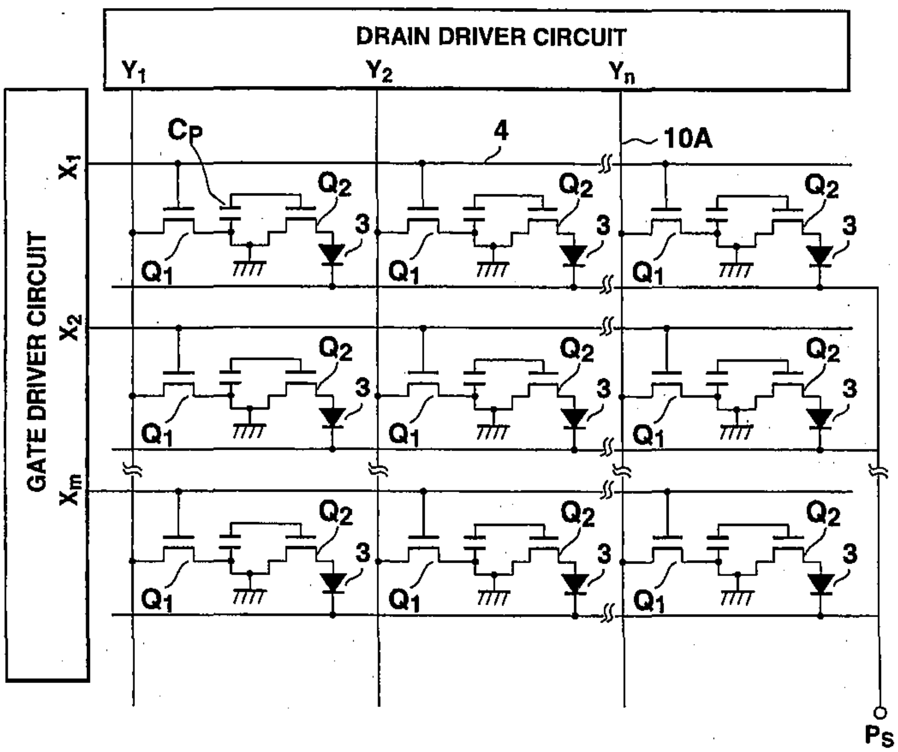
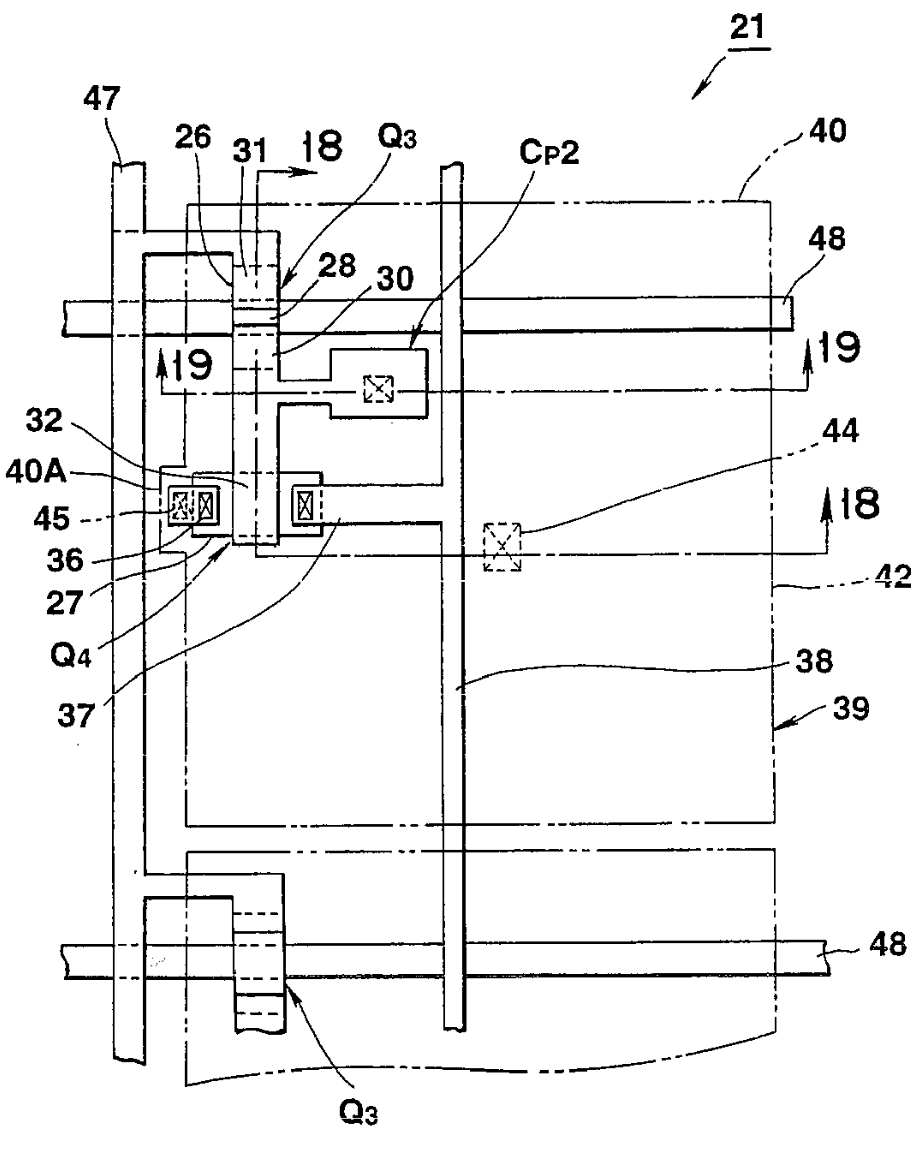

