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(54) **DISPLAY DEVICE AND METHOD OF MANUFACTURING DISPLAY DEVICE**

(71) Applicant: **JOLED INC.**, Tokyo (JP)

(72) Inventor: **Hiroki YAMAMOTO**, Tokyo (JP)

(73) Assignee: **JOLED INC.**, Tokyo (JP)

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(57) **ABSTRACT**

A display device including: an organic EL element that is provided in each of pixels and emits light according to flow of current; and a resistance element that is provided in each of the pixels and is connected in parallel to the organic EL element. Resistance of the light-emitting element and resistance of the resistance element increase over time after energization of the light-emitting element and the resistance element. The resistance of the resistance element is higher than the resistance of the organic EL element.

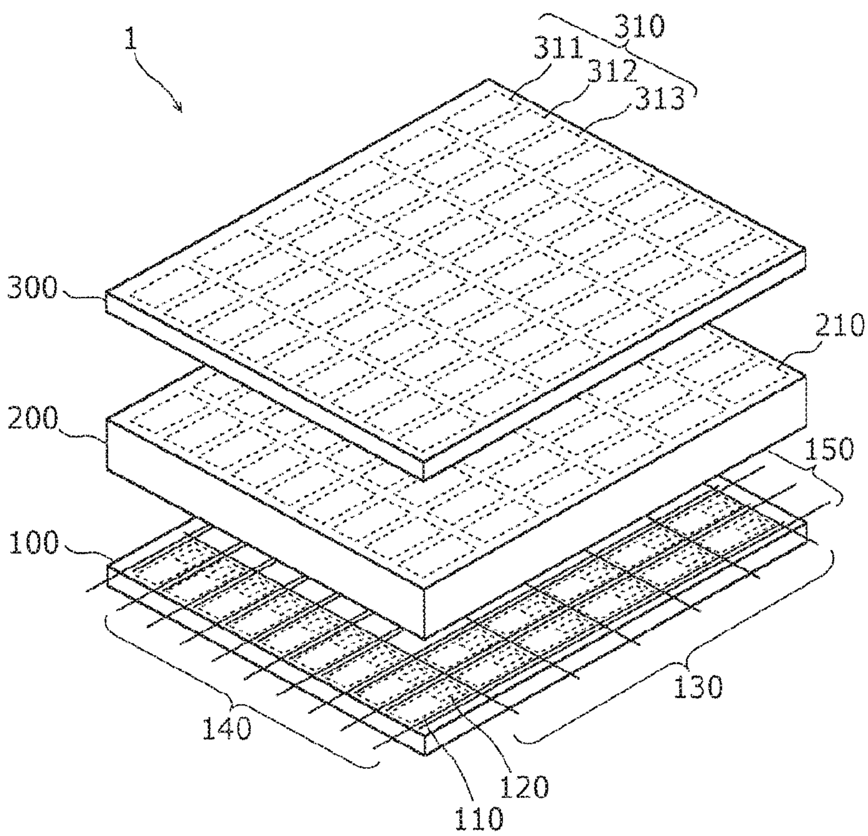


FIG. 1

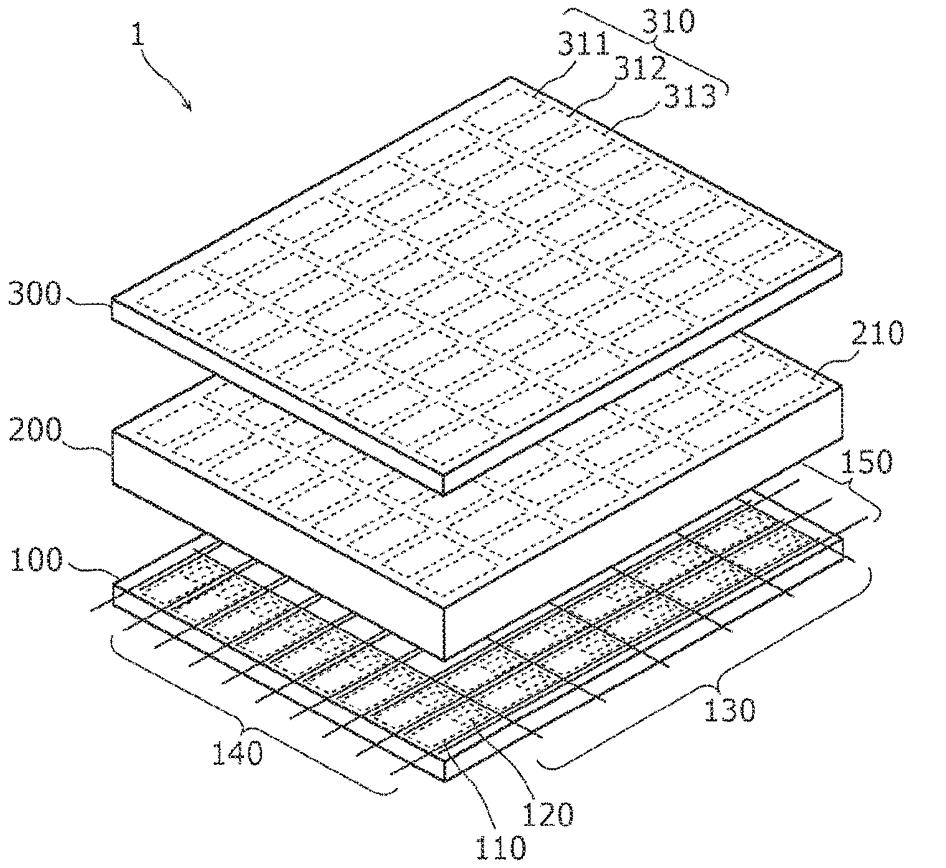
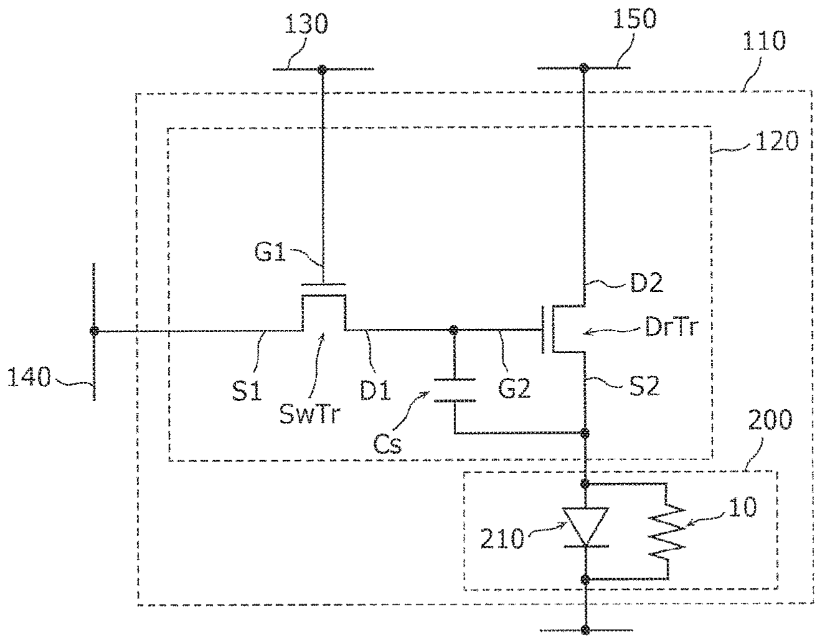
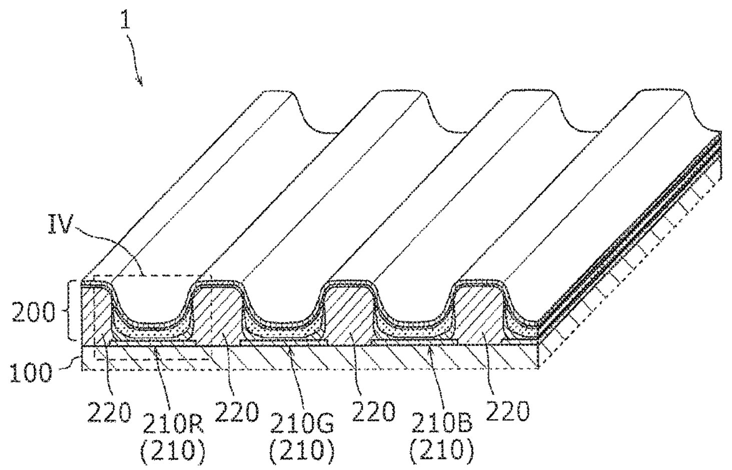


