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**Omoto**

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(54) **ORGANIC ELECTROLUMINESCENCE  
DISPLAY AND ELECTRONIC EQUIPMENT**

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(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 236 days.

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(30) **Foreign Application Priority Data**

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**H01L 51/52** (2006.01)  
**H01L 27/32** (2006.01)  
**H01L 51/50** (2006.01)

(52) **U.S. Cl.**

CPC ..... **H01L 51/5281** (2013.01); **H01L 27/322** (2013.01); **H01L 27/326** (2013.01); **H01L 27/3276** (2013.01); **H01L 51/5044** (2013.01)

(58) **Field of Classification Search**

CPC . H01L 27/322; H01L 27/326; H01L 27/3276; H01L 51/5281; H01L 51/5044; G06F 3/038; H05B 33/14

See application file for complete search history.

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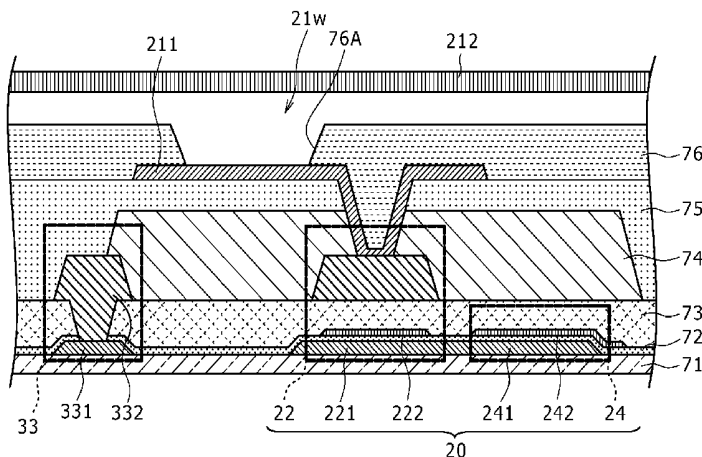
*Primary Examiner* — Aneeta Yodichkas

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(57) **ABSTRACT**

An organic electroluminescence display has a bottom emission structure in which a white organic electroluminescence element adapted to emit white light is formed, pixel by pixel, on a substrate, and in which light emitted by the white organic electroluminescence element is extracted from a rear side of the substrate. The organic electroluminescence display includes: a color filter used in combination with the white organic electroluminescence element to extract light of different colors; and metal interconnects formed, pixel by pixel, in such a manner as to surround a light-emitting section of the white organic electroluminescence element and the color filter.