DRAIN DRIVER CIRCUIT
GATE DRIVER CIRCUIT
Y1
Y2
Yn
X1
X2
Xm
CP
4
10A
Q1
Q2
3
PS

FIG.16



21
47
26
31
18
Q3
CP2
40
48
28
30
19
19
32
44
40A
18
45
36
42
27
38
Q4
39
37
48
Q3

FIG.17

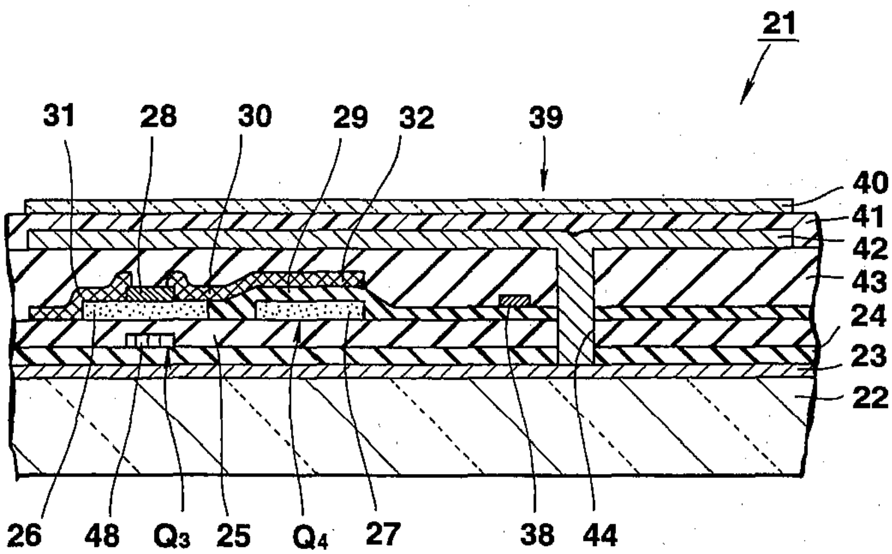


FIG.18

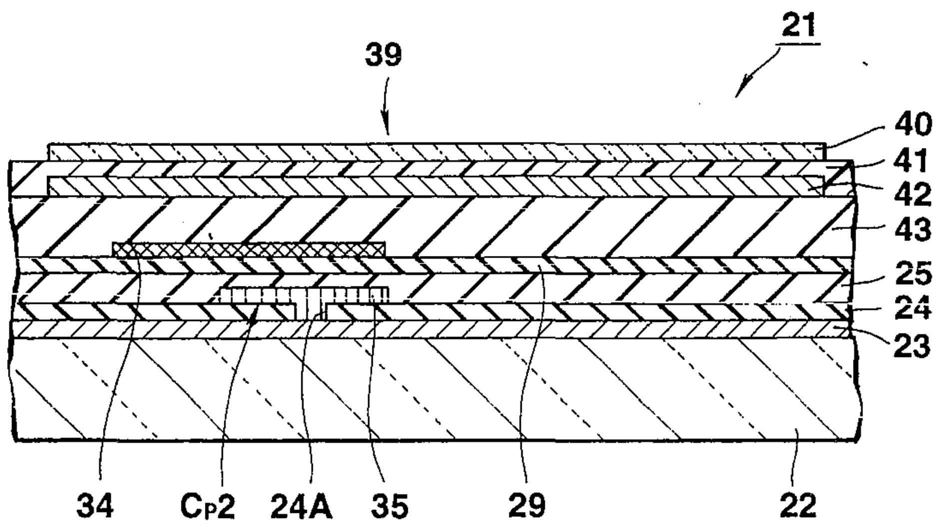


FIG.19

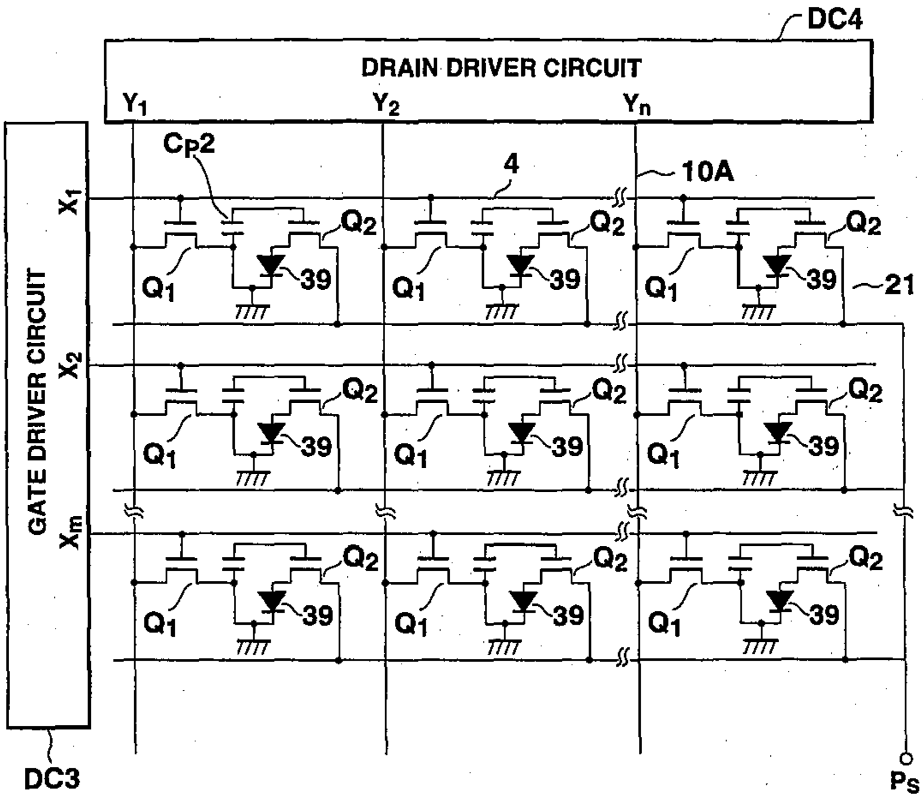

DC4
DRAIN DRIVER CIRCUIT
Y1
Y2
Yn
GATE DRIVER CIRCUIT
X1
X2
Xm
CP2
4
10A
Q1
Q2
39
21
DC3
PS

FIG.20

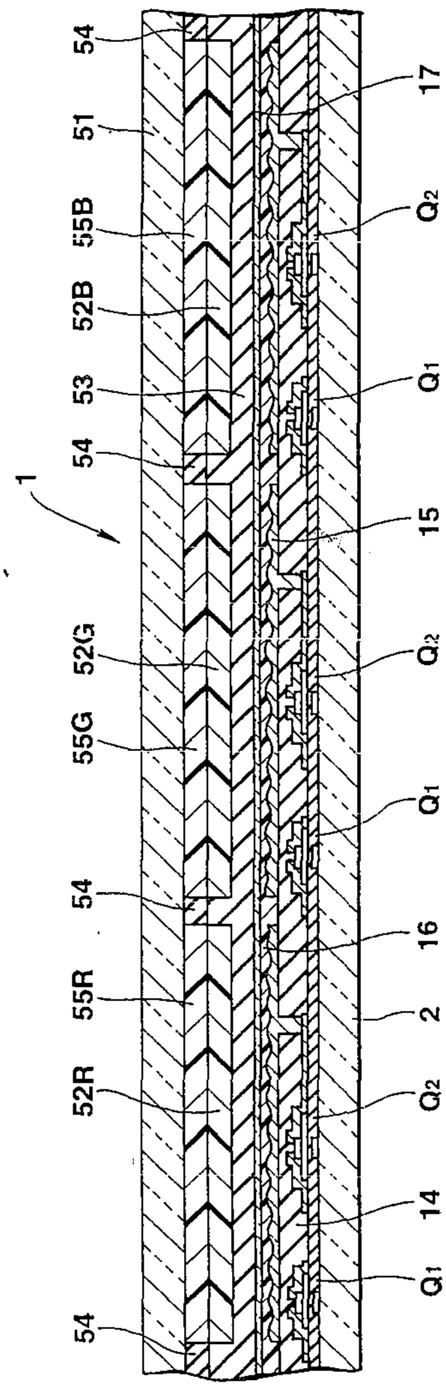

54
51
55B
52B
53
54
1
52G
55G
54
55R
52R
54
17
Q2
Q1
15
Q2
Q1
16
2
Q2
14
Q1

FIG.21

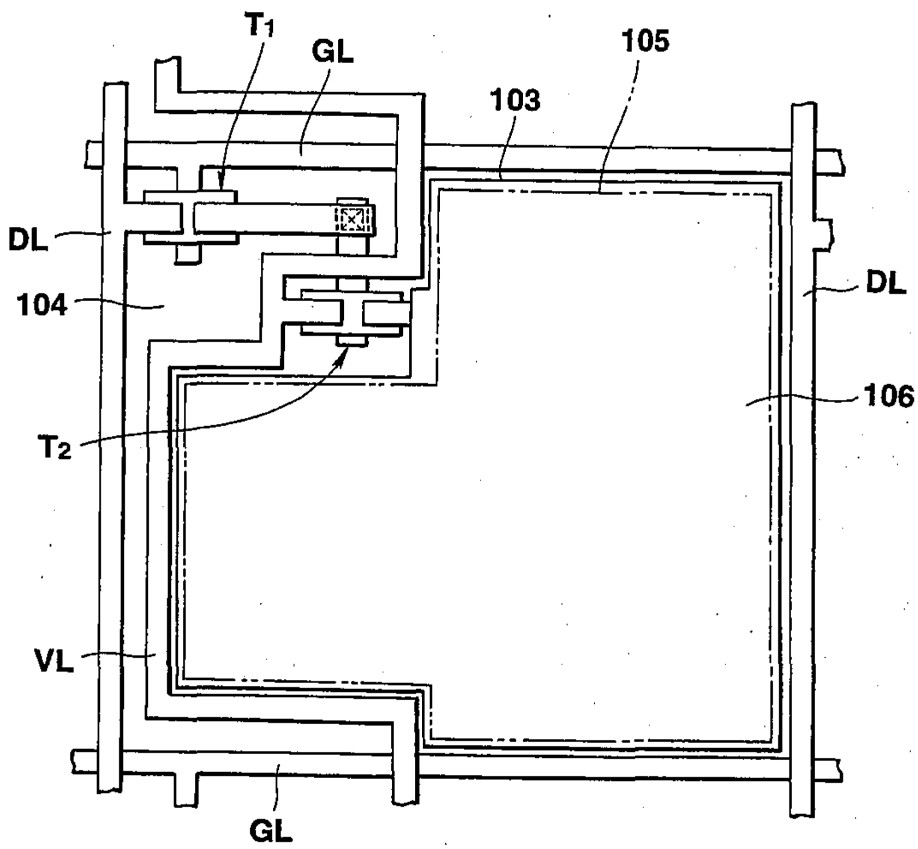


FIG.22

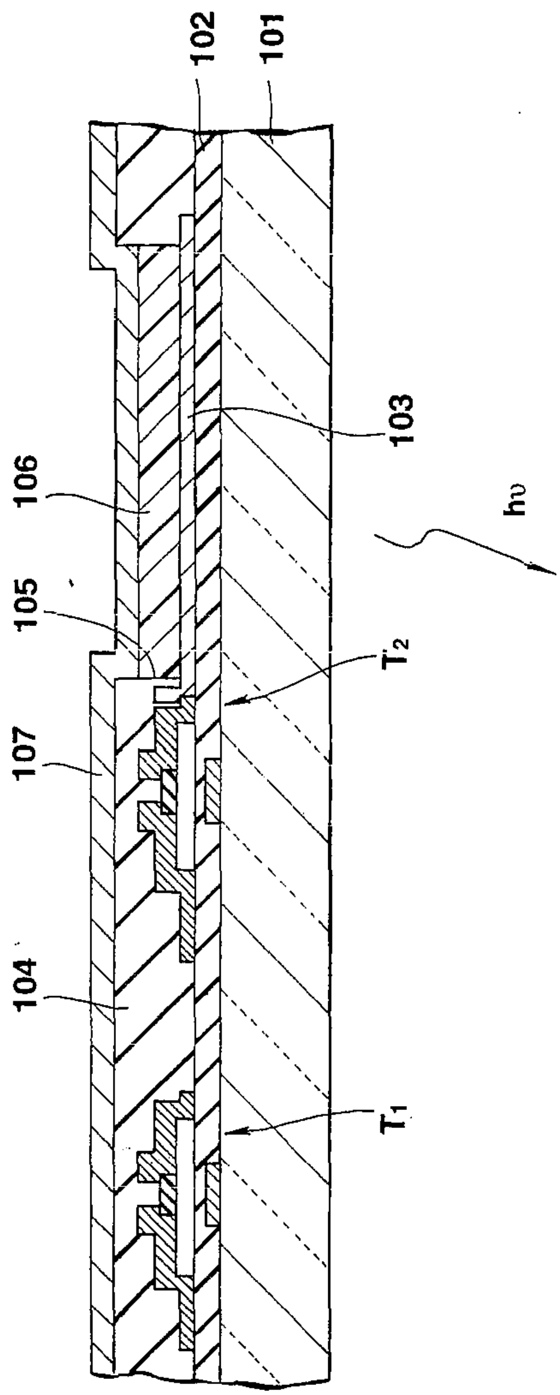


FIG.23

DISPLAY APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a display apparatus, and more particularly to an electroluminescent (hereinafter referred to as EL) display apparatus with a matrix display panel including EL elements.