FIG. 2



130
150
110
120
G1
D2
DrTr
140
S1
SwTr
D1
G2
S2
Cs
200
210
10

FIG. 3



1
IV
200
100
220
210R
(210)
220
210G
(210)
220
210B
(210)
220

FIG. 4

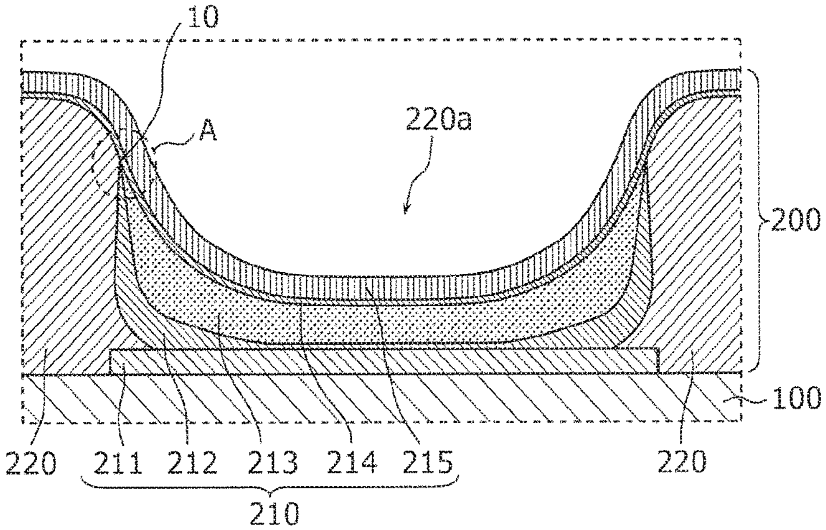

10
A
220a
200
100
220
211
212
213
214
215
220
210

FIG. 5

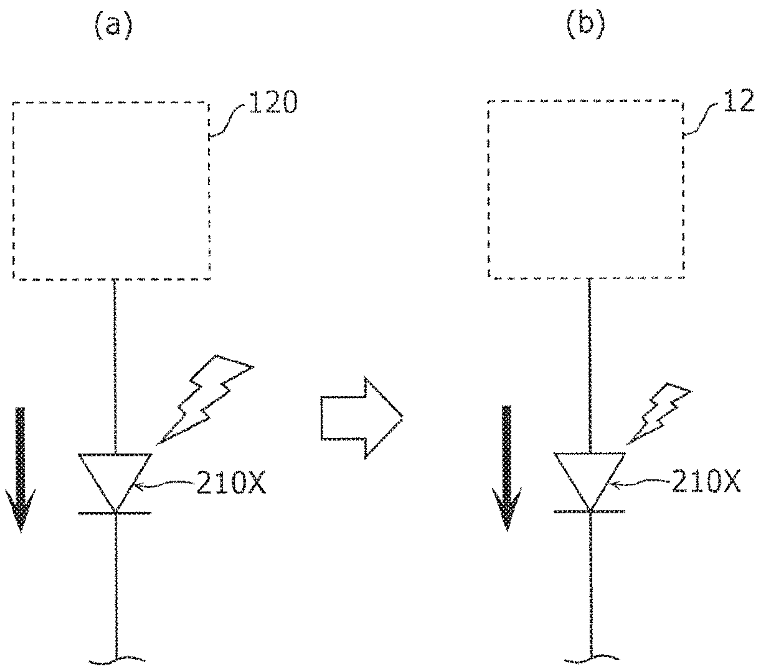

(a)
(b)
120
120
210X
210X

FIG. 6

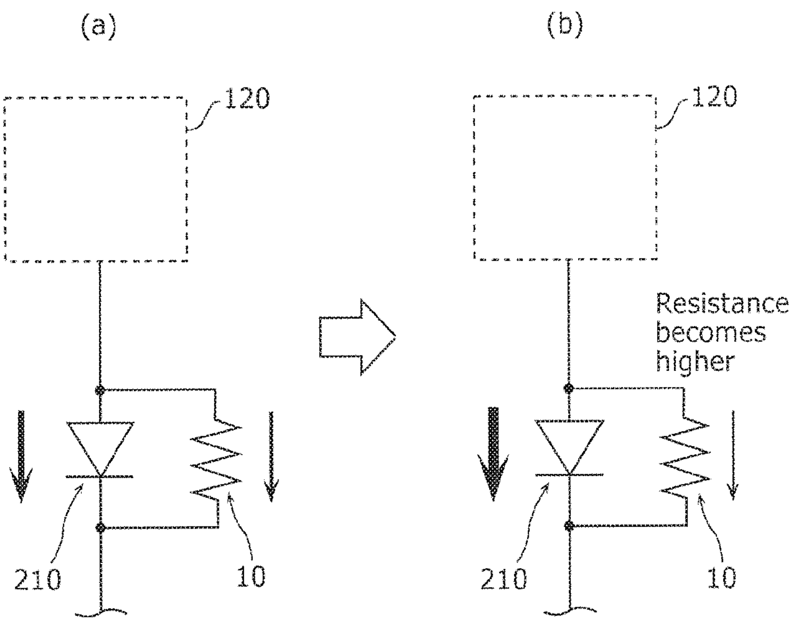

(a)
(b)
120
120
Resistance
becomes
higher
210
10
210
10

FIG. 7

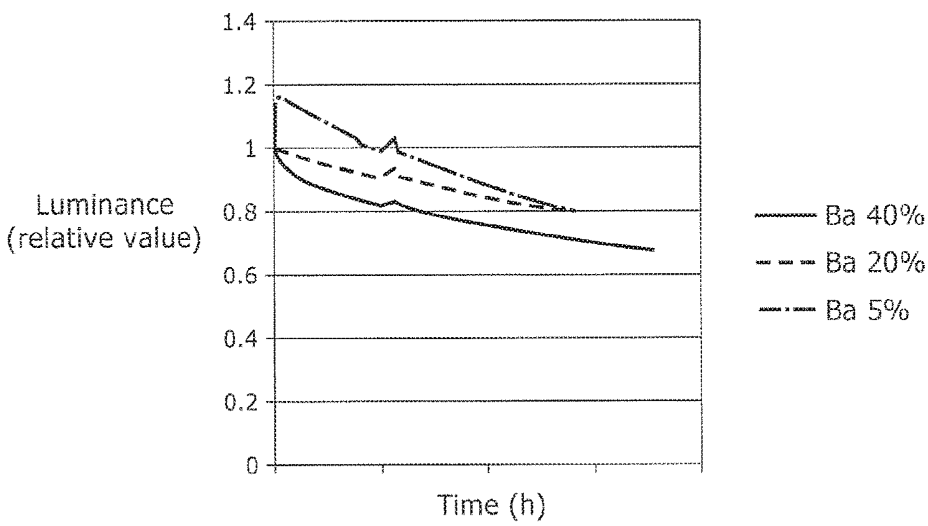

1.4
1.2
1
0.8
0.6
0.4
0.2
0
Luminance
(relative value)
Time (h)
Ba 40%
Ba 20%
Ba 5%