**23 Claims, 25 Drawing Sheets**



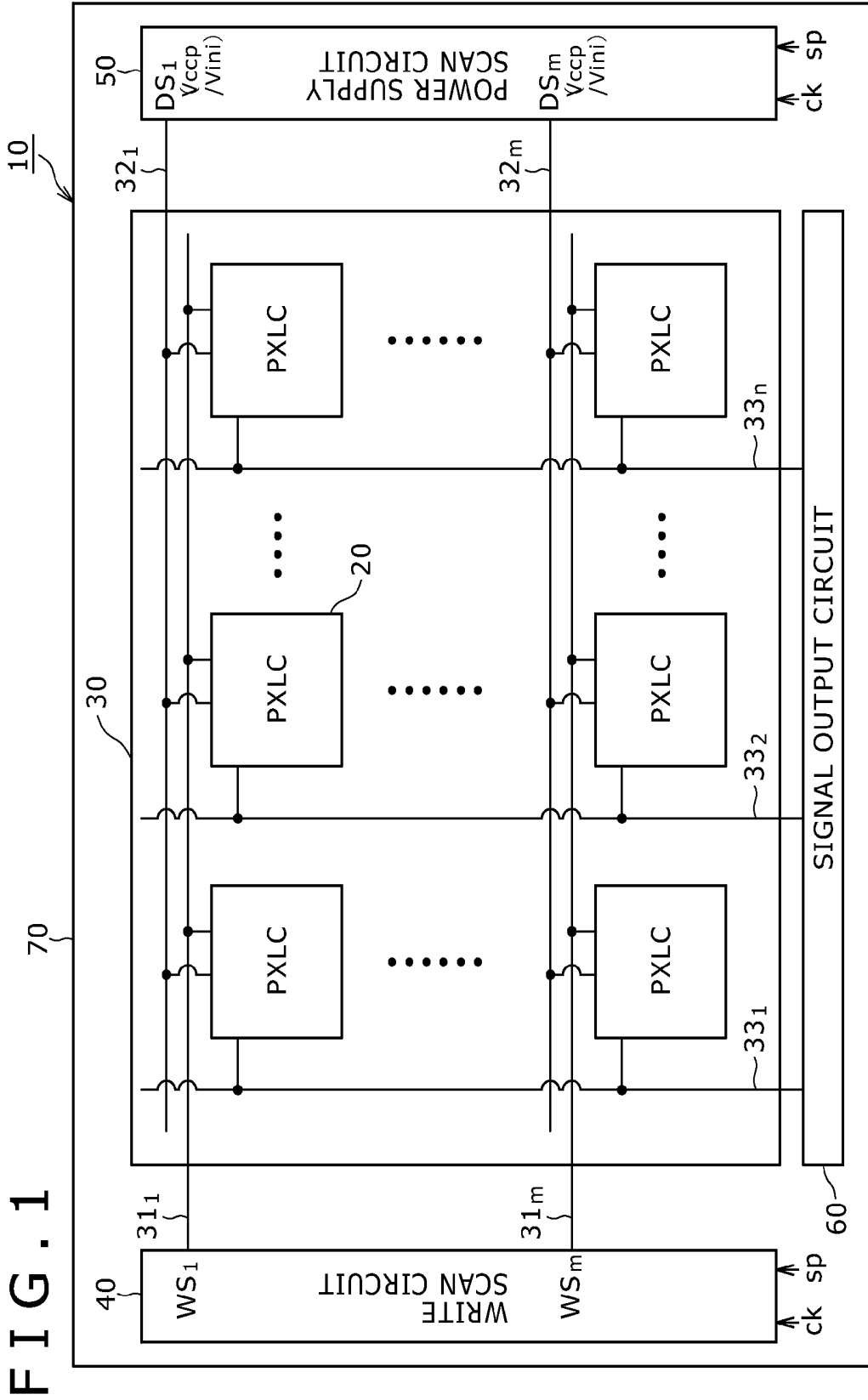


FIG. 1

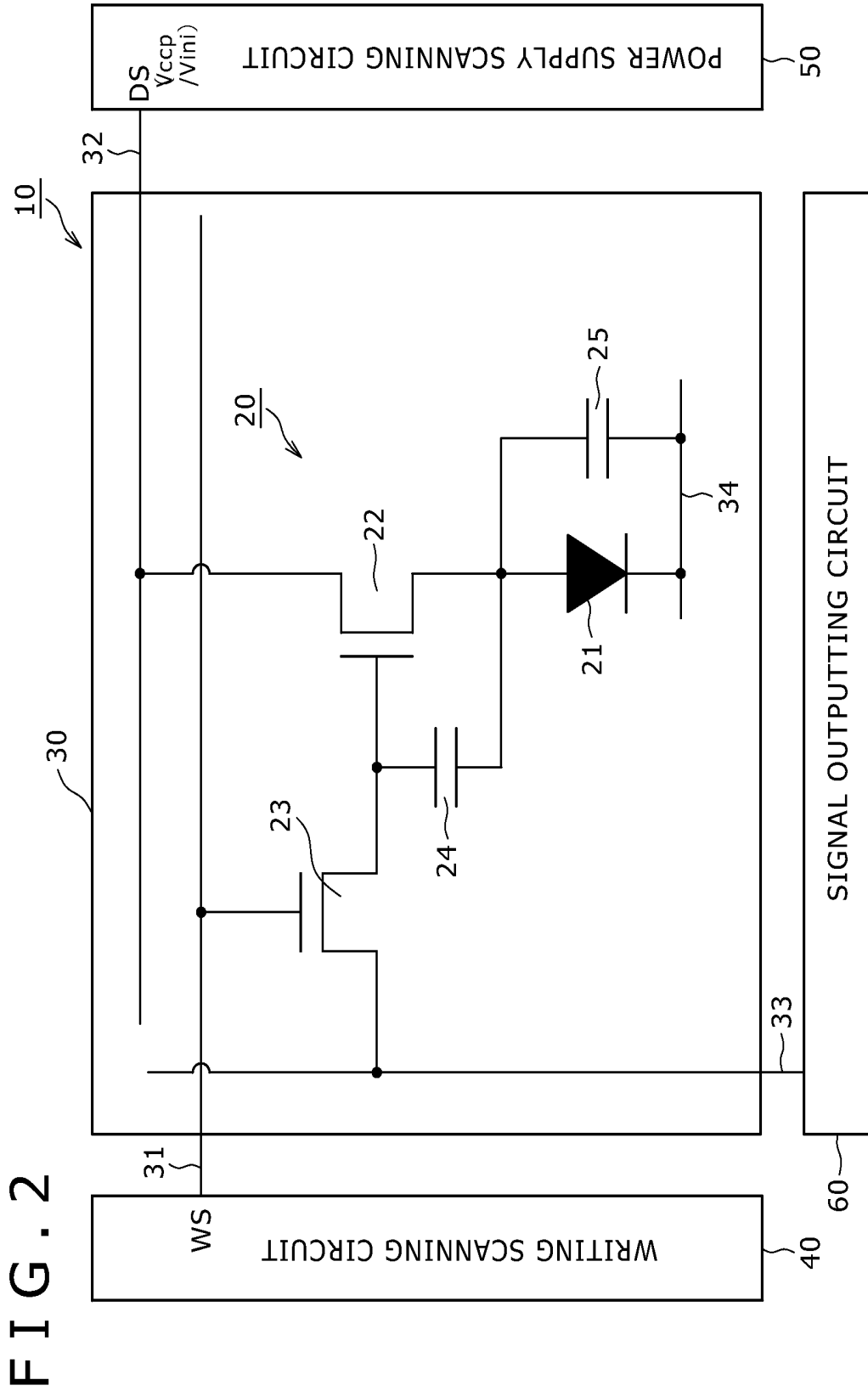


FIG. 3

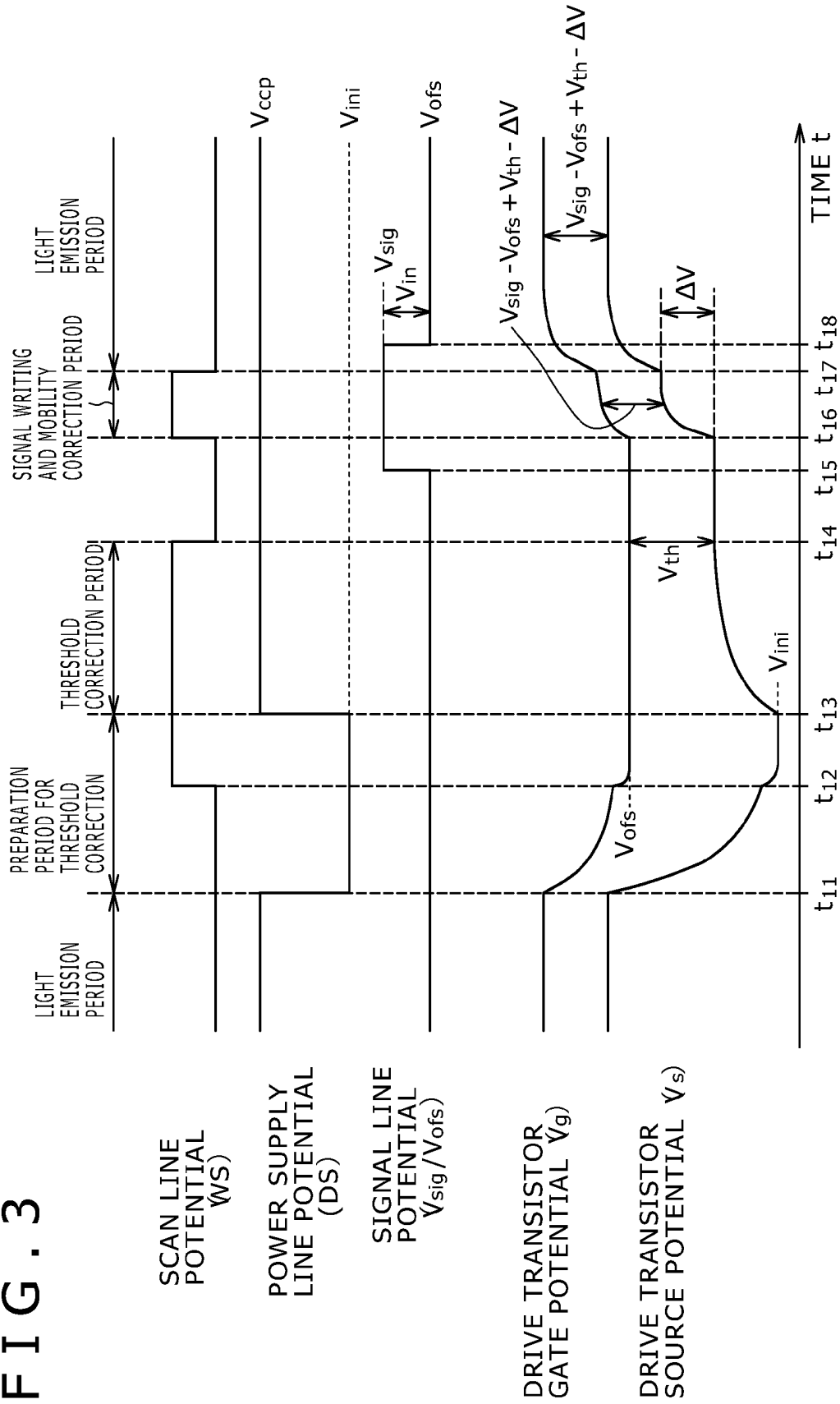


FIG. 4A

BEFORE  $t=t_{11}$

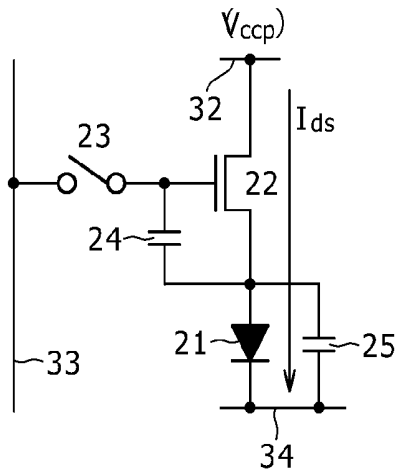


FIG. 4B

$t=t_{11}$

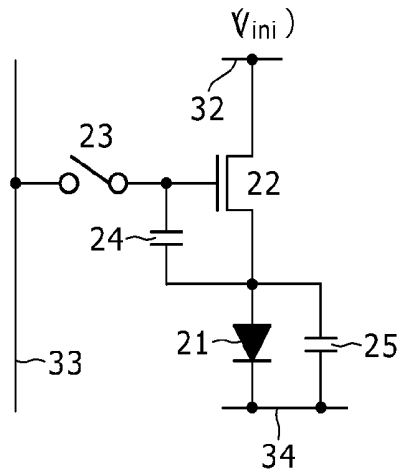


FIG. 4C

$t=t_{12}$

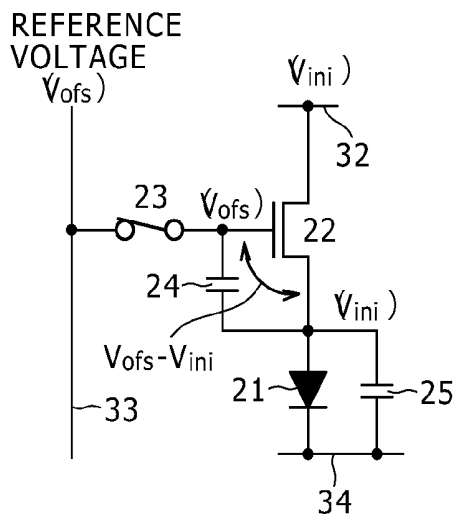


FIG. 4D

$t=t_{13}$

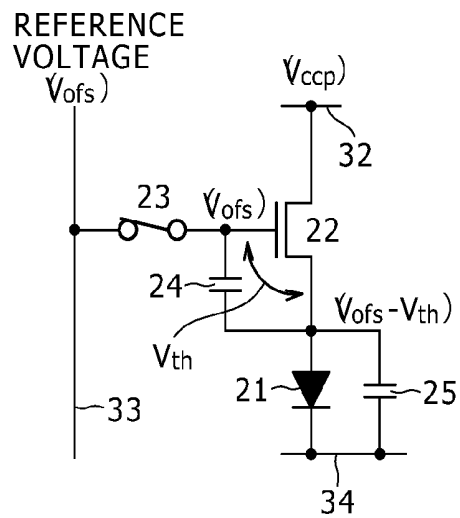


FIG. 5A

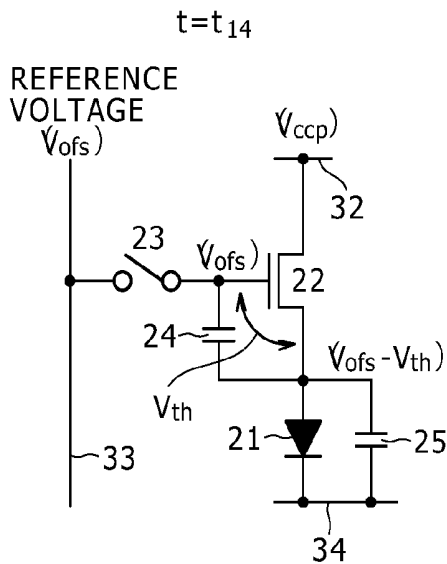


FIG. 5B

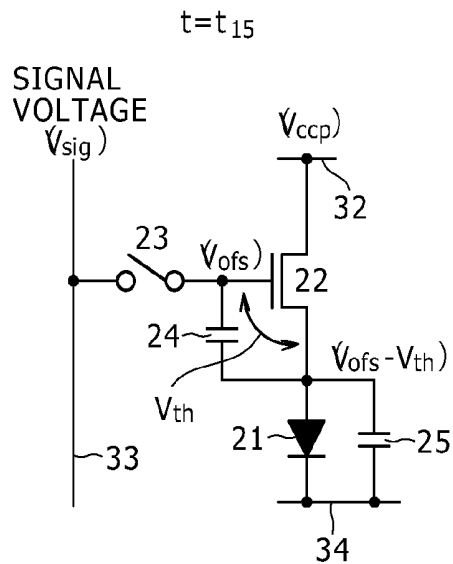


FIG. 5C

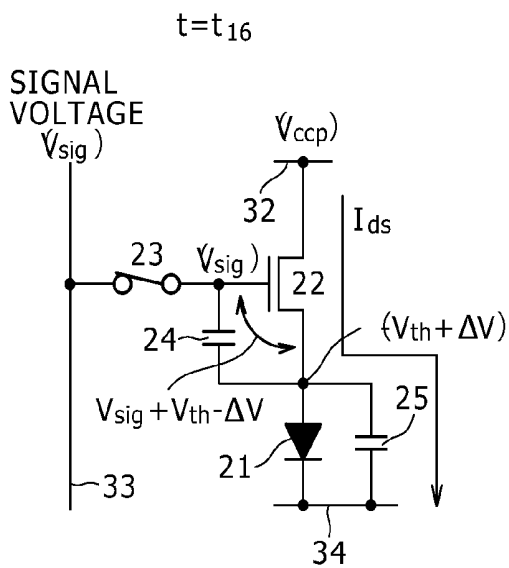


FIG. 5D

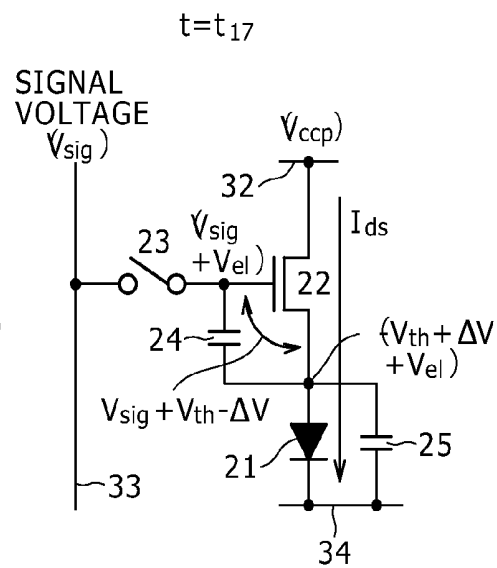


FIG. 6A

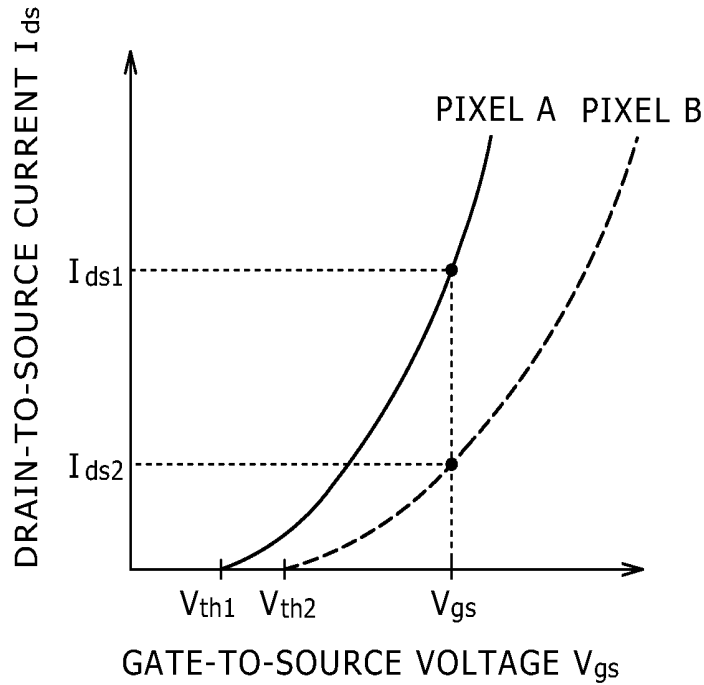


FIG. 6B

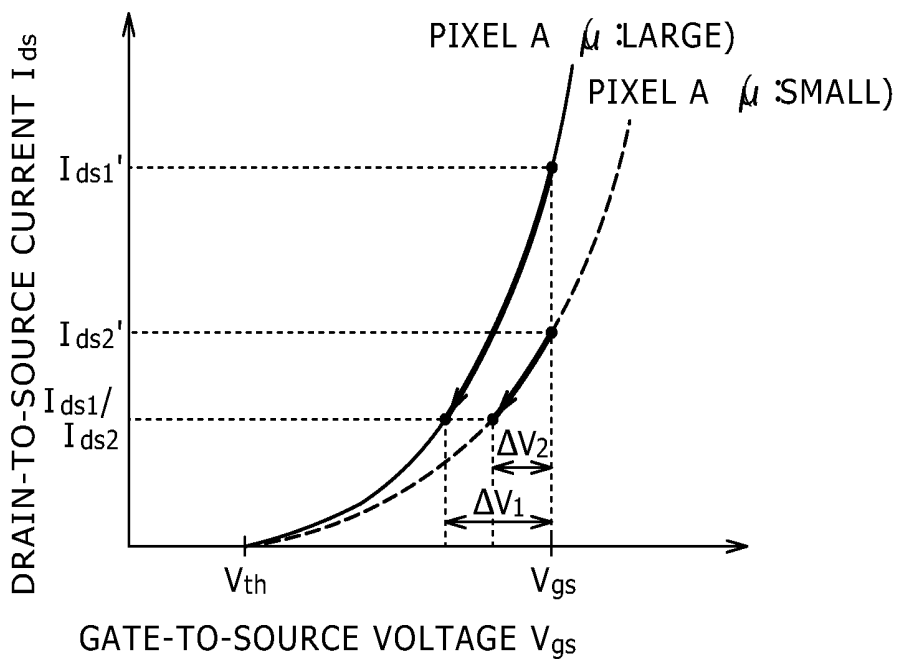


FIG. 7

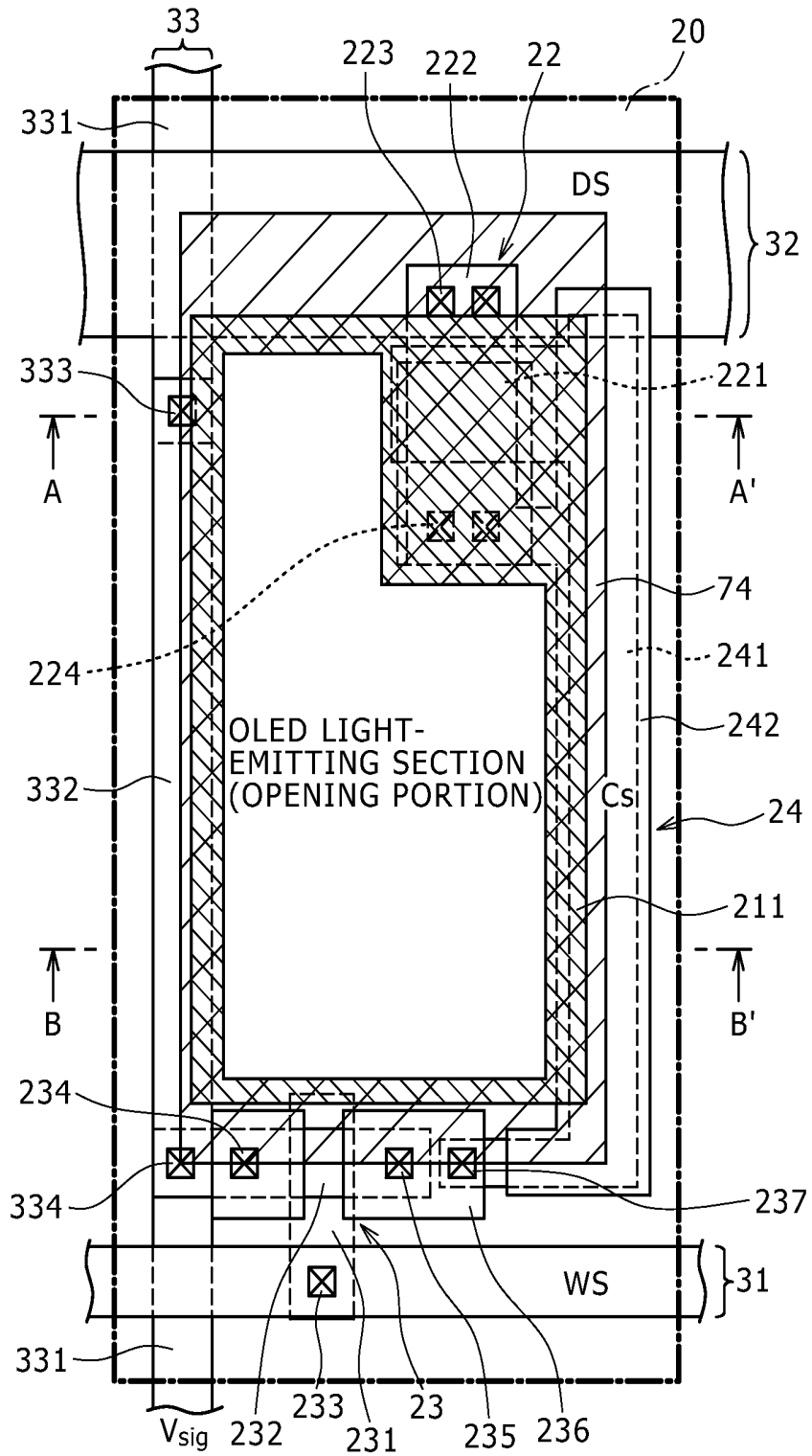


FIG. 8

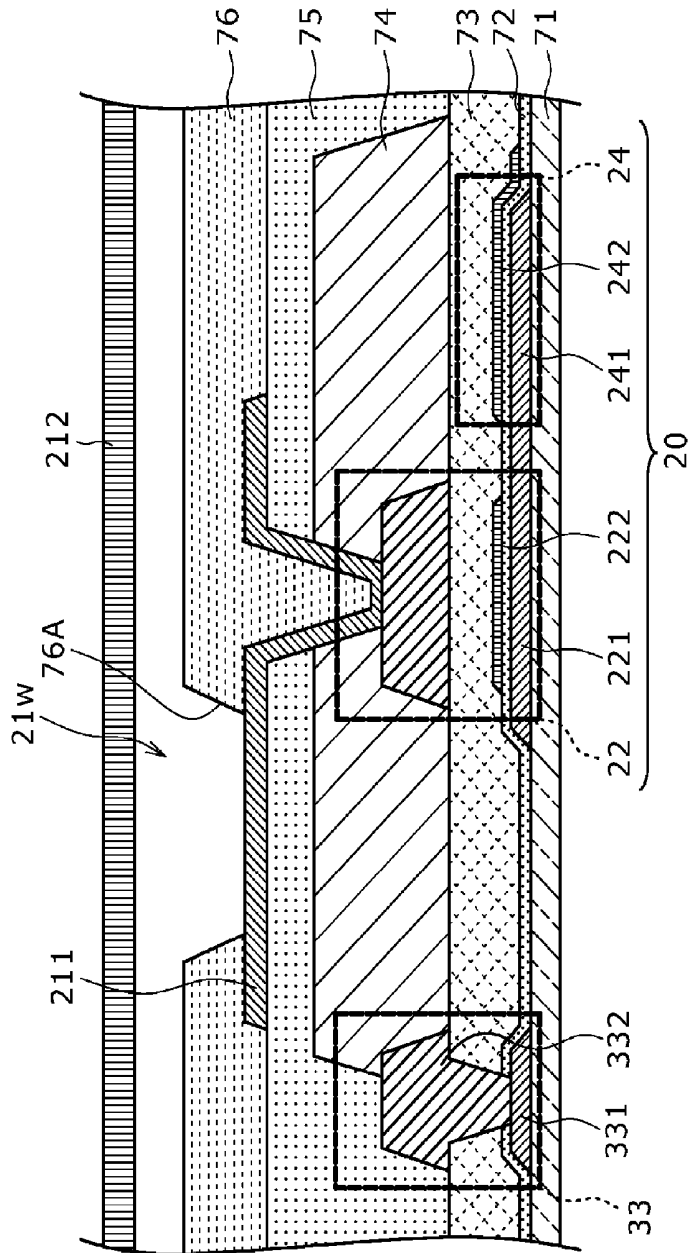


FIG. 9

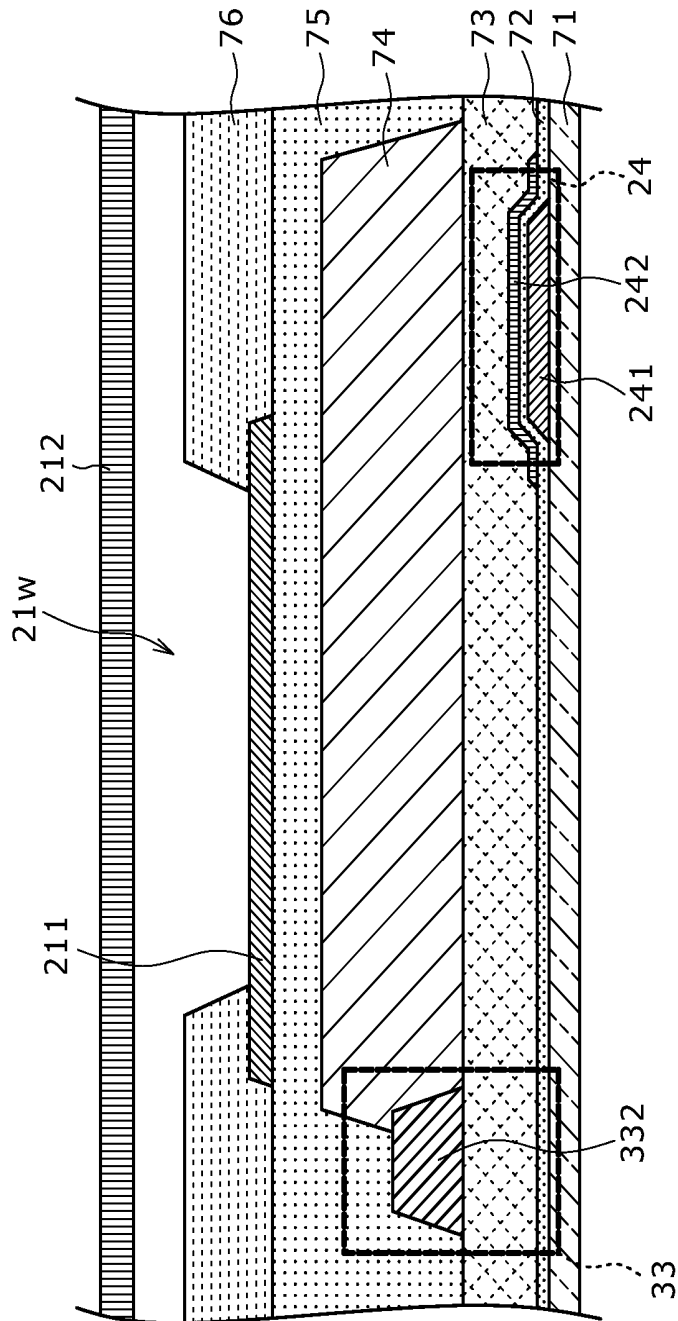


FIG. 10

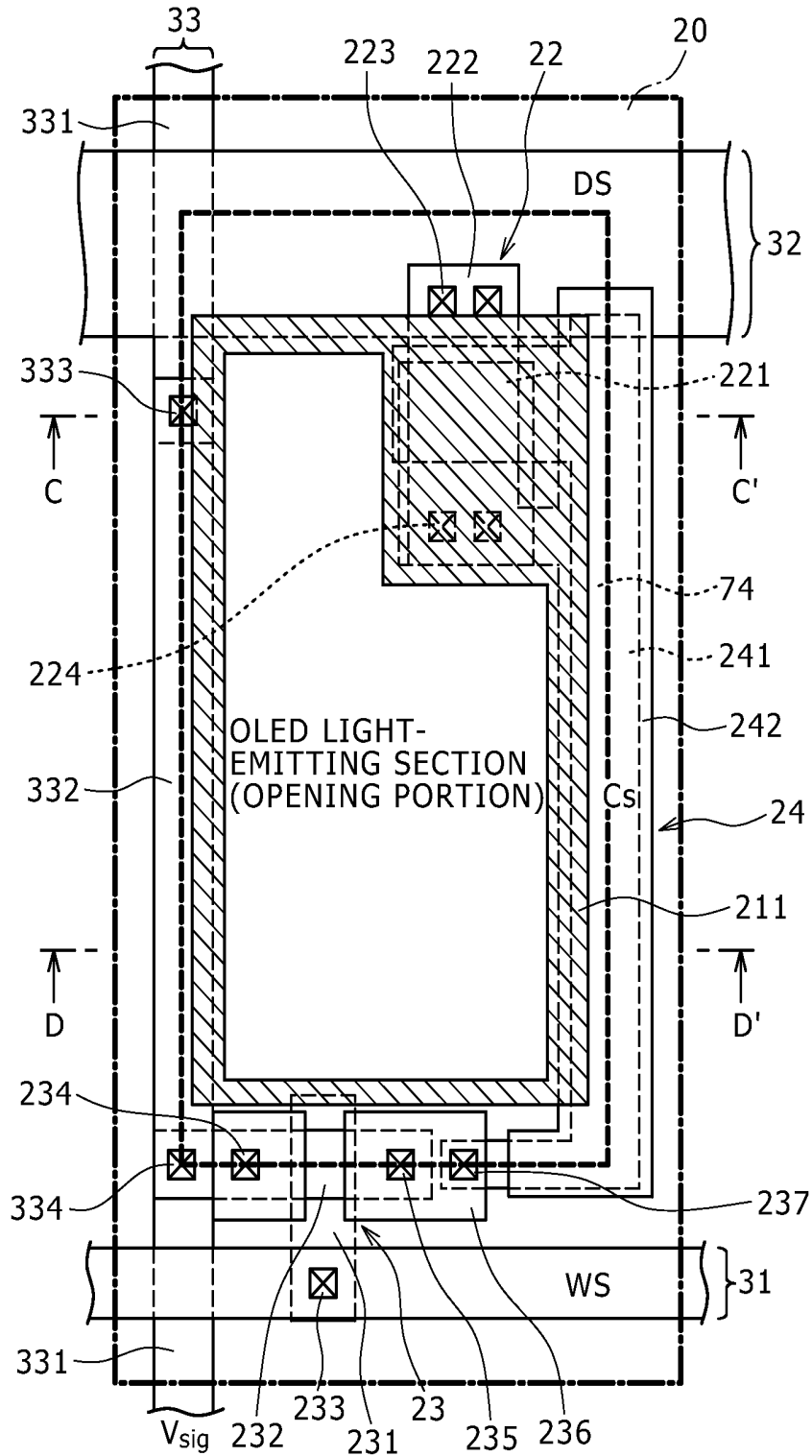




FIG. 12

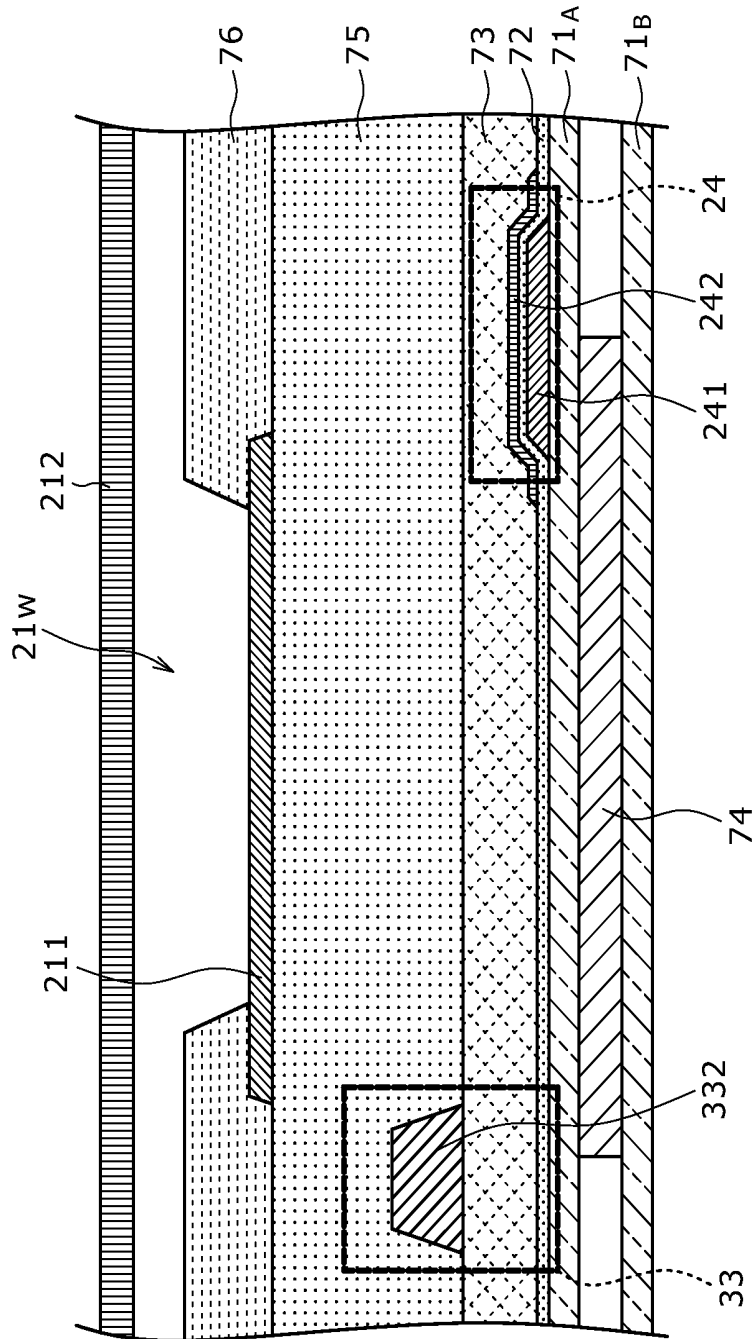


FIG. 13

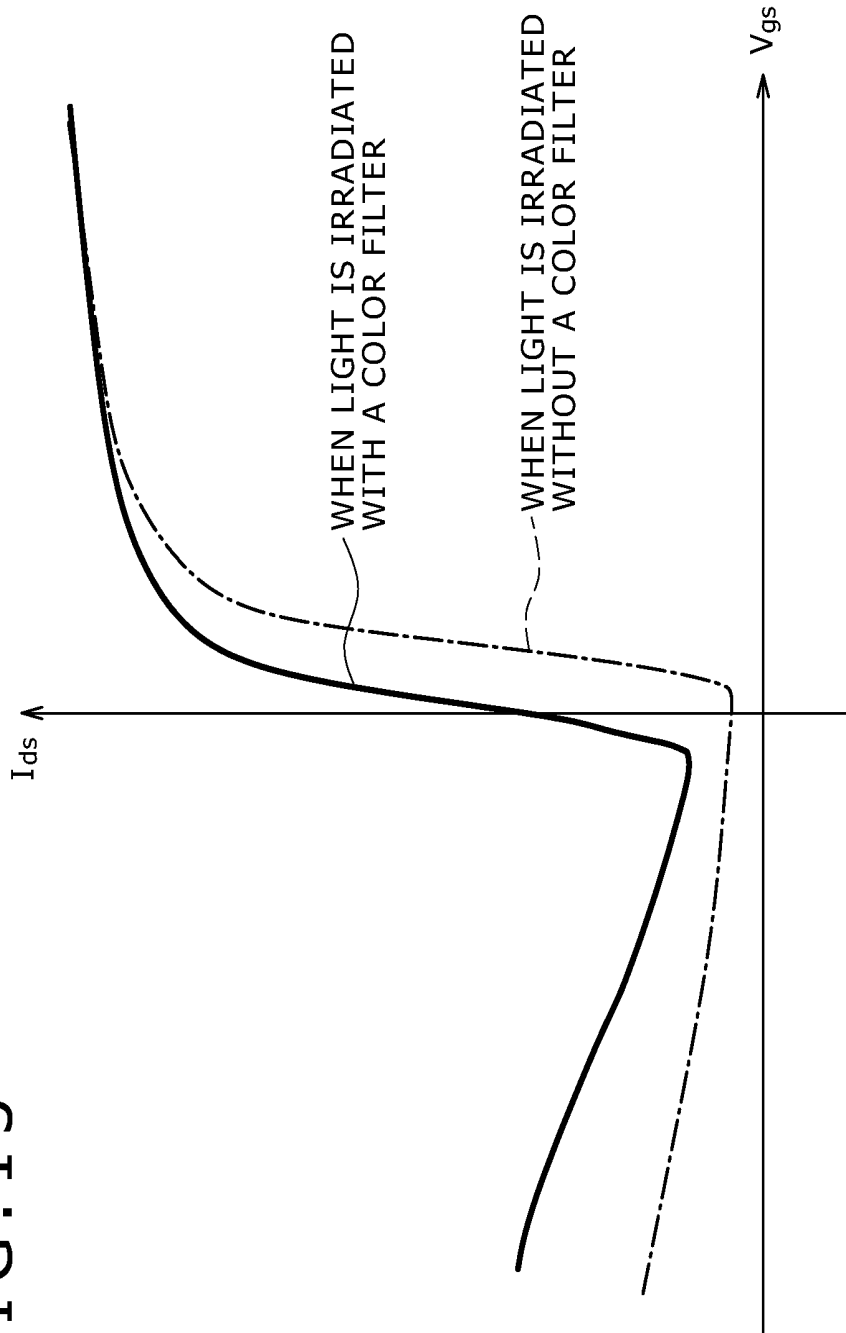


FIG. 14

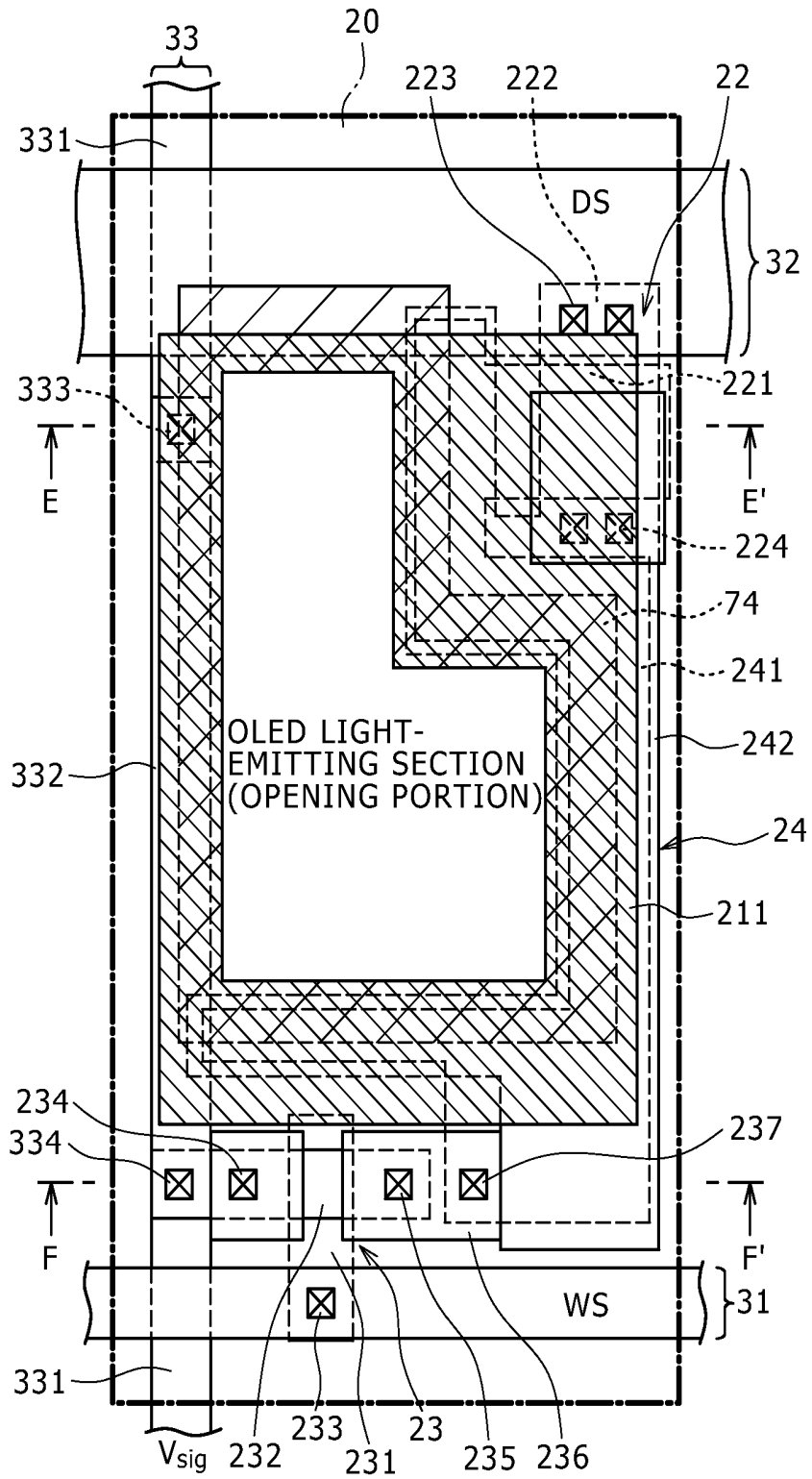


FIG. 15

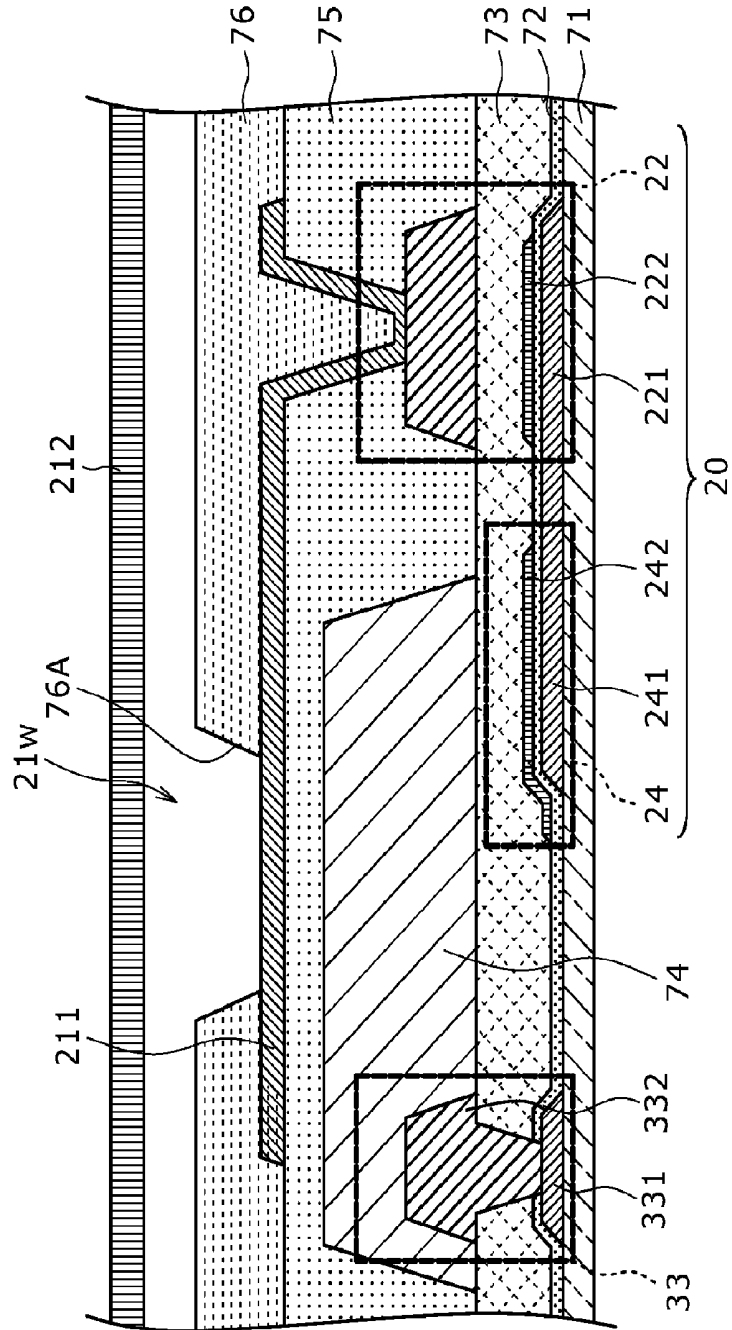


FIG. 16

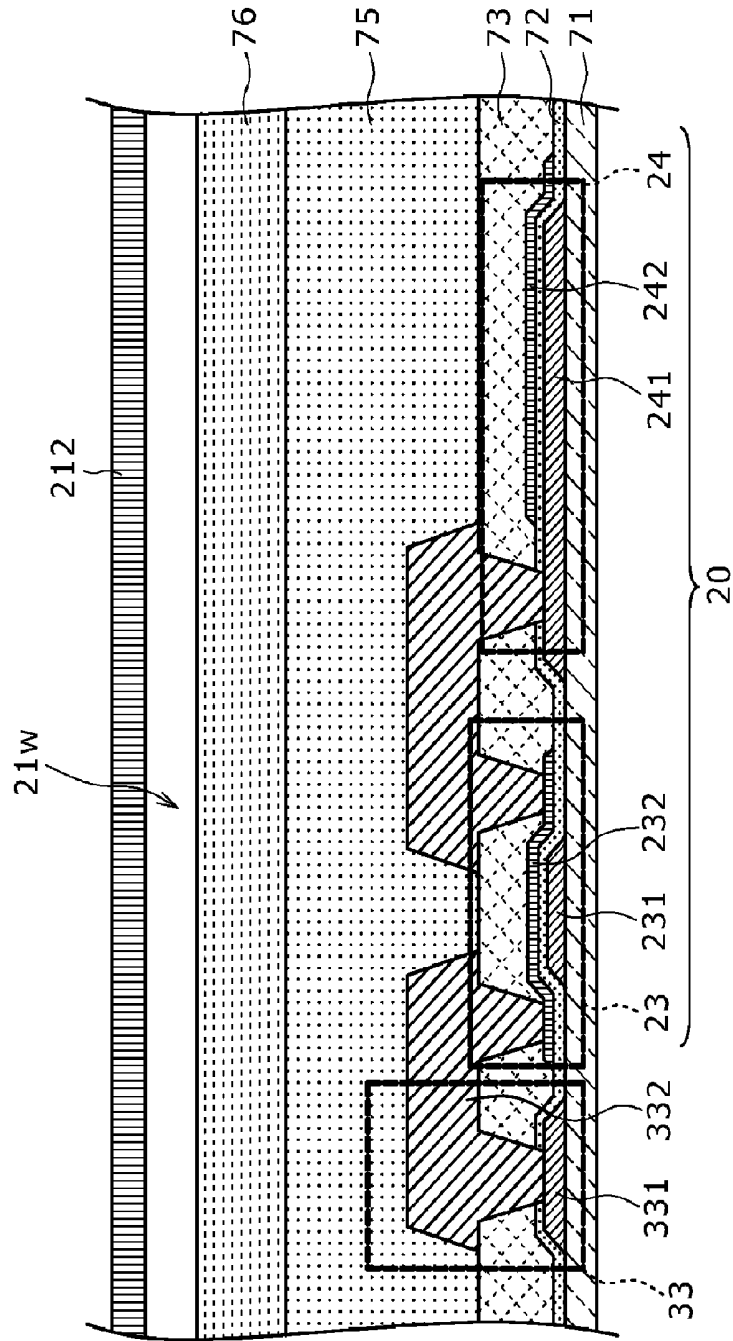


FIG. 17

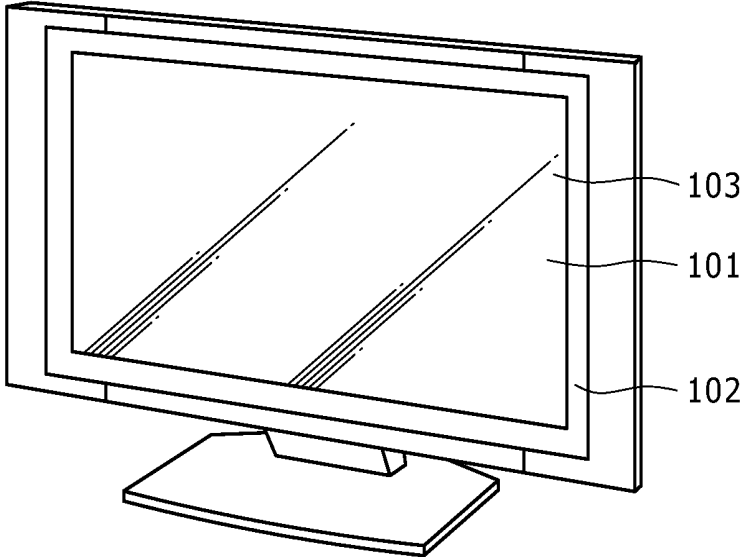


FIG. 18A

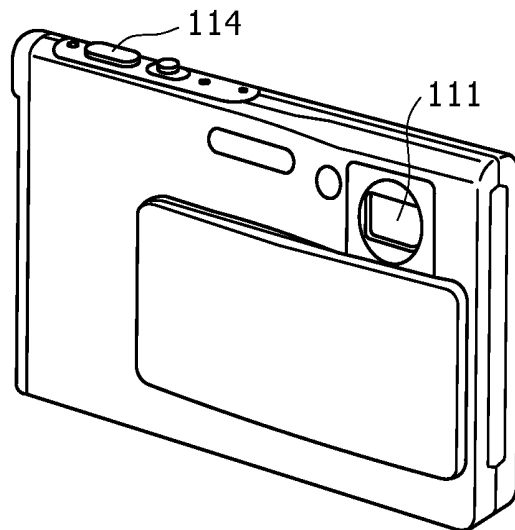


FIG. 18B

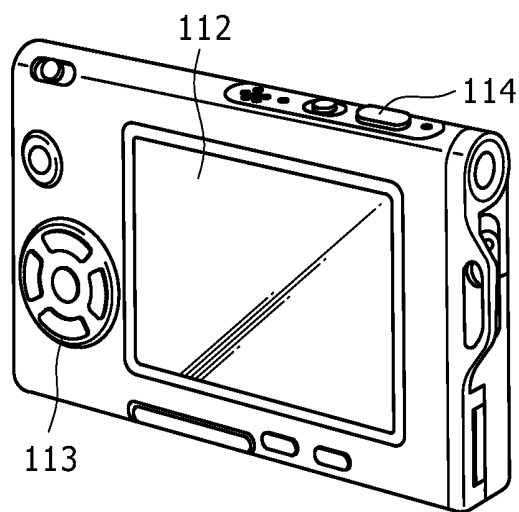


FIG. 19

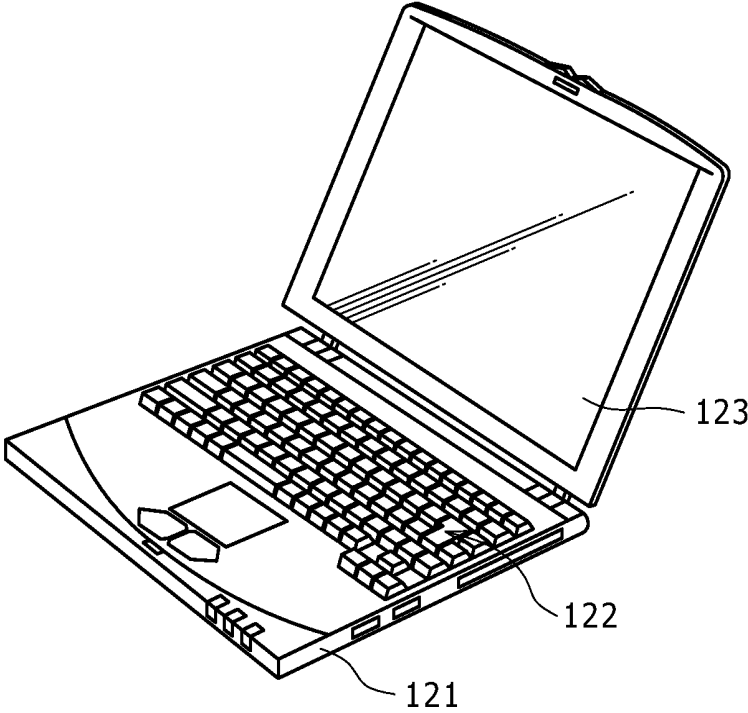


FIG. 20

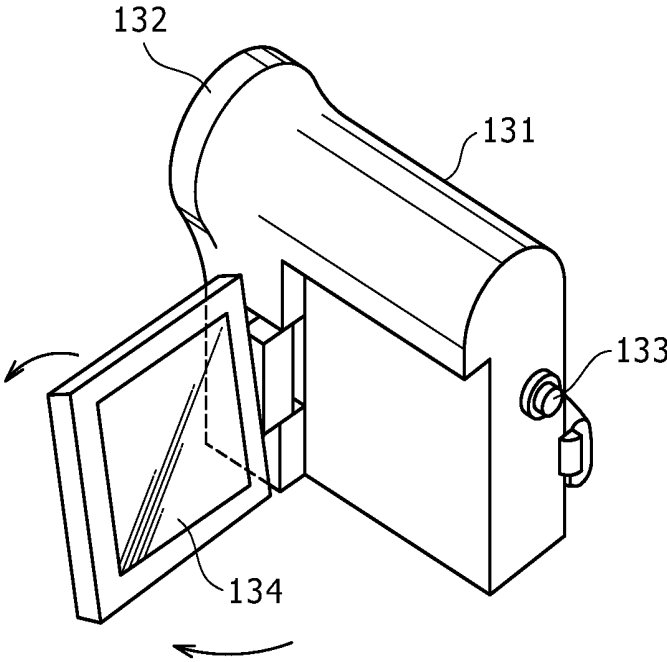


FIG. 21A FIG. 21B

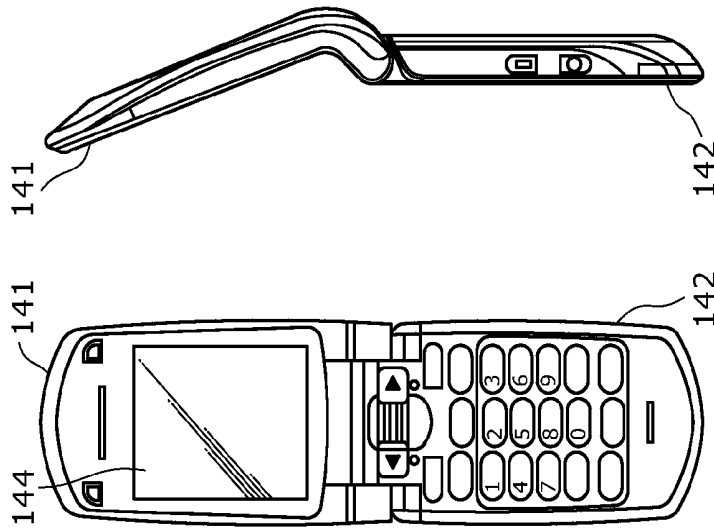


FIG. 21F

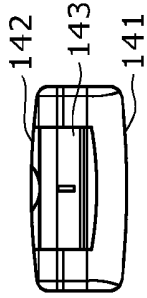


FIG. 21D

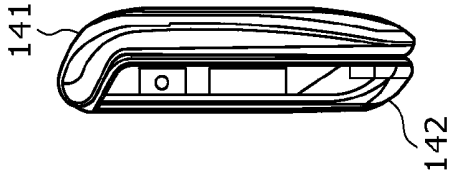


FIG. 21C

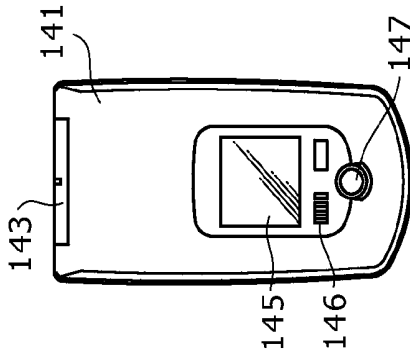


FIG. 21G

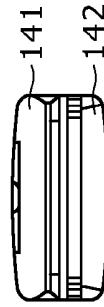


FIG. 21E

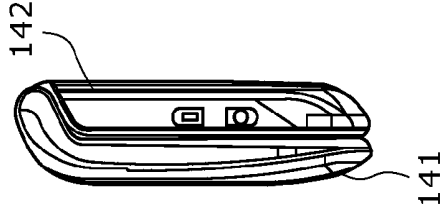


FIG. 22

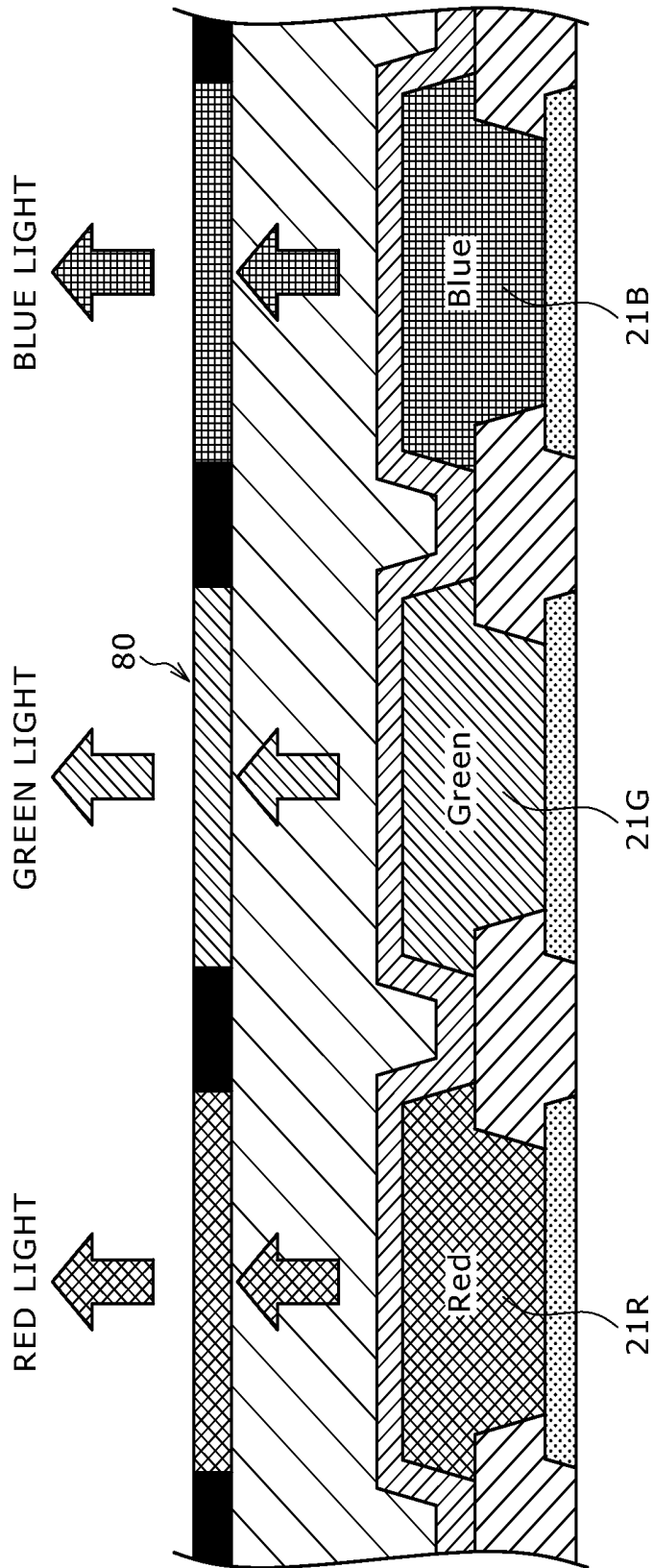


FIG. 23

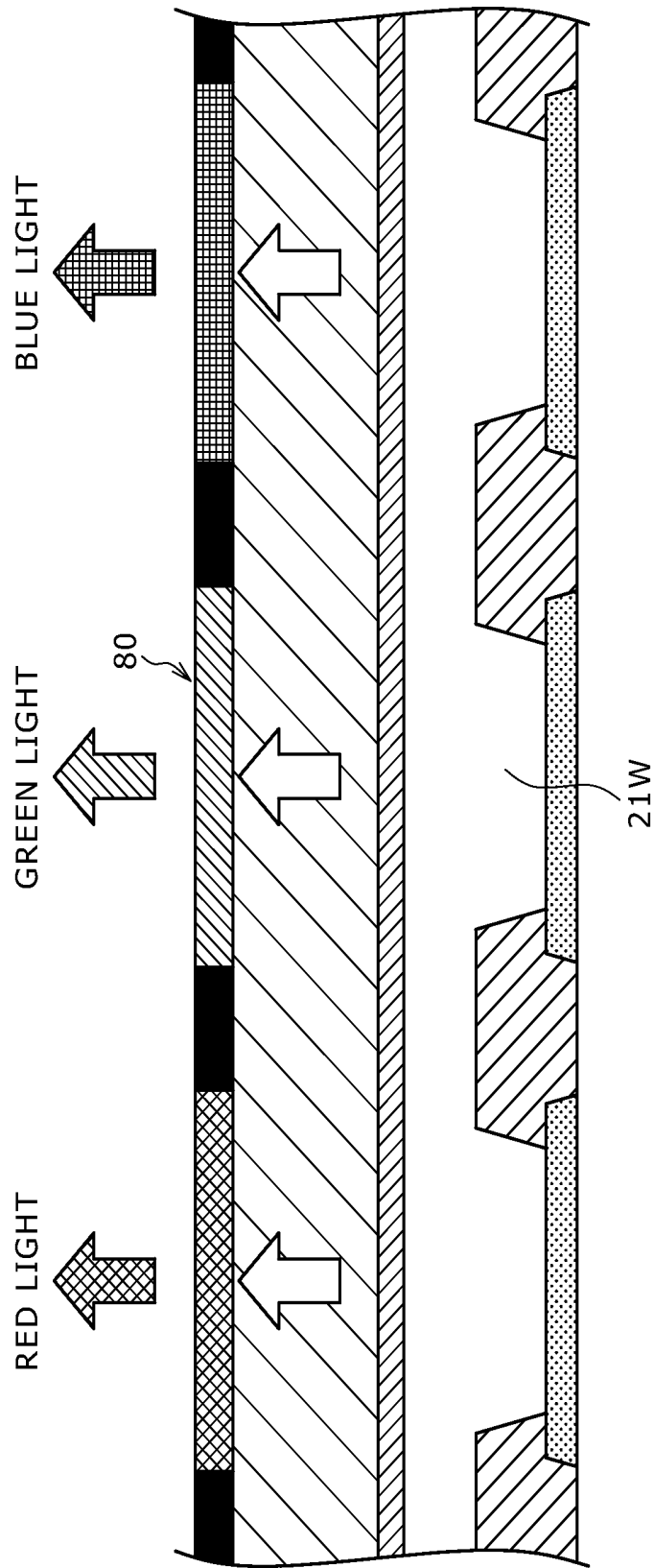


FIG. 24

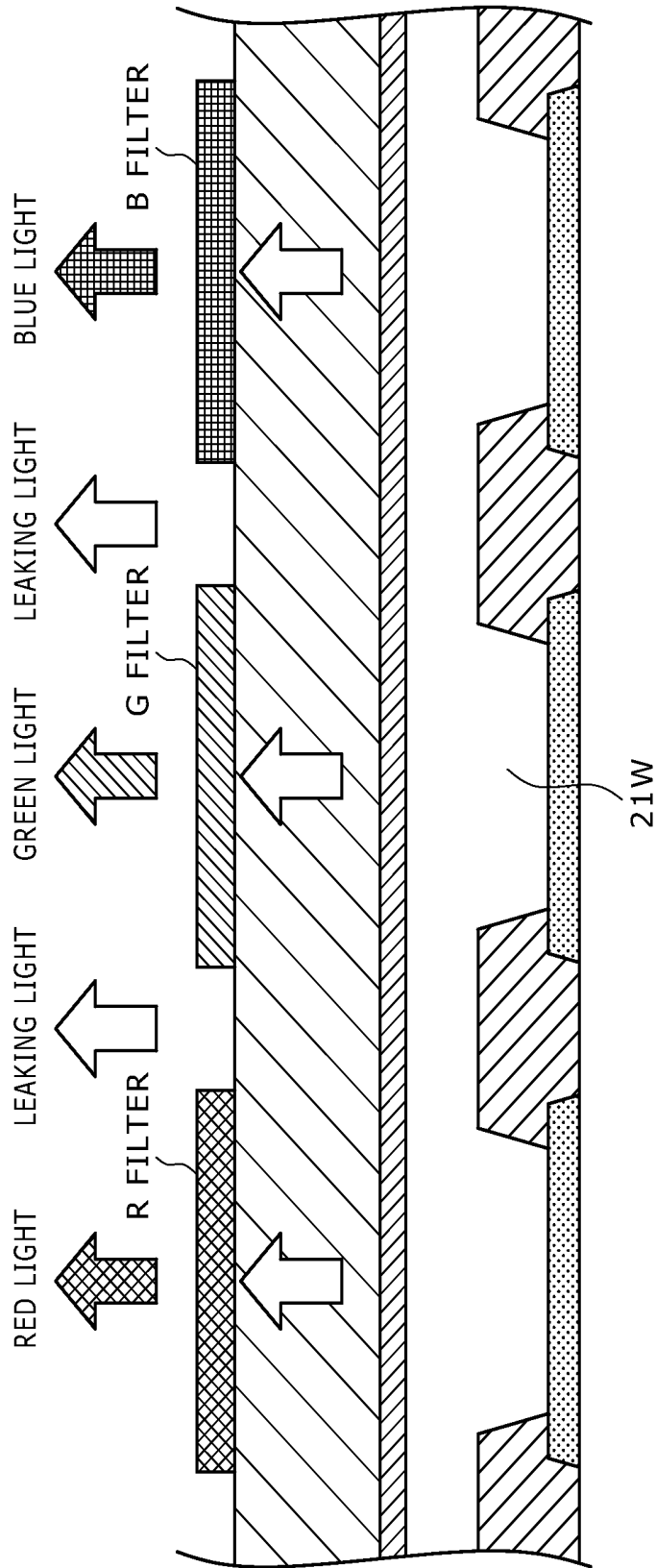
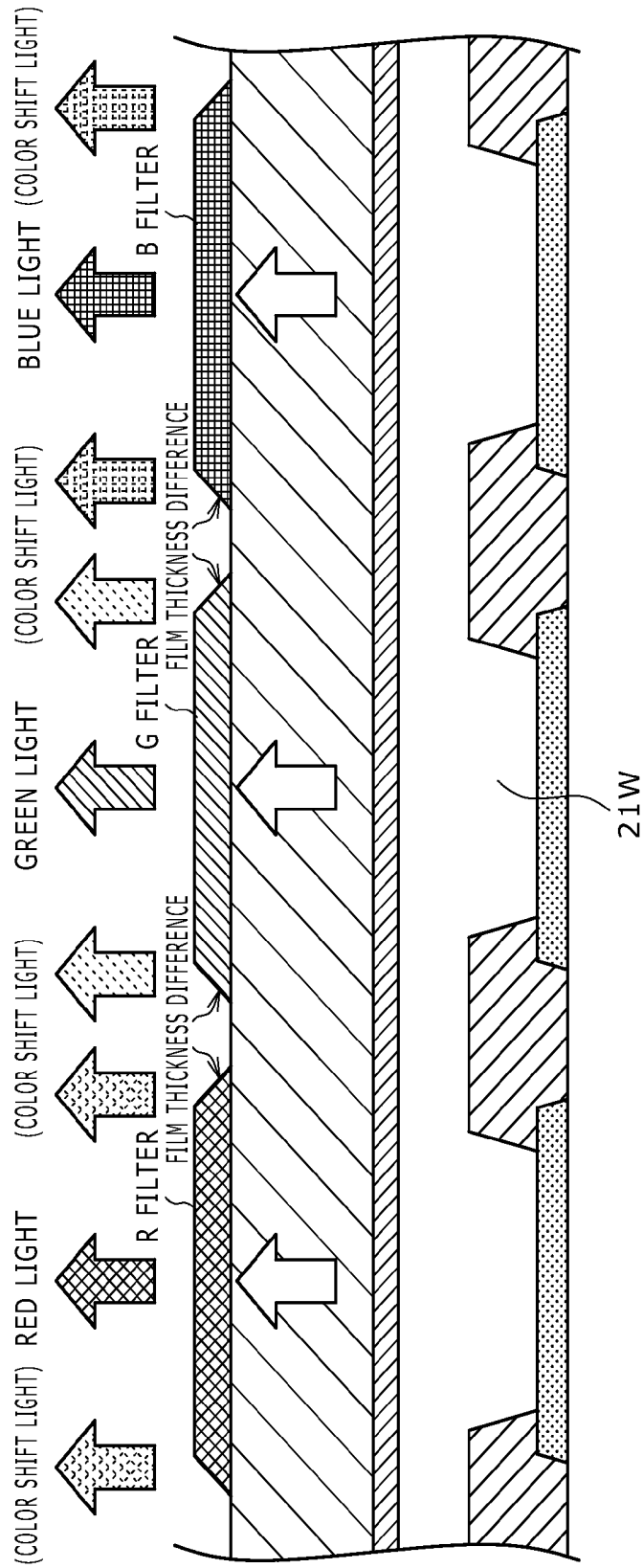


FIG. 25



## ORGANIC ELECTROLUMINESCENCE DISPLAY AND ELECTRONIC EQUIPMENT

### BACKGROUND

The present disclosure relates to an organic EL display and electronic equipment.

Among flat panel displays, some use a so-called current-driven electro-optical element, whose emission brightness changes according to the current flowing through the device, as a light-emitting section (light-emitting element) of each of the pixels. Organic EL elements that are based on electroluminescence (EL) of an organic material and emit light when an electric field is applied to the organic thin film are known as current-driven electro-optical elements.

An organic EL display using an organic EL element as a light-emitting section of each of the pixels offers the following features. That is, the organic EL element can be driven by application of a voltage of 10V or less, making the organic EL display low in power consumption. The organic EL element is self-luminous, thus allowing for the organic EL display to provide higher image visibility than liquid crystal displays. Moreover, it is not necessary for the organic EL display to have any lighting members such as backlight, thus making the weight and thickness reduction easy. Further, the organic EL element has an extremely high response speed of the order of several microseconds, thus making the organic EL display free from afterimage during display of a moving image.

Incidentally, organic EL displays based on a so-called side-by-side patterning of RGB subpixels using a mask are generally known. In this process, R(red), G(green) and B(blue) organic EL materials are patterned by vapor deposition using a mask. In an organic EL display based on this scheme, RGB organic EL elements **21R**, **21G** and **21B** and a color filter **80** are used in combination as illustrated in FIG. **22**. Using the color filter **80** in combination provides higher color purity. In order to achieve a high definition organic EL display with the side-by-side patterning of RGB subpixels using a mask, however, the patterning of pixels of different colors is extremely difficult.