2. Description of the Related Art

An EL display apparatus with organic EL elements, that is, display elements which emit light spontaneously and which are arranged in a matrix pattern, is known conventionally. A passive matrix type EL display apparatus is available as such an EL display apparatus. In this type of EL display apparatus, parallel cathode lines serve as common lines, while parallel anode lines which are perpendicular to the cathode lines and which are made of ITO (indium tin oxide) serve as data lines. An organic EL layer is arranged between the set of the cathode lines and the set of the anode lines. A positive voltage is applied to the data lines in each of cathode selection periods, thereby driving organic EL elements located at the intersections of the common lines and the data lines. The display apparatus displays an image which corresponds to the voltage applied to the data lines. In the case of the passive matrix type EL display apparatus which displays an image by driving such organic EL elements, the larger the number of common lines and/or the number of data lines, the shorter the selection period (duty H) per pixel. The period of time over which the organic EL layer keeps emitting light even after the application of a voltage between the set of the cathode lines and the set of the anode lines is short. In consideration of this, according to the conventional passive matrix type EL display apparatus, the instantaneous luminance of the organic EL layer of each pixel during the selection periods is intensified so that the organic EL layer apparently emits light over 1 frame period. The organic EL layer can emit light at a high instantaneous luminance by applying a high voltage to the organic EL layer. In this case, however, the organic EL layer can easily deteriorate.

In the passive matrix type EL display apparatus, the larger the number of common lines and data lines, the more possibility of the occurrence of crosstalk. This makes it difficult to enable the passive matrix type EL display apparatus to display a highly precise image.

Proposed as a display apparatus free from the above-described problems is an active matrix type display apparatus which includes, as shown in FIG. 22, pairs of thin film transistors which confer a voltage storing capability on the pixels. Each of the pairs of thin film transistors consists of a selection transistor T1 and a drive transistor T2. The selection transistor T1 is connected to a data line DL for supplying a data signal and a gate line GL for supplying a gate signal. The gate electrode of the drive transistor T2 is connected to the selection transistor T1. The source of the drive transistor T2 is connected to a constant voltage line VL. In this display apparatus, as shown in FIG. 23, the thin film transistors T1 and T2 are formed in a pixel area on a glass substrate **101**, and the gates of the thin film transistors are covered with a gate insulation film **102**. In an area adjacent to the thin film transistors T1 and T2, a transparent anode electrode **103** is provided on the gate insulation film **102**. The transparent anode electrode **103** is connected to the drain of the drive transistor T2. A passivation film **104** covers the thin film transistors T1 and T2. A contact hole extending up to the transparent anode electrode **103** is formed in that part of the passivation film **104** which is located on the transparent anode electrode **103**. An organic EL layer **106**, which absorbs the energy generated due to the recombination of electrons and holes when a current flows, is deposited in the contact hole **105** extending up to the transparent anode electrode **103**. A cathode electrode **107**, which reflects visible light and which extends over a plurality of pixels, is laminated on the passivation film **104** and the organic EL layer **106**. In this EL display apparatus, the efficiency of the injection of carriers into the organic EL layer **106** depends on the ionization potential of the anode electrode **103** and the electron affinity (the work function) of the cathode electrode **107**. In order to improve the light emitting efficiency of the organic EL layer **106** which depends on the carrier injection efficiency, the cathode electrode **107** is formed using a material whose work function is low. Since the cathode electrode **107** is normally formed of a metal such as magnesium whose work function is low, the cathode electrode **107** reflects light having a wavelength in a range of wavelength of light which the organic EL layer **106** emits. Due to this, in the above EL display apparatus, the light emitted by the organic EL layer **106** travels through the anode electrode **103** and the substrate **101**. The organic EL layer **106** is arranged so as not to overlap the thin film transistors T1 and T2. The purpose of thus arranging the organic EL layer **106** is to prevent the light emitted by the organic EL layer **106** from entering the thin film transistors T1 and T2. If the emitted light entered the thin film transistors T1 and T2, unnecessary photoelectromotive force would be generated in the channel regions of the thin film transistors T1 and T2, which entails the possibility of the thin film transistors T1 and T2 malfunctioning.

In the active matrix type EL display apparatus described above, the light emitting area of each pixel in which a part of the organic EL layer **106** is located is limited to an area in which the thin film transistors T1 and T2 are not located, and therefore the ratio of the light emitting area to the pixel area is small. If the light emitting area is enlarged and if a voltage applied to the organic EL layer **106** is intensified to attain the desired luminance, the organic EL layer **106** will be considerably deteriorated. The cathode electrode **107** is made of a metal, while the organic EL layer **106** is made of an organic material. Hence, it is difficult to join the cathode electrode **107** and the organic EL layer **106** together in a preferred condition. As time passes, a gap can easily occur between the cathode electrode **107** and the organic EL layer **106**, which entails the possibility that the organic EL layer **106** may become emit no light. The organic EL layer can emit light at the same luminance as that of an inorganic EL layer even when the organic EL layer is formed as thin as 40 nm to 250 nm. The thicker the organic EL layer **106**, the higher an effective voltage/current for causing the organic EL layer to emit light at the desired luminance. This limits the range of value at which the thickness of the organic EL layer can be set Meanwhile, the thickness of the passivation film **104**, which covers the thin film transistors T1 and T2, is set at such a value as to prevent the occurrence of a parasitic capacitance in the thin film transistors T1 and T2. Owing to a difference in thickness between the passivation film **104** and the organic EL layer **106**, a step is present on the upper surfaces of the passivation film **104** and organic EL layer **106**. There is the possibility that the cathode electrode **107** may break at that step. If the cathode electrode **107** breaks, the display apparatus cannot perform a display operation.

SUMMARY OF THE INVENTION

It is accordingly one object of the present invention to provide a display apparatus which has a light emitting area enlarged so as to emit light at a satisfactorily high luminescence even though a voltage applied to an EL layer is low, and which has a long luminance life.

It is another object of the present invention to provide a display apparatus which prevents light from entering active elements such as transistors, to thereby avoid the malfunction of the active elements.

In order to achieve the above objects, a display apparatus according to one aspect of the present invention comprises:

a substrate;

active elements which are formed over the substrate and which are driven by an externally supplied signal;

an insulation film formed over the substrate so as to cover the active elements and having at least one contact hole;

at least one first electrode formed on the at least one insulation film so as to cover the active elements, and connected to the active elements through the at least one contact hole, the at least one first electrode being made of a material which shields visible light;

an electroluminescent layer formed on the at least one first electrode and including at least one layer which emits light in accordance with a voltage applied to the at least one layer; and

at least one second electrode formed on the electroluminescent layer.

In this display apparatus, the at least one first electrode is formed so as to cover the active elements, and the electroluminescent layer and the at least one second electrode are laminated sequentially on the at least one first electrode. Under those conditions, the area occupied by an electroluminescent element, which is formed of the at least one first electrode, the electroluminescent layer and the at least one second electrode, is not limited by the active elements, and a light emitting area can be enlarged accordingly. This enables the electroluminescent layer to emit light at the same luminescence as that of a conventional display apparatus, even though a voltage applied to the electroluminescent layer is low. In this case, the load on the electroluminescent layer is small, which ensures a long life to the display apparatus. Since the at least one first electrode is made of a material which shields visible light, the light emitted by the electroluminescent layer does not enter the active elements, and therefore the active elements do not malfunction due to the light.

In order to achieve the above-described objects, a display apparatus according to the second aspect of the present invention comprises:

a substrate;

selection transistors formed over the substrate and arranged in a matrix pattern;

drive transistors formed over the substrate and arranged in a matrix pattern, each of the drive transistors being connected to one of the selection transistors;

address lines connected to the selection transistors and through which a signal for turning on the selection transistors is supplied;

data lines connected to the selection transistors, a signal which corresponds to image data being supplied to the drive transistors through the data lines and the selection transistors while the selection transistors is on;

an insulation film formed over the substrate so as to cover the drive transistors, the address lines and the data lines, the insulation film having contact holes formed in correspondence with the drive transistors;

first electrodes made of a material which shields visible light, and formed on the insulation film so as to cover the election transistors and the drive transistors, the first electrodes being arranged in a matrix pattern in areas surrounded by the address lines and the data lines, and being connected to the drive transistors through the contact holes;

an electroluminescent layer formed on the first electrodes and including at least one layer which emits light in accordance with an applied voltage;

a second electrode formed on the electroluminescent layer, a first driver circuit for selectively supplying the address signal to the address lines in sequence; and

a second driver circuit for supplying the image data to the data lines.