FIG. 8A

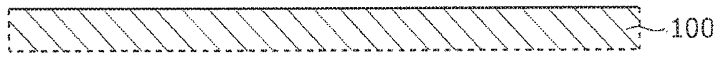


FIG. 8B

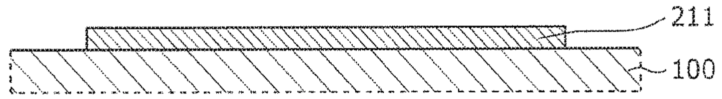


FIG. 8C

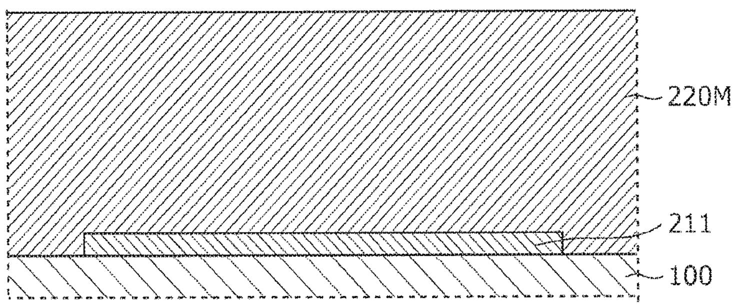


FIG. 8D

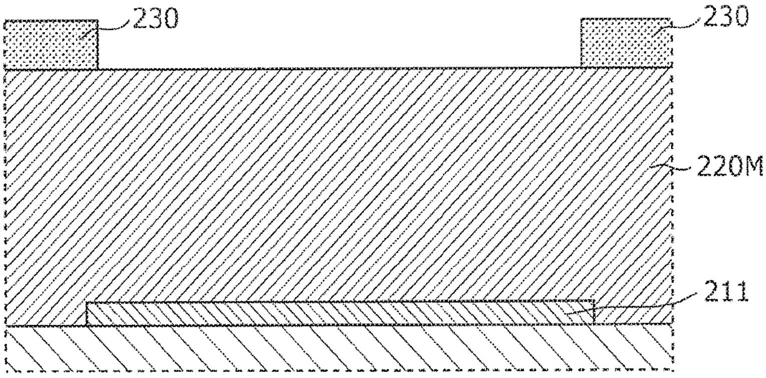


FIG. 8E

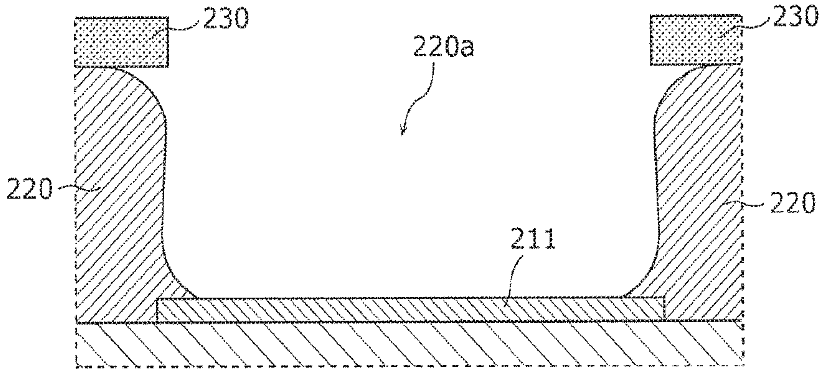


FIG. 8F

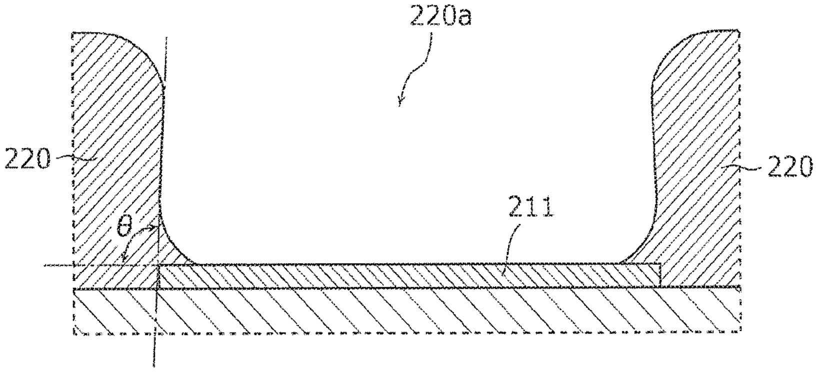


FIG. 8G

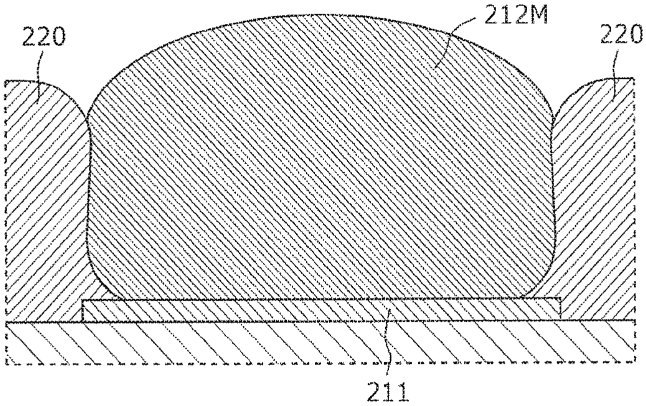


FIG. 8H

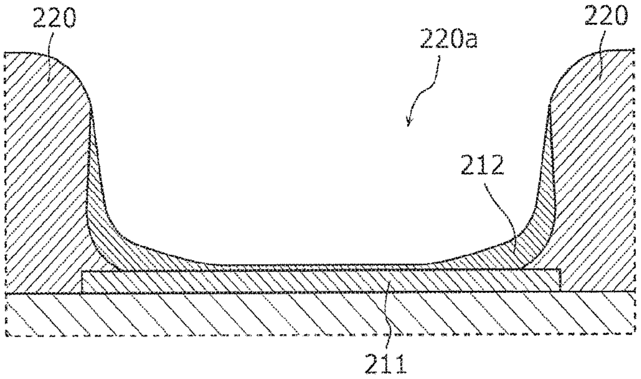


FIG. 8I

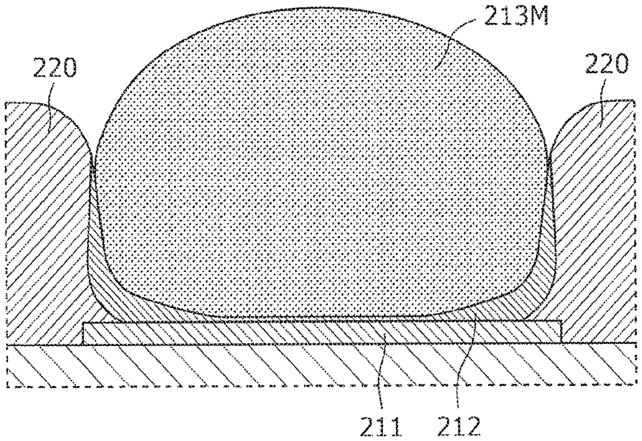


FIG. 8J

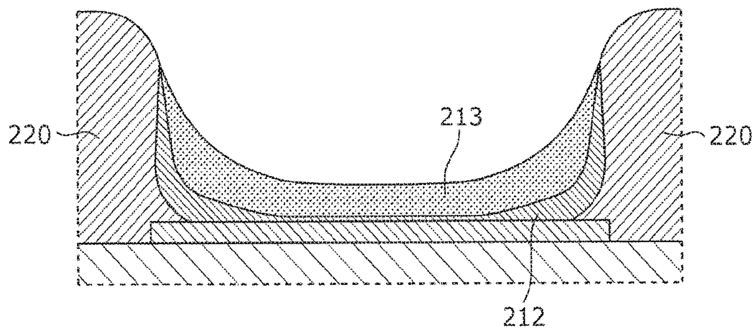