In contrast, some organic EL displays are not based on side-by-side patterning of RGB subpixels using a mask. Instead, these displays extract RGB light by using an organic EL element adapted to emit white light (hereinafter referred to as the "white organic EL element") **21W** and the color filter **80** in combination as illustrated in FIG. **23** (refer, for example, to Japanese Patent Laid-open No. 2003-123971). This scheme using the white organic EL element **21W** in combination with the color filter **80** is advantageous in increasing the size of the organic EL display and achieving higher definition.

### SUMMARY

However, when the white organic EL element **21W** and color filter **80** are used in combination, it is necessary to provide a light-shielding layer between every two RGB filters so as to extract each of RGB light beams using the color filter **80** from the white light emitted from the white organic EL element **21W**. If no light-shielding layers are provided, white light leaks between every two RGB filters as shown in FIG. **24**, thus resulting in poorer color reproducibility caused by light leak.

On the other hand, when a color filter is formed, a taper level difference is formed on the periphery of the color filter, thus making the periphery thinner than the center. That is, there is a difference in thickness in the periphery of the color

filter. Then, this difference in thickness leads to color shift, thus making it difficult to provide a desired emission color. Because of these reasons, it is necessary to provide a light-shielding layer between every two RGB filters if the white organic EL element **21W** and color filter **80** are used in combination. As a result, a step of forming light-shielding layers is necessary, thus resulting in more process steps.

In light of the foregoing, it is desirable to provide an organic EL display and electronic equipment having the same that can keep white light leak to a minimum without increasing the number of process steps in using white organic EL elements and color filter in combination.

According to an embodiment of the present disclosure, there is provided an organic EL display having a bottom emission structure in which a white organic EL element adapted to emit white light is formed, pixel by pixel, on a substrate, and in which light emitted by the white organic EL element is extracted from a rear side of the substrate. The white organic EL element is used in combination with a color filter to extract light of different colors. Metal interconnects are formed, pixel by pixel, in such a manner as to surround a light-emitting section of the white organic EL element and the color filter.

According to another embodiment of the present disclosure, there is provided electronic equipment having an organic electroluminescence display. The organic electroluminescence display has a bottom emission structure in which a white organic electroluminescence element adapted to emit white light is formed, pixel by pixel, on a substrate, and in which light emitted by the white organic electroluminescence element is extracted from a rear side of the substrate. The organic electroluminescence display includes a color filter used in combination with the white organic electroluminescence element to extract light of different colors, and metal interconnects formed, pixel by pixel, in such a manner as to surround a light-emitting section of the white organic electroluminescence element and the color filter.

In the organic EL display configured as described above, it is possible to prevent white light leak between every two filters without forming a light-shielding layer between every two color filters by surrounding the light-emitting section of the white organic EL element and the color filter with metal interconnects. This keeps the aggravation of color reproducibility caused by white light leaks and color shift to a minimum.

The present disclosure prevents white light leak without forming light-shielding layers when a white organic EL element and a color filter are used in combination. This provides an organic EL display free from aggravation of color reproducibility or color shift without increasing the number of process steps.

### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a system configuration diagram illustrating the outlined configuration of an active matrix organic EL display to which the present disclosure is applied;

FIG. **2** is a circuit diagram illustrating a specific example of a circuit configuration of a pixel (pixel circuit);

FIG. **3** is a timing waveform diagram used to describe the basic circuit operation of the organic EL display to which the present disclosure is applied;

FIGS. **4A** to **4D** are explanatory diagrams (1) of the basic circuit operation of the organic EL display to which the present disclosure is applied;

FIGS. 5A to 5D are explanatory diagrams (2) of the basic circuit operation of the organic EL display to which the present disclosure is applied;

FIG. 6A is a characteristic diagram for describing a problem caused by the variation in a threshold voltage of a drive transistor, and FIG. 6B is a characteristic diagram for describing a problem caused by the variation in mobility of the drive transistor;

FIG. 7 is a schematic plan view illustrating the pixel structure of the organic EL display according to a first embodiment of the present disclosure;

FIG. 8 is a sectional view taken along line of sight A-A' indicated by the arrows in FIG. 7;

FIG. 9 is a sectional view taken along line of sight B-B' indicated by the arrows in FIG. 7;

FIG. 10 is a schematic plan view illustrating the pixel structure of the organic EL display having a color filter attached to substrates;

FIG. 11 is a sectional view taken along line of sight C-C' indicated by the arrows in FIG. 10;

FIG. 12 is a sectional view taken along line of sight D-D' indicated by the arrows in FIG. 10;

FIG. 13 is a characteristic diagram of a gate-to-source voltage vs a drain-to-source current of an N-channel transistor when light is irradiated to the transistor with and without the color filter;

FIG. 14 is a schematic plan view illustrating the pixel structure of the organic EL display according to a second embodiment of the present disclosure;

FIG. 15 is a sectional view taken along line of sight E-E' indicated by the arrows in FIG. 14;

FIG. 16 is a sectional view taken along line of sight F-F' indicated by the arrows in FIG. 14;

FIG. 17 is a perspective view illustrating the appearance of a television set to which the present disclosure is applied;

FIGS. 18A and 18B are perspective views illustrating the appearance of a digital camera to which the present disclosure is applied, and FIG. 18A is a perspective view as seen from the front, and FIG. 18B is a perspective view as seen from the back;

FIG. 19 is a perspective view illustrating the appearance of a laptop personal computer to which the present disclosure is applied;

FIG. 20 is a perspective view illustrating the appearance of a video camcorder to which the present disclosure is applied;

FIGS. 21A to 21G are appearance views illustrating a mobile phone to which the present disclosure is applied, and FIG. 21A is a front view in an open position, FIG. 21B is a side view thereof, FIG. 21C is a front view in a closed position, FIG. 21D is a left side view, FIG. 21E is a right side view, FIG. 21F is a top view, and FIG. 21G is a bottom view;

FIG. 22 is a sectional view illustrating the pixel structure when side-by-side patterning of RGB subpixels is used;

FIG. 23 is a sectional view illustrating the pixel structure when a white organic EL element and color filter are used in combination;

FIG. 24 is an explanatory diagram of white light leak caused by the absence of a light-shielding layer; and

FIG. 25 is an explanatory diagram of color shift caused by the difference in thickness at the edge of the color filter.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A detailed description will be given below of the modes for carrying out the techniques of the present disclosure (hereinafter written as the "embodiments") with reference to the

accompanying drawings. It should be noted that the description will be given in the following order.

1. Organic EL display to which the present disclosure is applied