In this display apparatus, the first electrodes are arranged in the areas surrounded by the address lines and the data lines. Under this condition, electroluminescent elements, each being formed of one of the first electrodes and the electroluminescent layer and the second electrode, do not overlap the address lines or the data lines. Consequently, no parasitic capacitance occurs between the address/data lines and the electrodes of the electroluminescent elements, thus preventing signal transmission from being slowed down.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a plan view of an display apparatus according to one embodiment of the present invention;

FIG. 2 is a cross section taken along the line 2—2 show in FIG. 1;

FIG. 3 is an equivalent circuit diagram showing an EL display circuit corresponding to one pixel;

FIG. 4 is an equivalent circuit diagram which specifically shows the structure of the EL display circuit;

FIG. 5 is a graph showing the electric characteristic of a drive transistor Q2;

FIG. 6 is a graph showing the luminance of an organic EL element;

FIG. 7 is a diagram illustrating driver circuits used in the display apparatus depicted in FIG. 1;

FIG. 8 is a diagram showing waveforms for driving the display apparatus;

FIG. 9 is a sectional view of a display apparatus which includes cathode electrodes, an organic EL layer, and a dielectric film between the organic EL layer and the cathode electrodes;

FIG. 10 is a sectional view of a display apparatus having R, G and B wavelength range conversion layers;

FIG. 11 is a sectional view of a display apparatus having R and G wavelength range conversion layers;

FIG. 12 is a sectional view of a display apparatus having R, G and B wavelength range conversion layers and color filter layers;

FIG. 13 is a sectional view of a display apparatus having color filter layers;

FIG. 14 is a sectional view of a display apparatus having R and G wavelength range conversion layers and color filter layers;

FIG. 15 is a sectional view of a display apparatus having concave R, G and B wavelength range conversion layers and color filters;

FIG. 16 is a diagram showing driver circuits used in a display apparatus which includes drive transistors Q2 and anode electrodes connected to the drive transistors Q2:

FIG. 17 is a plan view of a display apparatus according another embodiment of the present invention;

FIG. 18 is a cross section taken along the line 18—18 shown in FIG. 17;

FIG. 19 is a cross section taken along the line 19—19 shown in FIG. 17;

FIG. 20 is a diagram showing driver circuits used in the display apparatus illustrated in FIG. 17;

FIG. 21 is a sectional view of a display apparatus including a cathode electrode having a rough surface;

FIG. 22 is a plan view of a display apparatus according to the related art; and

FIG. 23 is a sectional view of the display apparatus illustrated in FIG. 21.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Display apparatuses according to embodiments of the present invention will now be described in detail, with reference to the accompanying drawings.

The structure of the display apparatus according to one embodiment of the present invention will now be described with reference to FIGS. 1 and 2. FIG. 1 is a plan view of that part of the display apparatus of this embodiment which corresponds to one pixel. FIG. 2 is a cross section taken along the line 2—2 shown in FIG. 1. In those drawings, a reference numeral 1 denotes the display apparatus. That part of the display apparatus 1 which is illustrated in FIGS. 1 and 2 includes a substrate 2, an n-channel transistor Q1, an n-channel transistor Q2, an organic EL element 3, etc. which are formed over the substrate 2. The substrate 2 is made of glass or synthetic resin, and make visible light pass through. The n-channel transistor Q1 serves as a selection transistor, while the n-channel transistor Q2 serves as a drive transistor.

The structure of the display apparatus 1 will be more specifically described. Parallel address lines 4 extending in a predetermined direction are formed at equal intervals on the substrate 2 by patterning a gate metal film which is made of aluminum (Al) or the like. The selection transistor Q1 has a gate electrode 4A formed in integration with one address line 4. The drive transistor Q2 has a gate electrode 4B. Anodic oxidation films 5 are formed on the gate electrodes 4A and 4B and the address lines 4. A gate insulation film 6 which is made of silicon nitride is formed so as to cover the address lines 4, the gate electrodes 4A and 4B and the substrate 2. Semiconductor layers 7A and 7B, which are made of amorphous silicon (a-Si) or polycrystalline silicon (p-Si), are patterned on the gate insulation film 6 covering the gate electrodes 4A and 4B. Blocking layers 8A and 8B are formed on the middle portions of the semiconductor layers 7A and 7B, respectively, and extend in a channel widthwise direction. Ohmic layers 9A and 9B are formed on the semiconductor layer 7A, and are isolated from each other at the blocking layer 8A. The ohmic layer 9A is located on that side (the drain side) of the semiconductor layer 7A which is dose to a drain, while the ohmic layer 9B is located on that side (the source side) of the semiconductor layer 7A which is close to a source. Ohmic layers 9C and 9D are formed on the semiconductor layer 7B, and are isolated from each other at the blocking layer 8B. The ohmic layer 9C is located on the drain side of the semiconductor layer 7B, while the ohmic layer 9D is located on the source side of the semiconductor layer 7B. In the selection transistor Q1, a data line 10A is laminated on and connected to the ohmic layer 9A located on the drain side, and a source electrode 10B is laminated on and connected to the ohmic layer 9B located on the source side. The source electrode 10B is connected to a contact hole 11 formed in the gate insulation film 6 of the drive transistor Q2. In the drive transistor Q2, a constant voltage line 12 which is set at a ground potential is laminated on and connected to the ohmic layer 9C located on the drain side, and a source electrode 13 having two ends is laminated on the ohmic layer 9D located on the source side. One end of the source electrode 13 is connected to the ohmic layer 9D, while the other end of the source electrode 13 is connected to one of cathode electrodes 15 of organic EL elements 3. The gate electrode 4B, the constant voltage line 12 and the gate insulation film 6 therebetween form a capacitor Cp.

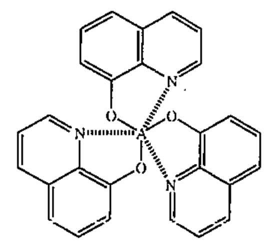
The structures of the organic EL elements 3 will now be described. In the entire display area of the display apparatus, a flat interlayer insulation film 14 is deposited to a thickness of about 400 nm to 1200 nm on selection transistors Q1, drive transistors Q2 and the gate insulation film 6. Contact holes 14A are formed in those parts of the interlayer insulation film 14 which are located at end portions of the source electrodes 13 of the drive transistors Q2. Each of the contact holes 14A and a corresponding one of the aforementioned end portions of the source electrodes 13 are located almost in the center of one pixel area. The cathode electrodes 15 which are made of MgIn or the like are patterned on the interlayer insulation film 14. Each cathode electrode 15 has an area and a shape (almost square in this embodiment) which are enough to cover the most part of one pixel area surrounded by the adjacent data lines 10A and the adjacent address lines 4. The selection transistors Q1 and the drive transistors Q2 are formed under the cathode electrodes 15.

In the entire display area, an organic EL layer 16 is formed on the cathode electrodes 15 and the interlayer insulation film 14, and a transparent anode electrode 17 which is made of ITO (indium tin oxide) or IZnO (indium zinc oxide) is formed on the organic EL layer 16. A driving power source (not shown) is connected to the anode electrode 17.

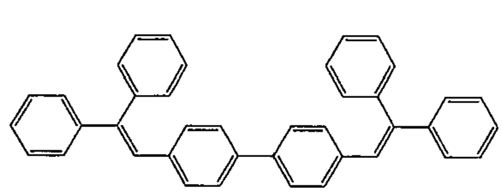
The organic EL layer 16 includes an electron carrying layer, a luminous layer and a hole carrying layer. Of those layers included in the organic EL layer 16, the electron carrying layer is closest to the cathode electrodes 15, and the hole carrying layer is farthest from the cathode electrodes 15. The electron carrying layer is made of aluminum-tris (8-hydroxyquinolinate) (hereinafter referred to as Alq3). The luminous layer is made of 96 wt % 4,4'-bis(2,2-diphenylvinylene)biphenyl (hereinafter referred to as DPVBi) and 4 wt % 4,4'-bis((2-carbazole)vinylene)biphenyl (hereinafter referred to as BCzVBi). The hole carrying layer is made of N,N'-di(α-naphthyl)-N,N'-diphenyl-1,1'-biphenyl-4,4'-diamine (hereinafter referred to as α-NPD). The thickness of the organic EL layer 16 is on the order of 40 nm to 250 nm.

The constitutional formulas of Alq3, DPVBi, BCzVBi and α-NPD are shown below:

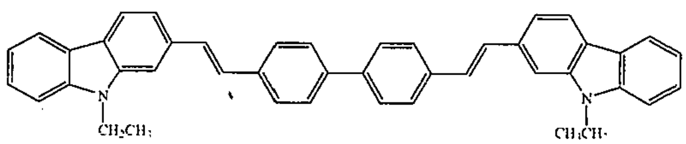
[Formula 1]



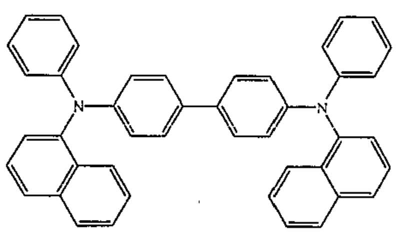
[Formula 2]



[Formula 3]



[Formula 4]

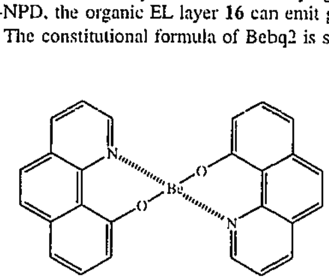


The organic EL layer **16** thus formed emits blue light upon the application of a predetermined voltage.