FIG. 8K

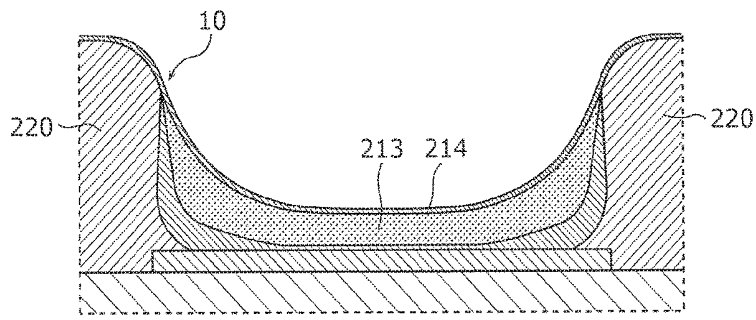
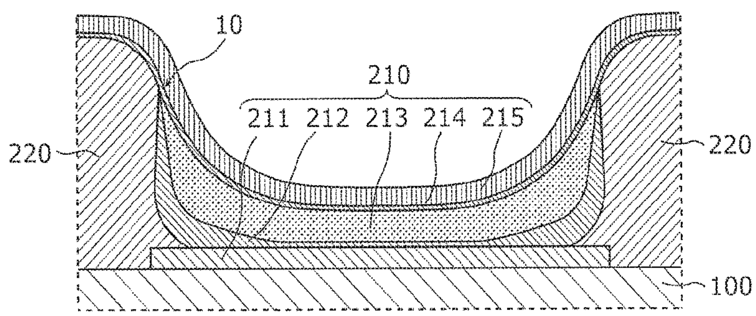


FIG. 8L



DISPLAY DEVICE AND METHOD OF MANUFACTURING DISPLAY DEVICE

CROSS REFERENCE TO RELATED APPLICATION

[0001] The present application is based on and claims priority of Japanese Patent Application No. 2017-179101 filed on Sep. 19, 2017. The entire disclosure of the above-identified application, including the specification, drawings and claims is incorporated herein by reference in its entirety.