1-1. System configuration

1-2. Basic circuit operation

2. First embodiment

3. Second embodiment

4. Application examples (electronic equipment)

#### 1. Organic EL Display to Which the Present Disclosure is Applied

[1-1. System Configuration]

FIG. 1 is a system configuration diagram illustrating the outlined configuration of an active matrix organic EL display to which the present disclosure is applied.

An active matrix organic EL display controls the current flowing through an organic EL element, i.e., a current-driven electro-optical element, using active elements such as insulating gate field-effect transistors provided in the same pixel as the organic EL element. TFTs (thin film transistors) are typically used as insulating gate field-effect transistors.

As illustrated in FIG. 1, an organic EL display 10 according to the present application example includes a plurality of pixels 20, each having an organic EL element, a pixel array section 30 and a drive circuit section provided around the pixel array section 30. The pixel array section 30 includes the pixels 20 arranged two-dimensionally in a matrix form. The drive circuit section includes a write scan circuit 40, power supply scan circuit 50, signal output circuit 60 and other sections and drives the pixels 20 of the pixel array section 30.

Here, if the organic EL display 10 is capable of color display, each pixel (unit pixel) making up the unit of color image formation includes a plurality of subpixels. Each of these subpixels corresponds to one of the pixels 20 shown in FIG. 1. More specifically, each of the pixels in a display capable of color display includes, for example, a subpixel adapted to emit red (R) light, another adapted to emit green (G) light and still another adapted to emit blue (B) light.

It should be noted, however, that the subpixels making up each of the pixels are not limited to a combination of subpixels of RGB or three primary colors. Instead, each of the pixels may include one or a plurality of subpixels of colors in addition to the subpixels of three primary colors. More specifically, each of the pixels may additionally include, for example, a subpixel adapted to emit white (W) light for improving luminance. Alternatively, each of the pixels may additionally include a subpixel adapted to emit light of a complementary color for a wider range of color reproduction.

The pixel array section 30 has scan lines 31<sub>1</sub> to 31<sub>m</sub> and power supply lines 32<sub>1</sub> to 32<sub>m</sub> disposed in the row direction (direction along the pixel rows) of the pixels 20 arranged in m rows by n columns. The scan lines 31<sub>1</sub> to 31<sub>m</sub> and power supply lines 32<sub>1</sub> to 32<sub>m</sub> are each disposed for one of the pixel rows. Further, the pixel array section 30 has signal lines 33<sub>1</sub> to 33<sub>n</sub> disposed in the column direction (direction along the pixel columns) of the pixels 20 arranged in m rows by n columns. The signal lines 33<sub>1</sub> to 33<sub>n</sub> are each disposed for one of the pixel columns.

The scan lines 31<sub>1</sub> to 31<sub>m</sub> are each connected to the output end of the associated row of the write scan circuit 40. The power supply lines 32<sub>1</sub> to 32<sub>m</sub> are each connected to the output end of the associated row of the power supply scan circuit 50. The signal lines 33<sub>1</sub> to 33<sub>n</sub> are each connected to the output end of the associated column of the signal output circuit 60.

The pixel array section **30** is normally formed on a transparent insulating substrate made, for example, of a glass substrate. As a result, the organic EL display **10** has a flat panel structure. The drive circuit of each of the pixels **20** of the pixel array section **30** can be formed by using amorphous silicon TFTs or low-temperature polysilicon TFTs. When low-temperature polysilicon TFTs are used, the write scan circuit **40**, power supply scan circuit **50** and signal output circuit **60** can be formed on a display panel (substrate) **70** on which the pixel array section **30** is formed as illustrated in FIG. 1.