When the organic EL layer **16** between the anode electrode **17** and the cathode electrodes **15** includes a luminous layer which can carry electrons and which is made of berylliumbis(10-hydroxybenzo[h] quinolinate) (hereinafter referred to as Bebq2), and a hole carrying layer made of α-NPD, the organic EL layer **16** can emit green light.

The constitutional formula of Bebq2 is shown below:

[Formula 5]



In the display apparatus **1** of this embodiment, each cathode electrode **15** covers one pixel area surrounded by the adjacent data lines **10A** and the adjacent address lines **4**, and therefore each EL element **3** emits light over the entirety of one pixel area. This remarkably improves the aperture ratio per pixel in the display apparatus **1** of this embodiment over that of the conventional active matrix type EL display apparatus. The cathode electrodes **15** are formed of MgIn which reflects light. Therefore, the light emitted by the organic EL layer **16** when a voltage is applied between the anode electrode **17** and the cathode electrodes **15** comes out through the anode electrode **17** without leaking downward (toward the substrate **2**). Thus, the light does not enter the selection transistors **Q1** and the drive transistors **Q2**, and hence the malfunction of the transistors **Q1** and **Q2** due to the photoelectromotive force is avoided. The light emitted by the organic EL layer **16** goes out of the display apparatus through the transparent anode electrode **17**, without the light being absorbed by the substrate **2**, etc., and therefore bright display is realized.

The area of the interface between the organic EL layer **16** and the cathode electrodes **15** is large. This permits the cathode electrodes **15** and the organic EL layer **16** to be joined together in a preferred condition, and ensures to the display apparatus **1** of this embodiment a luminous life improved over that of the conventional active matrix type

EL display apparatus. The cathode electrodes **15** are formed on a flat layer having no steps, and therefore are free from the possibility of the cathode electrodes 15 breaking at steps. The cathode electrodes **15** are arranged so as not to overlap the address lines 4 or the data lines **10A**. Consequently, the slowing down of signal transmission, caused by a parasitic capacitance which would occur if the cathode electrodes **15** were arranged so as to overlap the address lines 4 or the data lines **10A**, is prevented.

When a layer like the organic EL layer **16** is subjected to a temperature higher than a glass-transition temperature for an organic EL material, its light emitting characteristic deteriorates considerably. In consideration of this, according to the display apparatus of this embodiment, the organic EL layer **16** is formed after the selection transistors Q1 and the drive transistors Q2 are manufactured by a heat treatment under a temperature of several-hundred degrees. The organic EL layer **16** is not subjected to a temperature higher than the glass-transition temperature, and therefore the deterioration of the light emitting characteristic does not occur.

The organic EL layer **16** is thinner than an inorganic EL layer. Moreover, the thickness to which the organic EL layer is formed through vapor deposition using the organic EL material can be very easily controlled during the process of forming the organic EL layer. When the organic EL layer **16** is formed to the thickness corresponding to the wavelength at the luminance peak of the light emitted by the organic EL layer **16** (in other words, the wavelength of the most intense component of the light emitted by the organic EL layer **16**), the resonance effect which permits light to easily come out from the organic EL layer **16** can be achieved. For example, in the case of an organic EL element which emits blue light, the resonance effect can be attained when it is formed to the thickness of 40 nm to 50 nm. In the case of an organic EL element which emits green light, the resonance effect can be attained when it is formed to the thickness of 50 nm to 60 nm.

The driving principle of the display apparatus according to this embodiment will now be described. FIGS. **3** and **4** are equivalent circuit diagrams showing that part of the display apparatus **1** which corresponds to one pixel. As shown in FIG. 3, a display circuit in that part of the display apparatus **1** which corresponds to one pixel includes an organic EL element 3 and a voltage controller Cv. As shown in FIG. **4**, the voltage controller Cv has a selection transistor **Q1**, a drive transistor **Q2** and a capacitor Cp. The driving power source Ps for supplying a constant voltage Vdd is connected to the anode electrode **17** of the organic EL element **3**. The voltage controller Cv is connected to the cathode electrode of the organic EL element 3. The drain electrode of the drive transistor Q2 in the voltage controller Cv is grounded via the constant voltage line **12**.

The voltage controller Cv can control a voltage so that the luminance of the organic EL element 3 varies in accordance with gradation data corresponding to image data which is input at the time of selection. An address line **4** is connected to the gate electrode **4A** of the selection transistor Q1, and a data line **10A** is connected to the drain electrode of the selection transistor **Q1**. The gate of the selection transistor **Q1** is turned on in response to a selection signal supplied through the address line **4**. While the selection transistor Q1 is on, an image data voltage supplied through the data line **10A** is accumulated in the capacitor Cp. The capacitor Cp retains the image data voltage almost over 1 frame period. The resistance in the drive transistor Q2 is controlled by the voltage retained in the capacitor Cp. The organic EL element **3** emits light according to written information, in other words, the retained voltage.

The electric characteristic of the organic EL element **3** will now be described with reference to FIGS. **5** and **6**. As shown in FIG. **5**, the source-drain current Ids of the drive transistor Q2 is shifted in accordance with a gate voltage Vg applied to the gate electrode of the drive transistor Q2. The source-drain current Ids of the drive transistor Q2 becomes saturated when a source-drain voltage Vsd applied between the source and drain of the drive transistor Q2 exceeds approximately 5V. As shown in FIG. **6**, the organic EL element **3** has a luminance characteristic according to an anode-cathode voltage Vac (a forward bias is positive). In this embodiment, the luminance (gradation) of the organic EL element **3** is controlled by controlling the anode-cathode voltage Vac in a range of 0(V) to Vdd (M).

The source electrode **10B** of the selection transistor Q1 is connected to the gate electrode **4B** of the drive transistor Q2 through a contact hole **14B**. A writing/deleting voltage is applied to the drain electrode of the selection transistor Q2 through the data line **10A**.

Driver circuits used in the display apparatus **1** will now be explained with reference to FIG. **7**. As shown in this drawing, one selection transistor **Q1**, one drive transistor Q2 and one organic EL element **3** are provided in each pixel area. One address line **4** is connected to the gate electrode **4A** of each selection transistor Q1. One data line **10A** is connected to the drain electrode of each selection transistor **Q1**. Moreover, as shown in FIG. **8**, a selection voltage Vad having a positive potential is applied to a selected one of the address lines **4**, and a non-selection voltage Vnad having a ground potential is applied to the other non-selected address lines **4**. In the selection periods, a writing voltage Vr according to the luminance is applied to the data lines **10A**. The driving power source Ps continually applies the constant voltage Vdd to the anode electrode **17**.

The operation of the display apparatus **1** according to this embodiment will now be described.

A gate driver circuit **DC1** illustrated in FIG. **7** applies voltages through its terminals **X1** to Xm to the address lines **4**, thereby sequentially selecting the address lines **4**. When selecting one address line **4** connected to the terminal **X1**, the gate driver circuit DC1 applies the selection voltage Vad to that address line, and applies the non-selection voltage Vnad to the other address lines. At that time, a drain driver circuit **DC2** applies the writing voltage Vr through its terminals **Y1** to Yn and the data lines **10A** to the drain electrodes of those of the selection transistors Q1 which are connected to the address line **4** connected to the terminal **X1**. In accordance with the writing voltage Vr, a voltage of 0V to Vdd (V) is applied to those of the organic EL elements **3** which correspond to pixels P (**1**, **1**) to P (**1**, n), and the organic EL elements **3** applied with the voltage emit light at the luminance (gradation) according to the applied voltage. In a non-selection period during which the address line **4** connected to the terminal **X1** is not selected, the capacitors Cp connected to that address line retain the writing voltage Vr over 1 frame period. Consequently, currents keep flowing into the drains of drive transistors Q2 and then into organic EL elements 3 over 1 frame period, and those EL elements emit light over 1 frame period. In place of the selection voltage Vad, the gate driver circuit **DC1** applies the non-selection voltage Vnad to the address line **4** connected to the terminal **X1**. In order to select another address line **4** connected to the terminal **X2**, the gate driver circuit **DC1** applies the selection voltage Vad to the address line **4** connected to the terminal **X2**. In the same manner as that descried above, those of the organic EL elements **3** which correspond to pixels P (**2**, **1**) to P (**2**, n) emit light at the luminance according to the applied voltage.

Thus, in the display apparatus 1 of this embodiment, the organic EL elements 3 can keep emitting light even while their corresponding address lines 4 are not selected.

Accordingly, even though the display apparatus 1 is designed to display a highly precise image, the luminance of the organic EL elements 3 need not be set high. For example, in order to attain a luminance of 100 cd/m^2 at the surface of the screen of a conventional passive matrix type display apparatus, the organic EL elements have to emit light at a luminance of about 48000 cd/m^2. However, in the case of the display apparatus of this embodiment, a luminance of approx 100 cd/m^2 suffices as the luminance of the organic EL elements 3.