FIELD

[0002] The present disclosure relates to a display device and a method of manufacturing the display device, and particularly relates to an organic electroluminescence (EL) display device having organic EL elements, and a method of manufacturing the organic EL display device. The present disclosure relates to a display device and a method of manufacturing the display device, and particularly relates to an organic electroluminescence (EL) display device having organic EL elements, and a method of manufacturing the organic EL display device.

BACKGROUND

[0003] In recent years, organic EL display devices utilizing organic EL elements have drawn attention as selfluminous display devices having excellent response with high contrast and wide view angle. In particular, the development of active matrix organic EL display devices that are advantageous for use in high definition and large screen devices has been active.

[0004] An active matrix organic EL display device has, for example, pixels arranged in matrix, each pixel including an organic EL element and a pixel circuit for supplying the organic EL element with a driving current (see reference, for example, to Patent Literature 1).

CITATION LIST

Patent Literature

[0005] [Patent Literature 1] Japanese Unexamined Patent Application Publication No. 2009-186982

SUMMARY

Technical Problem

[0006] Luminance of a light-emitting element such as an organic EL element decreases due to the deterioration of the light-emitting element. Accordingly, the problem observed in selfluminous display devices is screen burn-in caused by the deterioration of light-emitting elements.

[0007] The technology disclosed in the present disclosure has an object to provide a display device with which luminance decrease can be prevented even though light-emitting elements deteriorate, and a method of manufacturing the display device.

Solution to Problem

[0008] In order to achieve the above-described object, a display device according to one aspect of the present disclosure includes: a light-emitting element that is provided in each of pixels and emits light according to flow of current; and a resistance element that is provided in each of the pixels and is connected in parallel to the light-emitting element. Resistance of the light-emitting element and resistance of the resistance element increase over time after energization of the light-emitting element and the resistance element, and the resistance of the resistance element changes at a higher rate than the resistance of the light-emitting element.

[0009] Moreover, a method of manufacturing a display device according to one aspect of the present disclosure includes: forming a bank that has an opening; forming a first charge functional layer by applying a first material inside the opening and drying the first material applied; forming a light-emitting layer on the first charge functional layer by applying a second material inside the opening and drying the second material applied; and forming a second charge functional layer on the light-emitting layer to cover the opening. The first charge functional layer and the second charge functional layer are close to or in contact with each other at a lateral wall of the bank.

Advantageous Effects

[0010] It is possible to prevent luminance decrease even though light-emitting elements deteriorate.

BRIEF DESCRIPTION OF DRAWINGS

[0011] These and other objects, advantages and features of the disclosure will become apparent from the following description thereof taken in conjunction with the accompanying drawings that illustrate a specific embodiment of the present disclosure.

[0012] FIG. **1** is an exploded perspective view schematically illustrating an organic EL display device according to an embodiment.

[0013] FIG. **2** is a diagram illustrating an electric circuit including a pixel circuit and an EL portion that are included in each pixel in the organic EL display device according to the embodiment.

[0014] FIG. **3** is a cross-sectional perspective view schematically illustrating the configuration of a portion of the organic EL display device according to the embodiment.

[0015] FIG. **4** is an enlarged view illustrating region IV enclosed by a dashed line in FIG. **3**.

[0016] FIG. **5** is a diagram illustrating a change in the amount of current when an organic EL element in a conventional organic EL display device deteriorates.

[0017] FIG. **6** is a diagram illustrating a change in the amount of current when an organic EL element and a resistance element in the organic EL display device according to the embodiment deteriorate.

[0018] FIG. **7** is a diagram illustrating a change in the luminance of an organic EL element with respect to a period of energization time.

[0019] FIG. **8**A is a cross-sectional view illustrating a process of preparing a TFT substrate in a method of manufacturing the organic EL display device according to the embodiment.

[0020] FIG. **8**B is a cross-sectional view illustrating a process of forming an anode of an organic EL element, in the method of manufacturing the organic EL display device according to the embodiment.

[0021] FIG. **8**C is a cross-sectional view illustrating a process of applying a resist film intended for bank, in the method of manufacturing the organic EL display device according to the embodiment.

[0022] FIG. **8**D is a cross-sectional view illustrating a process of exposing, to light, a resist film intended for bank, in the method of manufacturing the organic EL display device according to the embodiment.

[0023] FIG. **8**E is a cross-sectional view illustrating a process of developing the resist film intended for bank, in the method of manufacturing the organic EL display device according to the embodiment.

[0024] FIG. **8**F is a cross-sectional view illustrating a process of removing a mask at the time of exposing, to light, the resist film intended for bank, in the method of manufacturing the organic EL display device according to the embodiment.