The write scan circuit **40** includes, for example, a shift register circuit adapted to sequentially shift (transfer) a start pulse *sp* in synchronism with a clock pulse *ck*. When writing a video signal voltage to the pixels **20** of the pixel array section **30**, the same circuit **40** sequentially supplies write scan signals *WS* ( $WS_1$  to  $WS_m$ ) respectively to the scan lines  $31_1$  to  $31_m$ , thus scanning (progressively scanning) the pixels **20** of the pixel array section **30** in sequence on a row-by-row basis.

The power supply scan circuit **50** includes, for example, a shift register circuit adapted to sequentially shift the start pulse *sp* in synchronism with the clock pulse *ck*. The same circuit **50** supplies power supply potentials *DS* ( $DS_1$  to  $DS_m$ ) to the power supply lines  $32_1$  to  $32_m$  in synchronism with the progressive scan performed by the write scan circuit **40**. Each of the power supply potentials *DS* can be switched between two power supply potentials, i.e., a first power supply potential  $V_{ccp}$  and a second power supply potential  $V_{imi}$  lower than the first power supply potential  $V_{ccp}$ . As will be described later, the pixels **20** are controlled to emit light or stop emission by switching the power supply potentials *DS* between  $V_{ccp}$  and  $V_{imi}$ .

The signal output circuit **60** selectively outputs a video signal voltage (hereinafter may be simply written as the "signal voltage")  $V_{sig}$  commensurate with brightness information supplied from the signal source (not shown) or a reference voltage  $V_{ofs}$ . Here, the reference voltage  $V_{ofs}$  is a potential that serves as a reference (e.g., potential corresponding to the black level of the video signal) for the video signal voltage  $V_{sig}$  and is used during threshold correction which will be described later.

The signal voltage  $V_{sig}$  or reference voltage  $V_{ofs}$  output from the signal output circuit **60** is written via the signal lines  $33_1$  to  $33_m$ , on a pixel-row-by-pixel-row basis, to the pixels **20** of the pixel array section **30** in the pixel row selected as a result of scanning performed by the write scan circuit **40**. That is, the signal output circuit **60** progressively writes the signal voltage  $V_{sig}$  on a row-by-row (line-by-line) basis for driving purposes.

(Pixel Circuit)

FIG. 2 is a circuit diagram illustrating a specific example of a circuit configuration of the pixel (pixel circuit) **20**. The light-emitting section of the pixel **20** includes an organic EL element **21**, i.e., a current-driven electro-optical element whose emission brightness changes according to the current flowing through the device.

As illustrated in FIG. 2, the pixel **20** includes the organic EL element **21** and a drive circuit adapted to drive the organic EL element **21** by passing a current through the same element **21**. The organic EL element **21** has its cathode electrode connected to a common power supply line **34** (so-called solid interconnect) that is disposed to be shared by all the pixels **20**.

The drive circuit adapted to drive the organic EL element **21** includes a drive transistor **22**, write transistor **23**, holding capacitor **24** and auxiliary capacitor **25**. N-channel TFTs can be used as the drive transistor **22** and write transistor **23**. It

should be noted, however, that the combination of conductivity types of the drive transistor **22** and write transistor **23** shown here is merely an example and is not limited thereto.

The drive transistor **22** has one of its electrodes (source or drain electrode) connected to the anode electrode of the organic EL element **21** and the other electrode connected (drain or source electrode) connected to one of the power supply lines **32** ( $32_1$  to  $32_m$ ).

The write transistor **23** has one of its electrodes (source or drain electrode) connected to one of the signal lines **33** ( $33_1$  to  $33_m$ ) and the other electrode to the gate electrode of the drive transistor **22**. Further, the write transistor **23** has its gate electrode connected to one of the scan lines **31** ( $31_1$  to  $31_m$ ).

For the drive transistor **22** and write transistor **23**, the term "one of its electrodes" refers to a metal interconnect electrically connected to the source or drain region, and the term "the other electrode" refers to a metal interconnect electrically connected to the drain or source region. On the other hand, one of its electrodes may serve as a source or drain electrode, and the other electrode as a drain or source electrode, depending on the relationship in potential between one of its electrodes and the other electrode.

The holding capacitor **24** has one of its electrodes connected to the gate electrode of the drive transistor **22**, and the other electrode connected to the other electrode of the drive transistor **22** and the anode electrode of the organic EL element **21**.

The auxiliary capacitor **25** has one of its electrodes connected to the anode electrode of the organic EL element **21**, and the other electrode to the common power supply line **34**. The auxiliary capacitor **25** is provided as necessary to complement the lack of capacitance of the organic EL element **21** and provide higher gain for writing a video signal to the holding capacitor **24**. That is, the auxiliary capacitor **25** may not be necessary and may be omitted if the equivalent capacitance of the organic EL element **21** is sufficiently large.

Here, the other electrode of the auxiliary capacitor **25** is connected to the common power supply line **34**. However, the node to which the other electrode thereof is connected is not limited to the common power supply line **34**, and may be connected to any node so long as this node has a fixed potential. By connecting the other electrode of the auxiliary capacitor **25** to a fixed node potential, it is possible to serve the intended purposes, namely, to complement the lack of capacitance of the organic EL element **21** and provide higher gain for writing a video signal to the holding capacitor **24**.

In the pixel **20** configured as described above, the write transistor **23** goes into conduction in response to an active high write scan signal *WS* applied from the write scan circuit **40** to the gate electrode of the write transistor **23** via the scan line **31**. As a result, the write transistor **23** samples the video signal voltage  $V_{sig}$  commensurate with brightness information or the reference voltage  $V_{ofs}$  supplied from the signal output circuit **60** via the signal line **33**, writing the sampled voltage to the pixel **20**. The written video signal voltage  $V_{sig}$  or reference voltage  $V_{ofs}$  is applied to the gate electrode of the drive transistor **22** and held by the holding capacitor **24**.

The drive transistor **22** operates in a saturation region with one of its electrode serving as a drain electrode and the other electrode as a source electrode when the power supply potential *DS* of the power supply line **32** (one of  $32_1$  to  $32_m$ ) is at the first power supply potential  $V_{ccp}$ . As a result, the drive transistor **22** is supplied with a current from the power supply line **32**, thus current-driving the organic EL element **21** to emit light. More specifically, when the drive transistor **22** operates in the saturation region, a drive current commensurate with the level of the signal voltage  $V_{sig}$  held by the holding capaci-

tor **24** is supplied to the organic EL element **21**, thus current-driving the same element **21** to emit light.

Further, when the power supply potential DS changes from the first power supply potential  $V_{ccp}$  to the second power supply potential  $V_{imi}$ , the drive transistor **22** acts as a switching transistor with one of its electrode serving as a source electrode and the other as a drain electrode. As a result, the drive transistor **22** stops supplying a drive current to the organic EL element **21**, thus causing the same element **21** to stop emitting light. That is, the drive transistor **22** also has the functionality to control the organic EL element **21** to emit light or stop light emission.

Thanks to the switching operation of the drive transistor **22**, a period is provided during which the organic EL element **21** does not emit light (non-light emission period), thus making it possible to control the ratio (duty) between the light emission and non-light emission periods of the organic EL element **21**. This duty control contributes to reduced afterimage blur resulting from the pixel emitting light over a span of one display frame period, thus providing better moving image quality.

Of the first and second power supply potentials  $V_{ccp}$  and  $V_{imi}$  selectively supplied from the power supply scan circuit **50** via the power supply line **32**, the first power supply potential  $V_{ccp}$  is used to supply a drive current which drives the organic EL element **21** to emit light to the drive transistor **22**. In contrast, the second power supply potential  $V_{imi}$  is used to reverse-bias the organic EL element **21**. The second power supply potential  $V_{imi}$  is set to a potential lower than the reference voltage  $V_{ofs}$ , for example, lower than  $V_{ofs}-V_{th}$  where the threshold voltage of the drive transistor **22** is  $V_{th}$ , and preferably sufficiently lower than,  $V_{ofs}-V_{th}$  [1-2. Basic Circuit Operation]

A description will be given next of the basic circuit operation of the organic EL display **10** configured as described above based on the timing waveform diagram shown in FIG. **3** and with reference to the explanatory diagrams shown in FIGS. **4** and **5**. It should be noted that the write transistor **23** is represented by a switch symbol in the explanatory diagrams shown in FIGS. **4** and **5** for simplification. Further, the equivalent capacitor **25** of the organic EL element **21** is also shown.

The timing waveform diagram shown in FIG. **3** illustrates the changes in the potential (write scan signal) WS of the scan line **31**, the potential (power supply potential) DS of the power supply line **32**, the potential of the signal line **33** ( $V_{sig}/V_{ofs}$ ) and the gate potential  $V_g$  and source potential  $V_s$  of the drive transistor **22**.

(Light Emission Period of the Previous Display Frame)

In the timing waveform diagram shown in FIG. **3**, the period prior to time  $t_{11}$  is the light emission period of the organic EL element **21** in the previous display frame. During this light emission period in the previous display frame, the power supply potential DS of the power supply line **32** is at the first power supply potential (hereinafter referred to as the "high potential")  $V_{CCP}$ , and the write transistor **23** is not conducting.

At this time, the drive transistor **22** is designed to operate in the saturation region. As a result, a drive current (drain-to-source current)  $I_{ds}$  commensurate with a gate-to-source voltage  $V_{gs}$  of the drive transistor **22** is supplied from the power supply line **32** to the organic EL element **21** via the drive transistor **22** as illustrated in FIG. **4A**. This allows for the organic EL element **21** to emit light at the brightness commensurate with the level of the drive current  $I_{ds}$ . (Preparation Period for Threshold Correction)

At time  $t_{11}$ , a new display frame (current display frame) for progressive scan begins. Then, the potential DS of the power

supply line **32** changes from the high potential  $V_{ccp}$  to the second power supply potential  $V_{imi}$  (hereinafter referred to as the "lower potential") sufficiently lower than  $V_{ofs}-V_{th}$  where  $V_{ofs}$  is the reference potential of the signal line **33** as illustrated in FIG. **4B**.

Here, we let the threshold voltage of the organic EL element **21** be denoted by  $V_{thel}$  and the potential of the common power supply line **34** (cathode potential) by  $V_{cath}$ . At this time, assuming that the low potential  $V_{imi}$  has the following relationship with the above voltages:  $V_{imi} < V_{thel} + V_{cath}$ , the source potential  $V_s$  of the drive transistor **22** is almost equal to the low potential  $V_{imi}$ . As a result, the organic EL element **21** is reverse-biased, causing the same element **21** to stop emitting light.

Next, the potential WS of the scan line **31** changes from low to high potential at time  $t_{12}$ , thus bringing the write transistor **23** into conduction as illustrated in FIG. **4C**. At this time, the reference voltage  $V_{ofs}$  is supplied from the signal output circuit **60** to the signal line **33**. As a result, the gate potential  $V_g$  of the drive transistor **22** becomes equal to the reference voltage  $V_{ofs}$ . On the other hand, the source potential  $V_s$  of the drive transistor **22** is sufficiently lower than the reference voltage  $V_{ofs}$ , i.e., equal to the low potential  $V_{imi}$ .

At this time, the gate-to-source voltage  $V_{gs}$  of the drive transistor **22** is equal to  $V_{ofs}-V_{imi}$ . Here, the threshold correction described later cannot be performed unless  $V_{ofs}-V_{imi}$  is larger than the threshold voltage  $V_{th}$  of the drive transistor **22**. Therefore, it is necessary to ensure that the potential relationship  $V_{ofs}-V_{imi} > V_{th}$  holds.

As described above, the gate potential  $V_g$  of the drive transistor **22** is fixed at the reference voltage  $V_{ofs}$ , and then the source potential  $V_s$  is fixed at the low potential  $V_{imi}$  for initialization as a preparation (preparation for threshold correction) prior to the threshold correction process (threshold correction operation) which will be described later. Therefore, the reference voltage  $V_{ofs}$  and low potential  $V_{imi}$  serve respectively as the initial potentials of the gate potential  $V_g$  and source potential  $V_s$  of the drive transistor **22**.

(Threshold Correction Period)

Next, when the potential DS of the power supply line **32** changes from the low potential  $V_{imi}$  to the high potential  $V_{ccp}$  at  $t_{13}$  as illustrated in FIG. **4D**, the threshold correction process begins with the gate potential  $V_g$  of the drive transistor **22** maintained at the reference voltage  $V_{ofs}$ . That is, the source potential  $V_s$  of the drive transistor **22** begins to rise to the gate potential  $V_g$  of the drive transistor **22** minus the threshold voltage  $V_{th}$  thereof.

Here, the process adapted to change the source potential  $V_s$  relative to the initial potential  $V_{ofs}$  of the gate voltage  $V_g$  of the drive transistor **22** in such a manner that the same potential  $V_s$  varies to the initial potential  $V_{ofs}$  minus the threshold voltage  $V_{th}$  of the drive transistor **22** is referred to as the threshold correction process for convenience. As this threshold correction process progresses, the gate-to-source voltage  $V_{gs}$  of the drive transistor **22** will soon converge to the threshold voltage  $V_{th}$  of the drive transistor **22**. The voltage corresponding to the threshold voltage  $V_{th}$  is held by the holding capacitor **24**.

It should be noted that the potential  $V_{cath}$  of the common power supply line **34** is set so as to bring the organic EL element **21** into a cutoff state during the period in which the threshold correction process is performed (threshold correction period) so that the current flows exclusively through the holding capacitor **24**, and not through the organic EL element **21**.

Next, the potential WS of the scan line **31** changes to low potential at time  $t_{14}$ , thus bringing the write transistor **23** out of conduction as illustrated in FIG. **5A**. At this time, the gate

electrode of the drive transistor **22** is electrically disconnected from the signal line **33**, thus causing the gate electrode to float. However, the gate-to-source voltage  $V_{gs}$  is equal to the threshold voltage  $V_{th}$  of the drive transistor **22**. As a result, the drive transistor **22** is in a cutoff state. Therefore, the drain-to-source current  $I_{ds}$  does not flow through the drive transistor **22**.

(Signal Writing & Mobility Correction Period)

Next, the potential of the signal line **33** changes from the reference voltage  $V_{ofs}$  to the video signal voltage  $V_{sig}$  at time  $t_{15}$  as illustrated in FIG. **5B**. Then, the potential WS of the scan line **31** changes to high potential at time  $t_{16}$ , thus bringing the write transistor **23** into conduction and allowing for the same transistor **23** to sample the video signal voltage  $V_{sig}$  and write this voltage to the pixel **20** as illustrated in FIG. **5C**.

As a result of writing of the signal voltage  $V_{sig}$  by the write transistor **23**, the gate potential  $V_g$  of the drive transistor **22** becomes equal to the signal voltage  $V_{sig}$ . Then, when the drive transistor **22** is driven by the video signal voltage  $V_{sig}$ , the threshold voltage  $V_{th}$  of the drive transistor **22** is cancelled out by the voltage corresponding to the threshold voltage  $V_{th}$  held by the holding capacitor **24**. The principle behind this threshold cancellation will be described in detail later.

At this time, the organic EL element **21** is in a cutoff state (high impedance state). As a result, the current (drain-to-source current  $I_{ds}$ ) commensurate with the signal voltage  $V_{sig}$  flowing from the power supply line **32** to the drive transistor **22** flows into the equivalent capacitor of the organic EL element **21** and the auxiliary capacitor **25**. This initiates the charging of the equivalent capacitor of the organic EL element **21** and the auxiliary capacitor **25**.

As the equivalent capacitor of the organic EL element **21** and the auxiliary capacitor **25** are charged, the source potential  $V_s$  of the drive transistor **22** rises over time. At this time, the variation in the threshold voltage  $V_{th}$  of the drive transistor **22** between the pixels has already been cancelled out. As a result, the drain-to-source current  $I_{ds}$  of the drive transistor **22** is dependent on a mobility  $\mu$  of the same transistor **22**. It should be noted that the mobility  $\mu$  of the drive transistor **22** is the mobility of the semiconductor thin film forming the channel of the same transistor **22**.

Here, we assume that the ratio of the voltage  $V_{gs}$  held by the holding capacitor **24** to the video signal voltage  $V_{sig}$ , i.e., a write gain  $G$ , is 1 (ideal). As a result, when the source potential  $V_s$  of the drive transistor **22** rises to  $V_{ofs} - V_{th} + \Delta V$ , the gate-to-source voltage  $V_{gs}$  of the drive transistor **22** becomes equal to  $V_{sig} - V_{ofs} + V_{th} - \Delta V$ .

That is, an increment  $\Delta V$  in the source potential  $V_s$  of the drive transistor **22** acts so that it is subtracted from the voltage ( $V_{sig} - V_{ofs} + V_{th}$ ) held by the holding capacitor **24**. In other words, the increment  $\Delta V$  acts so that the holding capacitor **24** is discharged. In other words, the increment  $\Delta V$  in the source potential  $V_s$  is negatively fed back to the holding capacitor **24**. As a result, the increment  $\Delta V$  in the source potential  $V_s$  serves as a negative feedback amount.

As described above, it is possible to cancel out the dependence of the drain-to-source current  $I_{ds}$  of the drive transistor **22** on the mobility  $\mu$  by negatively feeding the feedback amount  $\Delta V$  commensurate with the drain-to-source current  $I_{ds}$  flowing through the drive transistor **22** back to the gate-to-source voltage  $V_{gs}$ . This cancellation is the mobility correction process adapted to correct the variation in the mobility  $\mu$  of the drive transistor **22** between the pixels.