According to the display apparatus 1 of this embodiment, unlike in the case of the passive matrix type organic EL display apparatus proposed conventionally, the organic EL elements 3 can keep emitting light over 1 frame period, and the display apparatus 1 can display an image without causing the organic EL elements 3 to emit light at a high luminance. The display apparatus 1 of this embodiment can display a highly precise halftone image, and the expressivity of the displayed image is improved. In order to vary a carrier potential at a high speed, a writing voltage which is applied to the data lines 10A while the organic EL elements 3 are emitting no light can be set at a negative potential in accordance with an increase in the number of address lines 4, insofar as a P-channel current is not adversely affected.

Further, as shown in FIG. 9, a dielectric film having a thickness of 5 nm or less and which is formed of at least one material selected from a group consisting of SiO2, Lif, Naf, CaF2 and Mgf2, may be provided between the organic EL layer 16 and the cathode electrodes 15. When a voltage having a predetermined value is applied between the anode electrode 17 and the cathode electrode 15, electrons are injected from the cathode electrodes 15 into the organic EL layer 16 through the dielectric film 18 due to the tunneling effect. After the formation of, for example, the cathode electrodes 15 which are easily oxidized, the dielectric film 18 is formed so as to cover the cathode electrodes 15 by a vacuum deposition method or the like. The cathode electrodes 15 covered by the dielectric film 18 are not exposed to the air. Accordingly, the electron injecting capability of the cathode electrodes 15 is maintained in an excellent condition. It is preferred that the dielectric film 18 be one which can be successfully joined with the cathode electrodes 15 and the organic EL layer 16 in a preferred state.

In the multicolor (full-color) type display apparatus 1 illustrated in FIG. 10, wavelength range conversion layers 52R, 52G and 52G, sandwiched between an insulation film 53 formed on the anode electrode 17 and a substrate 51, are provided in one-to-one correspondence with the cathode electrodes 15. A black mask containing chromium oxide is formed in the areas corresponding to the address lines 4 and the data lines 10A. The wavelength range conversion layers 52R have the photoluminescence effect of absorbing light which the organic EL layer 16 emits in a blue wavelength range and emitting light in a longer red wavelength range. The wavelength conversion layers 52G have the photoluminescent effect of absorbing light which the organic EL layer 16 emits in the blue wavelength range and emitting light in a longer green wavelength range. The wavelength conversion layers 52B have the photoluminescent effect of absorbing light which the organic EL layer 16 emits in the blue wavelength range and emitting light in a longer blue wavelength range.

In this display apparatus 1, the organic EL layer which emits blue light of a single color is satisfactory. The wavelength conversion layers 52R convert the blue light emitted by the organic EL layer 16 into red light, and emit the converted red light. The wavelength conversion layers 52G convert the blue light emitted by the organic EL layer 16 into green light, and emit the converted green light. The wavelength conversion layers 52B convert the blue light emitted by the organic EL layer 16 into blue light, and emit the converted blue light. Therefore, the display apparatus 1 can easily display a full-color image. The areas occupied by the wavelength conversion layers 52R, 52G and 52B are set equal to those occupied by the cathode electrodes 15, and therefore the light emitting area of each pixel is not small even through the transistors Q1 and Q2 are present. This permits the wavelength conversion layers to perform the energy conversion with efficiency.

It is preferred that a material having a refractive index which approximates to that of the wavelength conversion layers 52R, 52G and 52B, which are in contact with the insulation film 53, be selected as the material of the insulation film 53. This is because when the insulation film 53 is formed of such a material, the degree of the reflection of light at the interface between the insulation film 53 and the wavelength conversion layers 52R, 52G and 52B is small.

The display apparatus 1 illustrated in FIG. 11 includes the wavelength conversion layers 52R and 52G. This display apparatus 1 displays a multicolor (full-color) image, using as is the blue light emitted by the organic EL layer 16.

In the display apparatus 1 illustrated in FIG. 12, color filters 55R, 55G and 55B are provided between a substrate 1 and the wavelength conversion layers 52R, 52G and 52B, respectively. Of the light incident on the color filter layers 52R, the light components in the red wavelength range pass through the color filter layers 52R, but the light components in the other wavelength ranges are absorbed by the color filter layers 52R. Of the light incident on the color filter layers 52G, the light components in the green wavelength range pass through the color filter layers 52G, but the light components in the other wavelength ranges are absorbed by the color filter layers 52G. Of the light incident on the color filter layers 55B, the light components in the wavelength range in which the blue light emitted by the wavelength conversion layers 52B falls pass through the color filter layers 55B, but the other light components are absorbed by the color filter layers 55B. In other words, the color filter layers 55B absorb the blue light emitted by the organic EL layer 16, but allow the blue light emitted by the wavelength conversion layers 52B to pass through the color filter layers 55B.

The color filter layers 55R have such a characteristic that they absorb, of the incident light entering the wavelength conversion layers 52R through the substrate 51, the light components in the wavelength range of the light by which the wavelength conversion layers 52R are excited (i.e., the light components in the same wavelength range as that in which excitation light components of the blue light emitted by the organic EL layer 16 fall). Under this condition, the wavelength conversion layers 52R are not excited by the light coming from the outside of the display apparatus 1. The color filter layers 55G have such a characteristic that they absorb, of the incident light entering the wavelength conversion layers 52G through the substrate 51, the light components in the wavelength range of the light by which the wavelength conversion layers 52G are excited (i.e., the light components in the same wavelength range as that in which of the excitation light components of the blue light emitted by the organic EL layer 16 fall). Therefore, the color conversion layers 52G are not excited by the external light coming from the outside of the display apparatus 1. The wavelength conversion layers 52B emit blue light in a blue wavelength range wider than that of the blue light emitted by the organic EL layer 16. The color filter layers 55B have such a characteristic that they absorb the blue light emitted by the organic EL layer 16 but allow the blue light emitted by the wavelength conversion layers 52B to pass through the color filter layers 55B. Consequently, the wavelength conversion layers 52B are not excited by the external light coming from the outside of the display apparatus 1.

When the light emitted by the wavelength range conversion layers 52R, 52G and 52B enter the color filter layers 55R, 55G and 55B, light in narrower wavelength ranges than those of the light emitted by the layers 52R, 52G and 52B and having higher luminance peaks than those of the light emitted by the layers 52R, 52G and 52B, come out from the filter layers 55R, 55G and 55B. Accordingly, the color purity of light going outside the display apparatus 1 is high. The black mask 54 shields areas between the color filter layers 55R, 55G and 55B from the external light radiated toward those areas, and therefore the external light do not enter the wavelength conversion layers 52R, 52G and 52B so as to cause the layers 52R, 52G and 52B to perform light emission. The black mask 54 also prevents light from being reflected by the address lines 4 and the data lines 10A. This ensures a considerably excellent display characteristic to the display apparatus 1. Since no light enters also the transistors Q1 and Q2 by virtue of the presence of the black mask 54 and cathode electrodes 17, the malfunction of the transistors Q1 and Q2 does not occur.

As shown in FIG. 13, the organic EL layer 16 may include a red EL layer 16R, a green EL layer 16G and a blue EL layer 16B. It is possible to cause light emitted by those EL layers 16R, 16G and 16B to enter the color filter layers 55R, 55G and 55B, respectively, and to come out therefrom as light having higher luminance peaks.

In FIG. 14, color filter layers 56B have such a characteristic that when the blue light emitted by the organic EL layer 16 enters the color filter layers 56B, blue light in a narrower wavelength range than that of the blue light emitted by the organic EL layer 16 and having a higher luminance peak than that of the blue light emitted by the organic EL layer 16, comes out from the color filter layers 56B. Hence, without using a wavelength conversion layer for blue, the display apparatus 1 illustrated in FIG. 14 can display a full-color image if the wavelength conversion layers 52R and 52B are provided in correspondence with the color filter layers 55R and 55G.

The display apparatus 1 illustrated in FIG. 15 has wavelength conversion layers 57R, 57G and 57B each having a concave surface facing the organic EL layer 16. Even when the light emitted by the organic EL layer 16 is reflected at the interfaces between the insulation film 53 and the wavelength conversion layers 57R, 57G and 57B, the most part of the reflected light is reflected by the cathode electrodes 15. The light reflected by the cathode electrodes 15 falls on the interfaces between the insulation film 53 and the wavelength conversion layers 57R, 57G and 57B at an incident angle different from the initial incident angle. Under this condition, it is easy for the wavelength conversion layers 57R, 57G and 57B to catch the light reflected by the cathode electrodes 15. Thus, in the display apparatus 1 illustrated in FIG. 15, the light emitted by the organic EL layer 16 enters the wavelength conversion layers 57R, 57G and 57B without the light being wasted.

The display apparatus 1 of the above embodiment has the structure shown in FIG. 7. However, as shown in FIG. 16, the positions of the anode and cathode electrodes can be reversed. In this case, the driving power source Ps continually applies a constant negative voltage (−Vdd) to the cathode electrodes of the organic EL elements 3.

It is possible to provide the dielectric film 18 shown in FIG. 9 between an anode electrode 16 and the cathode electrodes 15 in the display apparatuses 1 illustrated in FIGS. 10 to 15.

The structure of a display apparatus according to another embodiment of the present invention will now be described with reference to FIGS. 17 to 20. FIG. 17 is a plan view of that part of the display apparatus of this embodiment which corresponds to one pixel. FIG. 18 is a cross section taken along the line 18—18 shown in FIG. 17. FIG. 19 is a cross section taken along the line 19—19 shown in FIG. 17.