[0025] FIG. **8**G is a cross-sectional view illustrating a process of applying the first organic solvent intended for hole injection layer of the organic EL element, in the method of manufacturing the organic EL display device according to the embodiment.

[0026] FIG. **8**H is a cross-sectional view illustrating a process of drying the first organic solvent intended for hole injection layer of the organic EL element, in the method of manufacturing the organic EL display device according to the embodiment.

[0027] FIG. **8**I is a cross-sectional view illustrating a process of applying the second organic solvent intended for light-emitting layer of the organic EL element, in the method of manufacturing the organic EL display device according to the embodiment.

[0028] FIG. **8**J is a cross-sectional view illustrating a process of drying the second organic solvent intended for light-emitting layer of the organic EL element, in the method of manufacturing the organic EL display device according to the embodiment.

[0029] FIG. **8**K is a cross-sectional view illustrating a process of forming an electron transport layer of the organic EL element, in the method of manufacturing the organic EL display device according to the embodiment.

[0030] FIG. **8**L is a cross-sectional view illustrating a process of forming a cathode of the organic EL element, in the method of manufacturing the organic EL display device according to the embodiment.

DESCRIPTION OF EMBODIMENT

[0031] The following describes exemplary embodiments with reference to the drawings. Note that each of the embodiments described below is merely one specific example of the present disclosure. Accordingly, the numerical values, shapes, materials, elements, arrangement and connection of the elements, etc., indicated in the following embodiments are given merely by way of illustrations and are not intended to limit the scope of the present disclosure. Therefore, among the elements in the following embodiments, those not recited in any one of the independent claims defining the broadest concepts of the present disclosure are described as optional elements.

[0032] Note also that the figures are schematic illustrations and are not necessarily precise depictions. Therefore, the scale sizes in the figures, for example, are not necessarily the same. Moreover, in the figures, elements that are essentially the same share like reference signs and duplicate description is omitted or simplified.

Embodiment

[0033] The following describes, as an example of a display device, organic EL display device **1** having organic EL elements **210**. FIG. **1** is an exploded perspective view schematically illustrating organic EL display device **1** according to an embodiment.

[0034] As illustrated in FIG. **1**, organic EL display device **1** includes TFT substrate **100**, EL portion **200**, and color-filter substrate **300**. TFT substrate **100**, EL portion **200**, and color-filter substrate **300** are laminated from bottom to top in the listed order. In other words, EL portion **200** is disposed on TFT substrate **100** and color-filter substrate **300** is disposed on EL portion **200**. More specifically, EL portion **200** is formed on a planarization layer of TFT substrate **100**. Moreover, EL portion **200** and color-filter substrate **300** are attached by an attaching layer (not shown in the diagram).

[0035] TFT substrate **100** is a TFT array substrate that has thin film transistors (TFTs). TFT substrate **100** has, in each of pixels **110** arranged in matrix, pixel circuit **120** formed from circuit elements such as TFTs and condensers. TFT substrate **100** has, for example, a substrate such as a glass substrate or a transparent resin substrate, wiring layers each including electrodes of the TFTs and wirings, and an interlayer insulating layer formed between the wiring layers.

[0036] More specifically, TFT substrate **100** has, as plural wirings, gate lines (scanning lines) **130** aligned in the row direction of pixels **110**, source lines (signal lines) **140** aligned in the column direction of pixels **110** to orthogonally intersect with gate lines **130**, and power lines **150** disposed substantially in parallel to source lines **140**. Each pixel **110** is sectioned, for example, by gate lines **130** and source lines **140** that orthogonally intersect with each other.

[0037] Gate line **130** is connected, on a per row basis, to a gate electrode of a switching transistor included in each pixel circuit **120**. Source line **140** is connected, on a per column basis, to a source electrode of a switching transistor included in each pixel circuit **120**. Source line **150** is connected, on a per column basis, to a source electrode of a switching transistor included in each pixel circuit **120**.

[0038] EL portion **200** includes organic EL element **210** provided in each of pixels **110**. Organic EL element **210** in each pixel **110** is an example of a light-emitting element and the drive of organic EL element **210** is controlled by pixel circuit **120** in each pixel **110**. In other words, the light emission of each organic EL element **210** is controlled by pixel circuit **120**. More specifically, since organic EL element **210** emits light according to the flow of current to organic EL element **210**, it is possible to cause organic EL element **210** to emit light by supplying organic EL element **210** with current by means of pixel circuit **120**.

[0039] Organic EL element **210** is formed on TFT substrate **100**. To be more specific, a planarization layer is formed in the upper layer of TFT substrate **100** and organic EL element **210** is formed on the planarization layer. Organic EL element **210** has a structure in which an anode, a light-emitting layer, and a cathode are laminated, which will be described in detail later on.

[0040] Color-filter substrate **300** has color filters **310** formed on a transparent substrate which is a glass substrate or a transparent resin substrate. In this embodiment, color filters **310** include red filter **311**, green filter **312**, and blue filter **313**. Red filter **311** transmits red light emitted from EL portion **200**. Green filter **312** transmits green light emitted from EL portion **200**. Blue filter **313** transmits blue light emitted from EL portion **200**.