More specifically, the higher the amplitude  $V_{in}$  ( $=V_{sig} - V_{ofs}$ ) of the video signal written to the gate electrode of the drive transistor **22**, the larger the drain-to-source current  $I_{ds}$ , and therefore the larger the absolute value of the negative

feedback amount  $\Delta V$ . As a result, the mobility correction process is performed according to the emission brightness.

On the other hand, if the video signal amplitude  $V_{in}$  is constant, the larger the mobility  $\mu$  of the drive transistor **22**, the larger the absolute value of the negative feedback amount  $\Delta V$ , thus eliminating the variation in the mobility  $\mu$  between the pixels. Therefore, the negative feedback amount  $\Delta V$  can be also referred to as the correction amount for the mobility correction process. The principle behind the mobility correction will be described in detail later.

(Light Emission Period)

Next, the potential WS of the scan line **31** changes to low potential at time  $t_{17}$ , thus bringing the write transistor **23** out of conduction as illustrated in FIG. **5D**. As a result, the gate electrode of the drive transistor **22** is electrically disconnected from the signal line **33**, thus causing the gate electrode to float.

Here, when the gate electrode of the drive transistor **22** floats, the gate potential  $V_g$  of the drive transistor **22** changes with change in the source potential  $V_s$  of the drive transistor **22** because the holding capacitor **24** is connected between the gate and source of the drive transistor **22**. The change in the gate potential  $V_g$  of the drive transistor **22** with change in the source potential  $V_s$  as described above is the bootstrapping action of the holding capacitor **24**.

When the gate electrode of the drive transistor **22** floats, and when the drain-to-source current  $I_{ds}$  of the drive transistor **22** begins to flow through the organic EL element **21** at the same time, the anode potential of the same element **21** rises with increase in the drain-to-source current  $I_{ds}$ .

Then, when the anode potential of the organic EL element **21** exceeds  $V_{the1} + V_{cath}$ , the drive current begins to flow through the same element **21**, allowing for the same element **21** to start emitting light. On the other hand, the rise of the anode potential of the organic EL element **21** is none other than the rise of the source potential  $V_s$  of the drive transistor **22**. Then, as the source potential  $V_s$  of the drive transistor **22** rises, the gate voltage  $V_g$  of the same transistor **22** also rises thanks to the bootstrapping action of the holding capacitor **24**.

At this time, assuming that the bootstrap gain is 1 (ideal), the increment in the gate potential  $V_g$  is equal to the increment in the source potential  $V_s$ . Therefore, the gate-to-source voltage  $V_{gs}$  of the drive transistor **22** is maintained constant at  $V_{sig} - V_{ofs} + V_{th} - \Delta V$  during the light emission period. Then, the potential of the signal line **33** changes from the video signal voltage  $V_{sig}$  to the reference voltage  $V_{ofs}$  at time  $t_{18}$ .

In the above series of circuit operations, the preparation for threshold correction, threshold correction, writing of the signal voltage  $V_{sig}$  (signal writing) and mobility correction are performed during one horizontal scan period (1H). Further, the signal writing and mobility correction are performed during a period from time  $t_{16}$  to time  $t_{17}$ .

[Divided Threshold Correction]

It should be noted that although a description has been given of an example of driving method in which the threshold correction is performed only once, this driving method is merely an example, and the present disclosure is not limited thereto. Instead, a driving method adapted to perform the so-called divided threshold correction may be, for example, used. This driving method is designed to perform the threshold correction on two or more separate occasions not only during the 1H period in which the threshold correction is conducted together with the mobility correction and signal writing but also during a plurality of horizontal scan periods preceding the 1H period.

This driving method based on divided threshold correction provides a sufficient amount of time spanning a plurality of

horizontal scan periods as a threshold correction period even if the time assigned as a horizontal scan period is reduced due to higher pixel count resulting from higher definition. Therefore, even if the time assigned as a horizontal scan period is reduced, it is possible to provide a sufficient amount of time as a threshold correction period, thus making it possible to positively conduct the threshold correction.

[Principle Behind the Threshold Cancellation]

A description will be given here of the principle behind the threshold cancellation (i.e., threshold correction) of the drive transistor **22**. The drive transistor **22** is designed to operate in the saturation region. As a result, the same transistor **22** acts as a constant current source. This allows for the constant drain-to-source current (drive current)  $I_{ds}$ , given by Formula 1 shown below, to be supplied from the drive transistor **22** to the organic EL element **21**.

$$I_{ds}=(1/2)\mu(W/L)C_{ox}(V_{gs}-V_{th})^2 \quad (1)$$

where  $W$  is the channel width of the drive transistor **22**,  $L$  the channel length, and  $C_{ox}$  the gate capacitance per unit area.

FIG. 6A illustrates the drain-to-source current  $I_{ds}$  vs gate-to-source voltage  $V_{gs}$  characteristic of the drive transistor **22**. As illustrated in the characteristic diagram of FIG. 6A, if the variation in the threshold voltage  $V_{th}$  of the drive transistor **22** between the pixels is not cancelled out (corrected), the drain-to-source current  $I_{ds}$  for the gate-to-source voltage  $V_{gs}$  is  $I_{ds1}$  when the threshold voltage  $V_{th}$  is  $V_{th1}$ .

In contrast, when the threshold voltage  $V_{th}$  is  $V_{th2}$  ( $V_{th2}>V_{th1}$ ) the drain-to-source current  $I_{ds}$  for the same gate-to-source voltage  $V_{gs}$  is  $I_{ds2}$  ( $I_{ds2}<I_{ds1}$ ). That is, when the threshold voltage  $V_{th}$  of the drive transistor **22** changes, the drain-to-source current  $I_{ds}$  also changes even if the gate-to-source voltage  $V_{gs}$  is constant.

In the pixel (pixel circuit) **20** configured as described above, on the other hand, the gate-to-source voltage  $V_{gs}$  of the drive transistor **22** during light emission is  $V_{sig}-V_{ofs}+V_{th}-\Delta V$  as described earlier. Therefore, when this is substituted into Formula 1, the drain-to-source current  $I_{ds}$  is expressed by Formula 2 shown below.

$$I_{ds}=(1/2)\mu(W/L)C_{ox}(V_{sig}-V_{ofs}-\Delta V)^2 \quad (2)$$

That is, the term of the threshold voltage  $V_{th}$  of the drive transistor **22** has been cancelled out. This makes the drain-to-source current  $I_{ds}$ , supplied from the drive transistor **22** to the organic EL element **21**, independent of the threshold voltage  $V_{th}$  of the drive transistor **22**. As a result, the drain-to-source current  $I_{ds}$  remains unchanged even in the event of a change in the threshold voltage  $V_{th}$  of the drive transistor **22** between the pixels due, for example, to manufacturing process variation or change over time, thus making it possible to maintain the light emission brightness of the organic EL element **21** constant.

[Principle Behind the Mobility Correction]

A description will be given next of the principle behind the mobility correction of the drive transistor **22**. FIG. 6B illustrates characteristic curves comparing a pixel A with the relatively large mobility  $\mu$  of the drive transistor **22** and a pixel B with the relatively small mobility  $\mu$  of the same transistor **22**. If the drive transistor **22** includes a polysilicon thin film transistor, there is inevitably a variation in the mobility  $\mu$  between the pixels such as the pixels A and B.

We consider a case in which the signal amplitude  $V_{in}$  ( $=V_{sig}-V_{ofs}$ ) of the same level is, for example, written to the gate electrodes of the drive transistors **22** in the pixels A and B when there is a variation in the mobility  $\mu$  between the pixels A and B. In this case, if the mobility  $\mu$  is not corrected at all, there will be a large difference between the drain-to-

source current  $I_{ds1}$  flowing through the pixel A with the large mobility  $\mu$  and the drain-to-source current  $I_{ds2}$  flowing through the pixel B with the small mobility  $\mu$ . If there is a large difference in the drain-to-source current  $I_{ds}$  between the pixels due to the variation in the mobility  $\mu$  between the pixels, the screen uniformity is impaired.

Here, as is clear from the transistor characteristic formula given by Formula 1, the larger the mobility  $\mu$ , the larger the drain-to-source current  $I_{ds}$ . Therefore, the larger the mobility  $\mu$ , the larger the negative feedback amount  $\Delta V$ . As illustrated in FIG. 6B, a feedback amount  $\Delta V_1$  of the pixel A with the large mobility  $\mu$  is larger than a feedback amount  $\Delta V_2$  of the pixel B with the small mobility  $\mu$ .

Therefore, if the feedback amount  $\Delta V$  commensurate with the drain-to-source current  $I_{ds}$  flowing through the drive transistor **22** is negatively fed back to the gate-to-source voltage  $V_{gs}$  in the mobility correction, the larger the mobility  $\mu$ , the larger the negative feedback amount. This makes it possible to keep the variation in the mobility  $\mu$  between the pixels to a minimum.

More specifically, if the pixel A with the large mobility  $\mu$  is corrected with the feedback amount  $\Delta V_1$ , the drain-to-source current  $I_{ds}$  drops significantly from  $I_{ds1}$  to  $I_{ds1}'$ . On the other hand, the feedback amount  $\Delta V_2$  of the pixel B with the small mobility  $\mu$  is small. Therefore, the drain-to-source current  $I_{ds}$  drops from  $I_{ds2}$  to  $I_{ds2}'$ , which is not a significant decline. As a result, the drain-to-source current  $I_{ds1}$  of the pixel A and the drain-to-source current  $I_{ds2}$  of the pixel B are roughly equal, thus correcting the variation in the mobility  $\mu$ .

Summing up the above, if the pixels A and B have the different mobilities  $\mu$ , the feedback amount  $\Delta V_1$  of the pixel A with the large mobility  $\mu$  is larger than the feedback amount  $\Delta V_2$  of the pixel B with the small mobility  $\mu$ . That is, the larger the mobility  $\mu$ , the larger the feedback amount  $\Delta V$ , and the more the drain-to-source current  $I_{ds}$  declines.

Therefore, the levels of the drain-to-source currents  $I_{ds}$  of the pixels with the different mobilities  $\mu$  are evened out by negatively feeding the feedback amount  $\Delta V$  commensurate with the drain-to-source current  $I_{ds}$  flowing through the drive transistor **22** back to the gate-to-source voltage  $V_{gs}$ . This makes it possible to correct the variation in the mobility  $\mu$  between the pixels. That is, negatively feeding the feedback amount (correction amount)  $\Delta V$  commensurate with the current (drain-to-source current  $I_{ds}$ ) flowing through the drive transistor **22** back to the gate-to-source voltage  $V_{gs}$  of the drive transistor **22**, i.e., the holding capacitor **24**, is the mobility correction.

A description will be given below of the organic EL display according to first and second embodiments of the present disclosure whose basic configuration and circuit operation are as described above.

## 2. First Embodiment

FIG. 7 is a schematic plan view illustrating the pixel structure of the organic EL display according to the first embodiment of the present disclosure. Further, FIG. 8 is a sectional view taken along line of sight A-A' indicated by the arrows in FIG. 7. FIG. 9 is a sectional view taken along line of sight B-B' indicated by the arrows in FIG. 7.

The organic EL display according to the first embodiment has a bottom emission structure (scheme) in which light emitted by the organic EL elements is extracted from the rear side of the transparent insulating substrate on which the pixel circuits, each including TFTs (Thin Film Transistors), capacitors and so on, are formed. Further, the organic EL display according to the first embodiment includes, as organic EL

elements, white organic EL elements adapted to emit white light that are used in combination with a color filter, thus allowing for light of different colors such as RGB light to be extracted.

In particular, the pixel circuit (drive circuit of the organic EL element  $21_w$ ) **20** including the drive transistor **22** and holding capacitor **24** is formed on a transparent insulating substrate such as a glass substrate **71** as illustrated in FIGS. **8** and **9**. More specifically, a gate electrode **221** of the drive transistor **22**, one electrode **241** of the holding capacitor **24** and an underlying interconnect **331** of the signal line **33** are made of an interconnect material such as molybdenum (Mo) and formed on the glass substrate **71**. The glass substrate **71** having the pixel circuits **20**, each including TFTs, formed thereon is generally referred to as a TFT substrate.

A semiconductor layer **222** forming the channel region and source/drain regions of the drive transistor **22** and other electrode **242** of the holding capacitor **24** are formed respectively above the gate electrode **221** of the drive transistor **22** and the one electrode **241** of the holding capacitor **24** with a gate insulating film **72** provided therebetween. A color filter **74** is formed directly on-chip above the pixel circuit **20** with an insulating film **73** provided therebetween. That is, the color filter **74** is an on-chip color filter.

An overlying interconnect **332** of the signal line **31** is made of an interconnect material such as aluminum (Al) and formed on the insulating film **73** with contact (electrical connection) made with the underlying interconnect **331**. Further, an insulating planarizing film **75** is stacked on top of the color filter **74**, and an anode electrode **211** of the white organic EL element  $21_w$  is formed on the insulating planarizing film **75** for each pixel.

The white organic EL element  $21_w$  is formed in a concave portion  $76_A$  of a window insulating film **76** stacked on the insulating planarizing film **75**. The concave portion  $76_A$  of the window insulating film **76** serves as a light-emitting section of the white organic EL element  $21_w$ , i.e., an OLED opening. A cathode electrode **212** of the white organic EL element  $21_w$  is formed to be shared by all the pixels. It should be noted that the cathode electrode **212** is not shown in FIG. **7**.

As described above, the organic EL display according to the first embodiment uses, as the organic EL elements **21**, the white organic EL elements  $21_w$  adapted to emit white light, thus providing light of different colors such as RGB light by using the on-chip color filter **74**. As the white organic EL elements  $21_w$ , multistage RGB organic EL elements, and more specifically, organic EL elements having a tandem structure formed by stacking the RGB light-emitting layers one on top of the other with a connecting layer provided therebetween may be, for example, used.

Further, the organic EL display according to the first embodiment has a bottom emission structure in which light emitted by the white organic EL elements  $21_w$  is extracted from the rear side of the glass substrate **71** on which the pixel circuits **20** are formed. When a bottom emission structure is used, the light extraction region is restricted by the presence of the circuit components and interconnects on the glass substrate **71**. As a result, the light utilization ratio of the organic EL elements **21** is generally lower than a top emission structure in which light is extracted from the front side of the substrate.

In the organic EL display according to the first embodiment, however, each of the pixel circuits **20** includes a small number of circuit components, namely, two transistors (**22** and **23**) and a capacitor (**24**). As a result, only a small number of transistors and interconnects are formed on the TFT substrate (glass substrate **71**). Therefore, even if a bottom emis-

sion structure is used, it is possible to provide better utilization ratio of light emitted by the organic EL elements **21** than when the pixel circuits, each including three or more transistors and other components, are used.

In particular, as is clear from FIG. **7**, the signal line **33** including the underlying interconnect **331** and overlying interconnect **332** runs longitudinally on the left edge side of the pixel (pixel circuit) **20**, and more specifically, along the left edge of the light-emitting section of the white organic EL element  $21_w$ . Contact (electrical connection) is made between the underlying interconnect **331** and overlying interconnect **332** by contact portions **333** and **334** at two locations in the pixel **20**.

The power supply line **32**, made of aluminum (Al) or other interconnect material, is formed laterally on the top edge side of the pixel **20**, and more specifically, along the top edge of the light-emitting section of the white organic EL element  $21_w$ . The drive transistor **22** is formed near the power supply line **32**. As described earlier, the drive transistor **22** includes the gate electrode **221** and semiconductor layer **222**. The gate electrode **221** is formed on the glass substrate **71**. The semiconductor layer **222** serves as the channel region and source/drain regions and is formed above the gate electrode **221** with the gate insulating film **72** provided therebetween.

The gate electrode **221** of the drive transistor **22** is formed integrally with the lower electrode **241** of the holding capacitor **24** along the top edge of the light-emitting section of the white organic EL element  $21_w$ . Contact is made between one of the source/drain regions of the semiconductor layer **222** and the upper electrode **242** of the holding capacitor **24** by means of a contact portion **224**. On the other hand, contact is made between the other source/drain region of the semiconductor layer **222** and the power supply line **32** by means of a contact portion **223**.

The holding capacitor **24** has the gate insulating film **72** serving as a dielectric sandwiched between the lower and upper electrodes **241** and **242** and is formed on the right edge side of the pixel **20** to span the almost entire longitudinal region thereof, and more specifically, along the right edge of the light-emitting section of the white organic EL element  $21_w$ . The capacitance of the holding capacitor **24** is determined by the area of the region between the lower and upper electrodes **241** and **242** opposed to each other, the distance between the two electrodes **241** and **242** and the dielectric constant of the gate insulating film **72**.

The scan line **31**, made of aluminum (Al) or other interconnect material, is formed laterally on the bottom edge side of the pixel **20**. The write transistor **23** is formed near the scan line **31**. The write transistor **23** includes a gate electrode **231** and semiconductor layer **232**. The gate electrode **231** is made, for example, of molybdenum (Mo) and formed on the glass substrate **71**. The semiconductor layer **232** serves as the channel region and source/drain regions and is formed above the gate electrode **231** with the gate insulating film **72** provided therebetween.

The gate electrode of the write transistor **23** is located near the bottom edge of the light-emitting section of the white organic EL element  $21_w$ . Contact is made between the gate electrode and the scan line **31** by means of a contact portion **233**. Contact is made between one of the source/drain regions of the semiconductor layer **232** and the signal line **33** by means of a contact portion **234**. The other source/drain region of the semiconductor layer **232** is electrically connected to the lower electrode **241** of the holding capacitor **24** via a contact portion **235**, metal interconnect **236** and contact portion **237**.