Reference numeral 21 in the drawings denotes the display apparatus. In the display apparatus 21 of this embodiment, as shown in FIGS. 17 to 19, a grounded electrode 23 is formed on a substrate 22 over the entire display area. A base insulation film 24, which is made up of a silicon oxide film and/or the like, is patterned on the grounded electrode 23. Formed on the base insulation film 24 are parallel address lines 48, which are connected each to one of terminals X1 to Xm connected to a gate driver circuit (described later), and which are spaced at predetermined intervals. A first gate insulation film 25 is formed on the address lines 48 and the base insulation film 24. As show in FIGS. 17 and 18, a first semiconductor layer 26 and a second semiconductor layer 27, which are made of amorphous silicon and/or the like, are patterned on the first gate insulation film 25. The first semiconductor layer 26 enables the address lines 48 to function as gate electrodes. A blocking layer 28 is patterned on that part of the semiconductor layer 26 which is the middle portion of the layer 26 in a gate lengthwise direction (a vertical direction in FIG. 17). A second gate insulation film 29 is formed so as to cover the upper and side surfaces of the second semiconductor layer 27. The blocking layer 28 and the second gate insulation film 29 are made of silicon nitride and/or the like, and are formed by a CVD method. A source electrode 30 and a drain electrode 31 are formed on both sides of the first semiconductor layer 26 with respect to a gate widthwise direction so that the source and drain electrodes 30 and 31 are connected to the first semiconductor layer 26 (in FIG. 18, the source electrode 30 is formed on the right part of the first semiconductor layer 26, while the drain electrode 31 is formed on the left part of the first semiconductor layer 26). The address lines 48, the first gate insulation film 25, the first semiconductor layer 26, the source electrode 30 and the drain electrode 31 thus formed constitute a selection transistor Q3. The input impedance of the selection transistor Q3 is set at a large value. The drain electrode 31 shown in FIG. 17 is patterned and formed in integration with a corresponding one of data lines 47, which are connected each to one of terminals Y1 to Yn connected to a drain driver circuit (described later). The source electrode 31 shown in FIG. 17 is patterned and formed in integration with a gate electrode 32 which crosses over the middle part of the second semiconductor layer 27, with the second gate insulation film 29 being located between the second semiconductor layer 27 and the gate electrode 32. The source electrode 30 and the gate electrode 32 are patterned and formed in integration with a capacitor upper electrode 34 included in a capacitor Cp2. The capacitor Cp2 includes the capacitor upper electrode 34, the second gate insulation film 29 formed under the capacitor upper electrode 34, the first gate insulation film 25 and a capacitor lower electrode 35. The capacitor lower electrode 35 is connected to the grounded electrode 23 through a contact hole 24A formed in the base insulation film 24.

A source electrode 36 and a drain electrode 37 are formed on both sides of the gate electrode 32 of the second semiconductor layer 27. The second semiconductor layer 27, the second gate insulation film 29, the gate electrode 32, the source electrode 36 and the drain electrode 37 form a drive transistor Q4. The drain electrode 37 shown in FIG. 17 is formed in integration with a power source line 38 which is parallel with the data lines 47 and which applies a voltage for driving organic EL elements 39. The source electrode 36 is connected to an EL upper electrode 40 included in an organic EL element 39. In the display apparatus 21, the selection transistor Q3, the drive transistor Q4 and the capacitor Cp2 form a voltage controller.

As shown in FIGS. 17 and 19, each organic EL element 39 includes a light-shielding EL lower electrode 42 made of MgIn and/or the like and serving as a cathode electrode, an organic EL layer 41 formed on the EL lower electrode 42, and a transparent EL upper layer 40 made of ITO and/or the like and formed on the organic EL layer 41. The EL upper electrode 40 serves as an anode electrode.

The organic EL layer 41 includes an electron carrying layer, a luminous layer and a hole carrying layer. Of those layers included in the organic EL layer 41, the electron carrying layer is closest to the EL lower electrode 42, and the hole carrying layer is farthest from the EL lower electrode 42. The electron carrying layer is made of Alq_3. The luminous layer is made of 96 wt % DPVBi and 4 wt % BCzVBi. The hole carrying layer is made of N,N'-di(α-naphthyl)-N,N'-diphenyl-1,1'-biphenyl-4,4'-diamine (referred to as α-NPD).

The organic EL element 39 is formed on an interlayer insulation film 43 which covers the selection transistor Q3 and the drive transistor Q4 and which is formed over the entire display area. The EL lower electrode 42 is connected to the grounded electrode 23 through a contact hole 44 formed in the first gate insulation film 25 and the base insulation film 24. Of the area surrounded by a two-dot chain line in FIG. 17, the part except a projecting portion 40A is covered by the EL lower electrode 42. The EL lower electrode 42, which is a rectangular electrode covering the selection transistor Q3, the drive transistor Q4 and the capacitor Cp2, etc., occupy the most part of the area occupied by one pixel. The organic EL layer 41 is a layer extending over the entire display area. The EL upper electrode 40 extends over the area surrounded by the two-dot chain line in FIG. 17. The projecting portion 40A of the EL upper electrode 40 is connected to the source electrode 36 of the drive transistor Q4 through a contact hole 45, as shown in FIG. 17. The power source line 38 is connected to the driving power source Ps which continually applies the constant voltage Vdd.

FIG. 20 is a diagram showing driver circuits included in the display apparatus 21 illustrated in FIG. 17.

A drive method for having the display apparatus 21 of this embodiment emit light will now be described.

A gate driver circuit DC3 is driven to output a selection signal to any one of the address lines 48. In synchronization with the output of the selection signal to one address line 48, a drain driver circuit DC4 is driven to output a data signal to the data lines 47. When the number of address lines 48 is N, 1 scanning period during 1 frame period T is T/N, and the selection signal has such a voltage value as to enable the writing voltage Vr exceeding the gate threshold value Vth of selection transistors Q3 to be applied to the address line 48 during 1 scanning period. Upon the application of the selection signal, selection transistors Q3 in FIG. 20 are turned on, and a voltage according to the data signal output to the data lines 47 is applied to the gate electrodes 32 of drive transistors Q4, and is stored in capacitors Cp2. The capacitors Cp2 retain the voltage according to the data signal over 1 frame period, and the value of the resistance in the drive transistors Q4 is controlled to a substantially constant value until the next selection period by the potential Vc retained in the capacitors Cp. In accordance with the value of the resistance in the drive transistors Q4, the potential Vdd is applied through the power source line 38 to the organic EL layer 41. As a result, a substantially constant current flows through the organic EL layer 41, and the organic EL layer 41 emits light at a substantially constant luminance during 1 frame period. By repeating those operations, the display apparatus 21 can maintain the state of emitting light, and accordingly the contrast in an image displayed on the display apparatus 21 is remarkably improved over the conventional passive matrix type EL display apparatus. Since a current supplied to the organic EL layer 41 can be precisely controlled through the use of the transistors Q3 and Q4, the display apparatus 21 can perform gray-scale display with ease. If wavelength conversion layers and/or color filter layers are used as shown in FIGS. 10 to 15, the display apparatus 21 can perform full-color (multicolor) display as well.

In the display apparatus 21 of this embodiment, the area occupied by each EL lower electrode 42 is not limited by the thin film transistors Q3 and Q4. Therefore, the ratio of the light emitting area to each pixel area can be enhanced, with the result that the organic EL elements 39 can emit light at the desired luminance without the application of an excessively high voltage.

Since the EL lower electrodes 42 are made of a light-shielding material, the light emitted by the organic EL layer 41 does not enter the selection transistors Q3 or drive transistors Q4 located below the EL lower electrodes 42. Accordingly, the transistors Q3 and Q4 are prevented From malfunctioning due to such light, and the display apparatus 21 of this embodiment can be reliably driven.

The area of the interface between the organic EL layer 41 and the EL lower electrodes 42 is large. This permits the organic EL layer 41 and the EL lower electrodes 42 to be joined together in a preferred condition, and ensures to the display apparatus 21 of this embodiment a luminous life improved over that of the conventional active matrix type EL display apparatus. The EL lower electrodes 42 are formed on a flat layer having no steps, and therefore are free from the possibility of the EL lower electrodes 42 breaking at steps.

The grounded electrode 23 formed over the entire display area is made of a light-shielding metal such as Al, and therefore can shield the light coming from the substrate 22 and can make the light enter the transistors Q3 and Q4.

In the embodiments described above, polycrystalline silicon can be used in place of amorphous silicon in order to form the semiconductor layers of the transistors. However, amorphous silicon elements are preferable to polycrystalline silicon elements.

In the above-described embodiments, impurity-doped silicon nitride films, which has a capability to catch carriers and store a gate voltage, can be employed as the gate insulation films of the drive transistors. By thus conferring the voltage storing capability on the drive transistors themselves in addition to the use of the capacitors, the voltage storing capability of the entire circuitry is improved.