The lower electrode **241** of the holding capacitor **24** is formed integrally with the gate electrode **221** of the drive

transistor 22 as described earlier. Thanks to contact made with the lower electrode 241 of the holding capacitor 24, therefore, the other source/drain region of the write transistor 23 is electrically connected to the gate electrode 221 of the drive transistor 22.

In the pixel 20, the white organic EL element 21<sub>w</sub> is formed in the center surrounded by the signal line 33 on the left, holding capacitor 24 on the right, the power supply line 32 on the top and the scan line 31 on the bottom, i.e., in the concave portion (opening portion) 76<sub>A</sub> of the window insulating film 76, in such a manner as to avoid the region where the drive transistor 22 is formed. The anode electrode 211 of the white organic EL element 21<sub>w</sub> is electrically connected to the other source/drain region of the drive transistor 22 and the upper electrode 242 of the holding capacitor 24.

The color filter 74 is formed below the white organic EL element 21<sub>w</sub> and along the opening of the concave portion 76<sub>A</sub> of the window insulating film 76 in such a manner as to avoid the drive transistor 22. It should be noted that the color filter 74 is hatched in FIG. 7 for clear identification. On the other hand, the anode electrode 211 of the white organic EL element 21<sub>w</sub> is shaded.

As described above, the light-emitting section of the white organic EL element 21<sub>w</sub> and the color filter 74 are surrounded by the metal interconnects such as the signal line 33, power supply line 32, gate electrode 221 of the drive transistor 22, electrode 241 of the holding capacitor 24 and gate electrode 231 of the write transistor 23. As is clear from FIGS. 8 and 9, these metal interconnects are primarily formed in the layer where the drive circuit of the white organic EL element 21<sub>w</sub> is formed.

Thus, the metal interconnects around the light-emitting section (opening portion) of the white organic EL element 21<sub>w</sub> and the color filter 74 act as a light-shielding layer adapted to shield light leaking between the different color filters of the color filter 74. This makes it possible to prevent white light leaks between the filters without forming a light-shielding layer between every two filters of different color filter 74, in other words, without providing a process step of forming a light-shielding layer. As a result, it is possible to keep the aggravation of color reproducibility caused by white light leaks and color shift to a minimum without increasing the number of process steps in using the white organic EL elements 21<sub>w</sub> and color filter 74 in combination.

Here, the metal interconnects around the light-emitting section of the white organic EL element 21<sub>w</sub> and the color filter 74 are preferably formed to overlap the periphery of the color filter 74. The reason for this is that because when the color filter 74 is formed, a taper level difference is formed on the periphery of the same filter 74, the overlapping can suppress the impact of the taper level difference. At this time, it is possible to positively suppress the impact of the taper level difference by ensuring that a metal interconnect 77 overlaps the periphery of the color filter 74 by as much as or more than the thickness of the color filter 74.

#### Modification Example

A description has been given of an example in which the present embodiment is applied to the organic EL display having the color filter 74 formed on-chip. However, the present embodiment is also applicable to an organic EL display having the color filter 74 attached to its substrate. FIGS. 10 to 12 illustrate the pixel structure of the organic EL display having the color filter 74 attached to its substrate.

FIG. 10 is a schematic plan view illustrating the pixel structure of the organic EL display having the color filter 74

attached to its substrates. On the other hand, FIG. 11 is a sectional view taken along line of sight C-C' indicated by the arrows in FIG. 10, and FIG. 12 is a sectional view taken along line of sight D-D' indicated by the arrows in FIG. 10. In FIG. 10, the color filter 74 is shown by a dashed line. As illustrated in FIGS. 11 and 12, the color filter 74 is sandwiched between and attached to two substrates 71<sub>A</sub> and 71<sub>B</sub>.

Thus, it is also possible to achieve the same action and effect in the organic EL display having the color filter 74 attached to the substrates 71<sub>A</sub> and 71<sub>B</sub> as in the first embodiment by forming the metal interconnects in such a manner as to surround the light-emitting section of the white organic EL element 21<sub>w</sub> and the color filter 74. At this time, the metal interconnects include the signal line 33, power supply line 32, gate electrode 221 of the drive transistor 22, electrode 241 of the holding capacitor 24 and gate electrode 231 of the write transistor 23 and so on.

### 3. Second Embodiment

Incidentally, if a bottom emission structure is used, and particularly when the color filter 74 is arranged within the region where the transistors making up the drive circuit of the white organic EL element 21<sub>w</sub> are formed, the characteristics of the transistors may change. More specifically, the material of the color filter 74 is charged by light emitted from the own pixel, thus changing (shifting) the characteristics of the transistors making up the drive circuit as illustrated in FIG. 13.

FIG. 13 illustrates, as an example, the gate-to-source voltage  $V_{gs}$  vs drain-to-source current  $I_{ds}$  characteristic of an N-channel transistor when light is irradiated to the transistor with and without the color filter 74. The material of the color filter 74 is charged by light emitted from the own pixel, thus affecting the channel of the transistor and shifting the threshold voltage  $V_{th}$  of the transistor in the negative direction. Further, the leak current increases in the OFF state of the transistor.

Then, if the characteristic of the write transistor 23 shifts under the influence of the charging of the color filter 74 in the organic EL display having the mobility correction function described above, the charge does not leak from the holding capacitor 24 during the light emission period, thus resulting in lower brightness. On the other hand, if the characteristic of the drive transistor 22 shifts under the influence of the charging of the color filter 74, the threshold voltage  $V_{th}$  shifts during light emission despite the fact that the variation in the threshold voltage  $V_{th}$  has been corrected by the threshold correction function, thus resulting in uneven brightness.

The organic EL display according to the second embodiment which will be described below has been implemented to resolve the problem caused by the charging of the material of the color filter 74. A description will be given below of the organic EL display according to the second embodiment with reference to FIGS. 14 to 16.

FIG. 14 is a schematic plan view illustrating the pixel structure of the organic EL display according to the second embodiment. FIG. 15 is a sectional view taken along line of sight E-E' indicated by the arrows in FIG. 14. FIG. 16 is a sectional view taken along line of sight F-F' indicated by the arrows in FIG. 14. In FIGS. 14 to 16, like components to those shown in FIGS. 7 to 9 are denoted by the same reference numerals.

The organic EL display according to the second embodiment has a bottom emission structure (scheme) for extraction of light emitted by the organic EL elements and uses the white organic EL elements 21<sub>w</sub> and color filter 74 in combination as does the counterpart according to the first embodiment.

As is clear particularly from FIG. 7, the organic EL display according to the first embodiment has the color filter 74 arranged in the region including where the drive transistor 22 and write transistor 23 are formed. In contrast, the organic EL display according to the second embodiment has the color filter 74 arranged in the region at least other than (avoiding) the channel regions of the transistors making up the drive circuit of the white organic EL element 21<sub>w</sub>, which are the drive transistor 22 and write transistor 23 in the present example.

More specifically, the drive transistor 22 is arranged (formed) closer to the right edge of the pixel 20 in FIG. 14 first. Then, the portion of the color filter 74 close to the power supply line 32 is formed in such a manner as to avoid at least the channel region of the drive transistor 22, and preferably the region where the drive transistor 22 is formed. Further, the portion of the color filter 74 close to the scan line 31 is formed in such a manner as to avoid at least the channel region of the write transistor 23, and preferably the region where the write transistor 23 is formed.

This ensures that the color filter 74, located between the light-emitting section of the white organic EL element 21<sub>w</sub> and the layer where the drive circuit is formed, is not laid out on or above the drive transistor 22 or write transistor 23 as is clear particularly from FIGS. 15 and 16. Therefore, even if the material of the color filter 74 is charged by light emitted from the own pixel, the channels of the drive transistor 22 and write transistor 23 remain unaffected by the charging. As a result, the transistor characteristics do not change (shift).

The organic EL display according to the second embodiment has the same configuration as the counterpart according to the first embodiment. That is, the metal interconnects such as the signal line 33, power supply line 32, gate electrode 221 of the drive transistor 22, electrode 241 of the holding capacitor 24 and gate electrode 231 of the write transistor 23 are formed in such a manner as to surround the light-emitting section of the white organic EL element 21<sub>w</sub> and the color filter 74.

The organic EL display according to the second embodiment described above provides the following action and effect in addition to the same action and effect as provided by the counterpart according to the first embodiment. That is, the color filter 74 is arranged in such a manner as to avoid at least the channel regions of the transistors making up the drive circuit of the white organic EL element 21<sub>w</sub>. This ensures that even if the material of the color filter 74 is charged by light emitted from the own pixel, the channels of the transistors remain unaffected by the charging.

In the case of the present configuration example using the pixel circuit shown in FIG. 2, the drive transistor 22 and write transistor 23 serve as the transistors making up the drive circuit of the white organic EL element 21<sub>w</sub>. However, the pixel circuit is not limited to that configured as shown in FIG. 2. Among other pixel circuits, a pixel circuit including a control transistor connected in series to the drive transistor 22 and adapted to control the white organic EL element 21<sub>w</sub> to emit light or stop emitting light is known. In the case of this pixel circuit, the control transistor is included among the transistors making up the drive circuit.

Then, the fact that the color filter 74 is arranged in such a manner as to avoid the channel regions of the drive transistor 22 and write transistor 23 ensures that even if the material of the color filter 74 is charged by light emitted from the own pixel, the channels of the transistors remain unaffected by the charging. If the color filter 74 is laid out in such a manner as to avoid not only the channel regions of the drive transistor 22 and write transistor 23 but also the entire region where these

transistors are formed, it is possible to positively ensure that the channels of the transistors 22 and 23 remain unaffected by the charging of the color filter 74.

If the channels of the drive transistor 22 and write transistor 23 remain unaffected by the charging of the color filter 74, a change (shift) in the characteristic of the drive transistor 22 or write transistor 23 does not take place. Therefore, the charge does not leak from the holding capacitor 24 during the light emission period, thus keeping brightness degradation to a minimum. Further, the threshold voltage  $V_{th}$  of the drive transistor 22 does not shift during light emission, thus keeping uneven brightness from occurring and thereby providing a high quality display image.

#### 4. Electronic Equipment

The organic EL display according to the present disclosure described above is applicable to the display section (display) of electronic equipment across all disciplines adapted to display a video signal fed thereto or generated therein. For example, the organic EL display according to the present disclosure is applicable to the display section of a variety of electronic equipment including a digital camera, laptop personal computer, personal digital assistant such as mobile phone and video camcorder shown in FIGS. 17 to 21G.

Using the organic EL display according to the present disclosure as the display section of a variety of electronic equipment contributes to improved display quality of these pieces of electronic equipment. That is, as is clear from the description of the embodiments, the organic EL display according to the first embodiment keeps the aggravation of color reproducibility caused by white light leaks and color shift to a minimum. On the other hand, the organic EL display according to the second embodiment keeps brightness degradation and uneven brightness to a minimum. As a result, using the organic EL displays according to the first and second embodiment contributes to an excellent image with high quality.

The organic EL display according to the present disclosure includes a display in a modular form having a sealed configuration. As an example, a display module formed by attaching an opposed section made, for example, of glass to the pixel array section corresponds to such a display. It should be noted that a circuit section adapted to exchange signals and other information between external equipment and the pixel array section, an FPC (flexible printed circuit) or other sections may be provided on the display module.

A description will be given below of specific examples of electronic equipment to which the present disclosure is applied.

FIG. 17 is a perspective view illustrating a television set to which the present disclosure is applied. The television set according to the present application example includes a video display screen section 101 made up of a front panel 102, filter glass 103 and other parts. The television set is manufactured by using the organic EL display according to the present disclosure as the video display screen section 101.

FIGS. 18A and 18B are perspective views illustrating a digital camera to which the present disclosure is applied. FIG. 18A is a front perspective view, and FIG. 18B a rear perspective view. The digital camera according to the present application example includes a flash-emitting section 111, display section 112, menu switch 113, shutter button 114 and other parts. The digital camera is manufactured by using the display according to the present disclosure as the display section 112.

FIG. 19 is a perspective view illustrating a laptop personal computer to which the present disclosure is applied. The

laptop personal computer according to the present application example includes a keyboard **122** adapted to be manipulated for entry of text or other information, a display section **123** adapted to display an image and other parts in a main body **121**. The laptop personal computer is manufactured by using the display according to the disclosure as the display section **123**.

FIG. **20** is a perspective view illustrating a video camcorder to which the present disclosure is applied. The video camcorder according to the present application example includes a main body section **131**, lens **132** provided on the front-facing side surface to capture the image of the subject, imaging start/stop switch **133**, display section **134** and other parts. The video camcorder is manufactured by using the organic EL display according to the present disclosure as the display section **134**.

FIGS. **21A** to **21G** are appearance views of a personal digital assistance such as mobile phone to which the present disclosure is applied. FIG. **21A** is a front view in an open position, FIG. **21B** a side view thereof, FIG. **21C** a front view in a closed position, FIG. **21D** a left side view, FIG. **21E** a right side view, FIG. **21F** a top view, and FIG. **21G** a bottom view. The mobile phone according to the present application example includes an upper enclosure **141**, lower enclosure **142**, connecting section (hinge section in this example) **143**, display **144**, subdisplay **145**, picture light **146**, camera **147** and other parts. The mobile phone according to the present application example is manufactured by using the organic EL display according to the present disclosure as the display **144** and subdisplay **145**.

The present technology contains subject matter related to that disclosed in Japanese Priority Patent Application JP 2011-022351 filed in the Japan Patent Office on Feb. 4, 2011, the entire content of which is hereby incorporated by reference.

While a preferred embodiment of the disclosed technique has been described using specific terms, such description is for illustrative purposes only, and it is to be understood that changes and variations may be made without departing from the spirit or scope of the following claims.

What is claimed is:

1. An organic electroluminescence display comprising: a window insulating film between a cathode electrode and a layer of metal interconnects, an opening portion extending through said window insulating film; an anode electrode between a color filter and said opening portion, said anode electrode touching said window insulating film and one of the metal interconnects; an organic electroluminescence element within said opening portion, said organic electroluminescence element being between said cathode electrode and said anode electrode; wherein said one of the metal interconnects is in said color filter, wherein said opening portion is a trench in said window insulating film.
2. The organic electroluminescence display of claim 1, wherein said organic electroluminescence element touches said cathode electrode and said anode electrode.
3. The organic electroluminescence display of claim 1, wherein said organic electroluminescence element touches said window insulating film.
4. The organic electroluminescence display of claim 1, wherein said opening portion terminates at said anode electrode.

5. The organic electroluminescence display of claim 1, wherein said organic electroluminescence element is configured to emit white light.

6. The organic electroluminescence display of claim 5, wherein said color filter is configured to extract light of a different color from said white light.

7. The organic electroluminescence display of claim 6, wherein said color filter is between said anode electrode and a transparent substrate, said light of the different color being transmissible through said transparent substrate.

8. The organic electroluminescence display of claim 1, wherein said one of the metal interconnects overlaps a periphery of the color filter.

9. The organic electroluminescence display of claim 8, wherein said one of the metal interconnects overlaps said periphery of the color filter by as much as or more than a thickness of the color filter.

10. The organic electroluminescence display of claim 1, wherein said layer of the metal interconnects is in an insulating planarizing film.

11. The organic electroluminescence display of claim 10, wherein said insulating planarizing film is between said color filter and said window insulating film.

12. The organic electroluminescence display of claim 10, wherein said anode electrode is between said insulating planarizing film and said window insulating film.

13. The organic electroluminescence display of claim 10, wherein said color filter is in said insulating planarizing film.

14. The organic electroluminescence display of claim 10, further comprising:

a drive transistor configured to provide electrical connection and disconnection between said anode electrode and a power supply line, said power supply being another of the metal interconnects.

15. The organic electroluminescence display of claim 14, wherein said insulating planarizing film is between said window insulating film and said layer of the metal interconnects.

16. The organic electroluminescence display of claim 15, wherein another portion of the anode electrode extends to a drive transistor one of the metal interconnects through said insulating planarizing film.

17. The organic electroluminescence display of claim 14, further comprising:

a write transistor configured to provide electrical connection and disconnection between a gate electrode of the drive transistor and a signal line of the metal interconnects.

18. The organic electroluminescence display of claim 17, wherein said signal line of the metal interconnects extends through an interlayer insulating film.

19. The organic electroluminescence display of claim 18, wherein said interlayer insulating film is between said drive transistor and said layer of the metal interconnects.

20. The organic electroluminescence display of claim 18, further comprising:

a terminal of a holding capacitor electrically connected to said gate electrode of the drive transistor, said anode electrode being electrically connected to another terminal of the holding capacitor.

21. The organic electroluminescence display of claim 20, wherein said gate electrode of the drive transistor is said terminal of the holding capacitor.

22. The organic electroluminescence display of claim 20, wherein said interlayer insulating film is between said layer of the metal interconnects and said holding capacitor.

23. Electronic equipment comprising: the organic electroluminescence display of claim 1;

an enclosure supporting said organic electroluminescence display.

\* \* \* \* \*

专利名称(译)	有机电致发光显示器和电子设备		
公开(公告)号	<a href="#">US9099683</a>	公开(公告)日	2015-08-04
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[标]申请(专利权)人(译)	索尼公司		
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当前申请(专利权)人(译)	JOLED INC.		
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摘要(译)

有机电致发光显示器具有底部发光结构，其中在基板上逐像素地形成适于发射白光的白色有机电致发光元件，并且其中由白色有机电致发光元件发射的光从后侧提取。基材。有机电致发光显示器包括：滤色器，与白色有机电致发光元件组合使用，以提取不同颜色的光；以这样的方式逐像素地形成金属互连，以围绕白色有机电致发光元件和滤色器的发光部分。