In the above embodiments, the transistors are MOS transistors. However, they may be bipolar transistors. Due to the input impedance of each of the selection transistors being set at a large value, the selection transistors have the effect of suppressing the amount of current flowing through the address lines to a great extent when a selection signal voltages is applied to the bases, even in the case where the number of selection transistors connected to each selection signal line is large. Accordingly, the amount of current which the organic EL elements require can be made small, and the life of the power source can be enhanced. Similarly in the case where a data signal voltage is applied to the drive transistors, the attenuation of the voltage stored in the capacitors can be suppressed to a great extent so as to prolong the period of time over which the data signal voltage is retained, due to the input impedance of those transistors being set at a large value.

The present invention is not limited to the above embodiments, and various changes can be made without departing from the scope of the present invention. For example, the cathode electrodes are made of MgIn in the above embodiments. However, a visible-light shielding material having a low work function and containing Mg and/or the like can also be used. It is also possible to form the cathode electrodes **15** so as to have rough surfaces and to form the organic EL layer **16** on those rough surfaces, as shown in FIG. **21**. The cathode electrodes **15** having such rough surfaces can be formed using an Mg material doped with Ag. In this case, not only flicker due to the reflection of the external light at the cathode electrodes **15** is suppressed, but also the area of the interface between the organic EL layer **16** and the cathode electrodes **15** is increased such that successful joining is attained between the organic EL layer **16** and the cathode electrodes **15**, ensuring a long luminous life to the organic EL elements **3**. The display apparatuses according to the above embodiments display images through utilization of the light emitted by the organic EL elements **3** only. However, the display apparatuses may include liquid crystal display panels as shutters.

In the above-described embodiments, the driving power source Ps continually applies a constant voltage to the organic EL elements. However, since the luminance of the organic EL elements is determined by the amount of recombination of electrons and holes, that is, the amount of current, the structure wherein the driving power source Ps applies a constant voltage is particularly advantageous when the areas occupied by the pixels are substantially equal to each other as in the case of matrix panels according to the above embodiments.

What is claimed is:

1. A display apparatus comprising:

a substrate;

active elements formed over said substrate and driven by an externally supplied signal;

an insulation film formed over said substrate so as to cover said active elements, said insulation having at least one contact hole;

at least one first electrode formed on said insulation film so as to cover said active elements, and connected to said active elements through said at least one contact hole, said at least one first electrode being made of a material which shields visible light;

an organic electroluminescent layer having an organic electroluminescent material formed on said at least one first electrode so as to cover said active elements and including at least one layer which emits light in accordance with a voltage applied to said at least one layer; and

at least one second electrode formed on said organic electroluminescent layer which covers said active elements.

2. The display apparatus according to claim **1**, wherein said at least one first electrode is formed of a conductive material containing magnesium.

3. The display apparatus according to claim **1**, wherein said at least one first electrode has a rough surface which is in contact with said organic electroluminescent layer.

4. The display apparatus according to claim **1**, wherein said active elements are a selection transistor which is turned on in response to an externally supplied address signal and a drive transistor, which is driven by a signal corresponding to image data supplied externally through said selection transistor while said selection transistor is on, for controlling a voltage to be applied to said organic electroluminescent layer, said selection transistor and said drive transistor forming a pair.

5. The display apparatus according to claim **4**, wherein said at least one first electrode is connected to said drive transistor through said at least one contact hole.

6. The display apparatus according to claim **4**, wherein:

said display apparatus further comprises a capacitor for retaining the signal corresponding to the image data externally supplied through said selection transistor while said selection transistor is on; and

while said selection transistor is off, said drive transistor is driven by the signal retained in said capacitor.

7. The display apparatus according to claim **1**, wherein:

said active elements are transistors forming pairs and arranged in a matrix pattern, one transistor of each of said pairs being a selection transistor which is turned on in response to an externally supplied address signal, and the other transistor of each of said pairs being a drive transistor, which is driven by a signal corresponding to image data supplied externally through said selection transistor while said selection transistor is on, for controlling a voltage to be applied to said organic electroluminescent layer;

said selection transistor of each of said pairs is connected to one of address lines and one of data lines, said address lines being formed over said substrate and being supplied with said address signal, and one of said data lines being formed over said substrate and being supplied with said image data; and

said at least one first electrode is plural in number, and the plurality of first electrodes are arranged in a matrix pattern in areas surrounded by said address lines and said data lines.

8. The display apparatus according to claim **1**, wherein a constant voltage is applied to said second electrode.

9. The display apparatus according to claim **1**, further comprising at least one wavelength conversion layer formed over said at least one second electrode, said at least one wavelength conversion layer emitting light in a first wavelength range by absorbing light in a second wavelength range emitted from said organic electroluminescent layer.

10. The display apparatus according to claim **9**, wherein said at least one wavelength conversion layer has a concave surface facing said at least one second electrode.

11. The display apparatus according to claim **9**, wherein said at least one wavelength conversion layer has at least two of a red conversion layer which emits light in a red wavelength range, a green conversion layer which emits light in a green wavelength range, and a blue conversion layer which emits blue light.

12. The display apparatus according to claim 1, wherein:

said display apparatus further comprises at least one filter formed above said at least one second electrode; and

light lays in a first wavelength range pass through said at least one filter selectively when incident light rays in a second wavelength range including said first wavelength range enter said at least one filter.

13. The display apparatus according to claim 12, wherein said at least one filter has a red filter which makes light in a red wavelength range pass through, a green filter which makes light in a green wavelength range pass through, and a blue filter which makes light in a blue wavelength range pass through.

14. The display apparatus according to claim 1, wherein said organic electroluminescent layer has a thickness whose value falls in a range of wavelength of light which said organic electroluminescent layer emits.

15. A display apparatus comprising:

a substrate;

selection transistors formed over said substrate and arranged in a matrix pattern;

drive transistors formed over said substrate and arranged in a matrix pattern, each of said drive transistors being connected to one of said selection transistors;

address lines connected to said selection transistors and through which a signal for turning on said selection transistors is supplied;

data lines connected to said selection transistors, a signal which corresponds to image data being supplied to said drive transistors through said data lines and said selection transistors while said selection transistors are on;

an insulation film formed over said substrate so as to cover said drive transistors, said address lines and said data lines, said insulation film having contact holes formed in correspondence with said drive transistors;

first electrodes made of a material which shields visible light, and formed on said insulation film so as to cover said selection transistors and said drive transistors, said first electrodes being arranged in a matrix pattern in areas surrounded by said address lines and said data lines, and being connected to said drive transistors through said contact holes;

an organic electroluminescent layer formed on said first electrodes which covers said selection transistors and said drive transistors and including at least one layer which emits light in accordance with an applied voltage;

a second electrode formed on said organic electroluminescent layer which covers said selection transistors and said drive transistors;

a first driver circuit for selectively supplying said address signal to said address lines in sequence; and

a second driver circuit for supplying said image data to said data lines.

16. The display apparatus according to claim 15, wherein a constant voltage is applied to said second electrode.

17. The display apparatus according to claim 1, wherein said display apparatus further comprises at least one filter, formed above said at least one second electrode, which selectively permits light rays in a first wavelength range to pass therethrough when incident light rays in a second wavelength range including said first wavelength range enter said at least one filter.

18. The display apparatus according to claim 17, wherein said at least one filter has a red filter which permits light in a red wavelength range to pass therethrough, a green filter which permits light in a green wavelength range to pass therethrough, and a blue filter which permits light in a blue wavelength range to pass therethrough.

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SEARCHED

Class	Sub.	Date	Exmr.
345	36	8/24/99	VCL
	45		
	76		
313	498 ↓ 512		
315	169.3		
Updated Search		1/12/00	VCL

INTERFERENCE SEARCHED

Class	Sub.	Date	Exmr.
Same	as above		VCL

SEARCH NOTES

	Date	Exmr.
• Conferred with Jeff Brier on Search Categories	7/29/99	VCL
• Conferred with Mark Zimmerman & Rich Hjerpe on rejection pronant.	8/2/99	VCL
• Amare Mengistu concurred with the allowability of claims 11+15	8/25/99	VCL
• Updated Search A.M	1/12/00	VCL
• Amare concurs with the allowance of claims 1-16.	1/12/00	VCL

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POSITION		ID NO.	DATE
CLASSIFIER		12	2/9/98
EXAMINER			
TYPIST			
VERIFIER			
CORPS CORR.			
SPEC. HAND			
FILE MAINT.			
DRAFTING			

INDEX OF CLAIMS

Claim		Date							
Final	Original	8/25/99	1/12/00						
1	(1)	✓	=						
\	2	✓	~~=~~						
2	3	O✓	=						
3	4	O✓	=						
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7	8	✓	=						
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10	11	O	=						
11	12	O✓	=						
12	13	O✓	=						
13	14	O✓	=						
14	15	O	=						
15	(16)	✓	=						
16	17	✓	=						
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SYMBOLS

✓ .... Rejected
= .... Allowed
- (Through numeral) Canceled
÷ .... Restricted
N .... Non-elected
I .... Interference
A .... Appeal
O .... Objected

Claim		Date							
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ORIGINAL CLASSIFICATION

CLASS	SUBCLASS
345	76

CROSS REFERENCE(S)

CLASS	SUBCLASS (ONE SUBCLASS PER BLOCK)			
345	36	45		
313	500	504		
315	169.3			

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PATENT APPLICATION

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APPROVED FOR LICENSE

INITIALS

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	5.	Amdt A	12-2-99
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