[0041] Organic EL display device **1** having such a configuration as described above is of top emission type and causes light emitted by organic EL element **210** to exit from a color-filter substrate **300** side (a side opposite to a TFT substrate **100** side). Note that organic EL display device **1** shall not be limited to a top emission type organic EL display device and may be a bottom emission type organic EL display device which causes light emitted by organic EL element **210** to exit from the TFT substrate **100** side. With a top emission type organic EL display device, it is possible to increase an aperture ratio thereof compared with a bottom emission type organic EL display device. Therefore, with a top emission type organic EL display device, efficiency in light emission is more enhanced than with a bottom emission type organic EL display device.

[0042] Next, the configurations of pixel circuit **120** of TFT substrate **100** and EL portion **200** that are included in each pixel **110** of organic EL display device **1** will be described with reference to FIG. **2**. FIG. **2** is a diagram, illustrating an electric circuit including pixel circuit **120** and EL portion **200** that are included in each pixel **110** of organic EL display device **1** according to the embodiment.

[0043] Pixel circuit **120** in each pixel **110** is a constant current circuit for supplying organic EL element **210** with a drive current for causing organic EL element **210** to emit light, and has circuit elements such as TFTs. In this embodiment, each pixel circuit **120** has a 2Tr1C circuit configuration having, as circuit elements, two TFTs and one condenser.

[0044] More specifically, each pixel circuit **120** is formed from a TFT formed as driving transistor DrTr, a TFT formed as switching transistor SwTr, and condenser Cs formed as a storage capacitor that stores data voltage (signal voltage), as illustrated in FIG. **2**.

[0045] Driving transistor DrTr is a TFT for driving organic EL element **210** and controls the current that flows to organic EL element **210**. Moreover, switching transistor SwTr is a TFT for selecting pixel **110** caused to emit light (i.e., organic EL element **210** caused to emit light) among pixels **110**. Switching transistor SwTr is connected to gate electrode G**2** which is a control terminal of driving transistor DrTr, and controls conduction and non-conduction of driving transistor DrTr.

[0046] Switching transistor SwTr includes gate electrode G**1** connected to gate line **130**, source electrode S**1** connected to source line **140**, drain electrode D**1** connected to one electrode of condenser Cs as well as gate electrode G**2** of driving transistor DrTr, and a semiconductor layer (not shown in the diagram) that functions as a channel layer. When a predetermined voltage is applied to gate line **130** and source line **140** to which switching transistor SwTr is connected, the voltage applied to source line **140** is held as data voltage by condenser Cs.

[0047] Driving transistor DrTr includes: gate electrode G**2** connected to drain electrode D**1** of switching transistor SwTr and the other electrode of condenser Cs; drain electrode D**2** connected to power line **150**; source electrode S**2** connected to an anode of organic EL element **210** and the other electrode of condenser Cs; and a semiconductor layer (not shown in the diagram) that functions as a channel layer. Driving transistor DrTr supplies the anode of organic EL element **210** with current in accordance with the data voltage held by condenser Cs from power line **150** through source electrode S**2**. With this, a drive current flows through organic EL element **210** from the anode to the cathode and a light-emitting layer in organic EL element **210** emits light. Then, by controlling the amount of current during energization of organic EL element **210** (amount of energization), it is possible to control the luminance of light emitted by organic EL element **210**.

[0048] Active matrix scheme for controlling light emission for each pixel **110** is adopted for organic EL display device **1** configured as described above. In other words, by causing organic EL elements **210** arranged in matrix to selectively emit light, using switching transistor SwTr and driving transistor DrTr in each pixel **110**, it is possible to cause organic EL display device **1** to display a desired image.

[0049] Moreover, EL portion **200** has, in each of pixels **110**, resistance element **10** connected in parallel to organic EL element **210**, as illustrated in FIG. **2**. Each of organic EL element **210** and resistance element **10** has properties such that resistance increases over time after the energization of these elements. In this embodiment, the resistance of organic EL element **210** and the resistance of resistance element **10** gradually increase due to deterioration over time after energization during normal operation. Moreover, the resistance of resistance element **10** changes at a rate higher than the resistance of organic EL element **210** in this embodiment. That is to say, the rate of change at which resistance increases is higher in resistance element **10** than in organic EL element **210**.

[0050] Next, detailed configurations of organic EL element **210** and resistance element **10** in organic EL display device **1** will be described with reference to FIG. **3** and FIG. **4**. FIG. **3** is a cross-sectional perspective view schematically illustrating the configuration of a portion of organic EL display device **1** according to the embodiment. FIG. **4** is an enlarged view illustrating region IV that is enclosed by a dashed line and is illustrated in FIG. **3**.

[0051] Pixels **110** in organic EL display device **1** include a red pixel, a green pixel, and a blue pixel. Organic EL elements **210** include organic EL element for red color **210**R corresponding to a red pixel, organic EL element for green color **210**G corresponding to a green pixel, and organic EL element for blue color **210**B corresponding to a blue pixel, as illustrated in FIG. **3**. Organic EL element for red color **201**R emits red light, organic EL element for green color **210**G emits green light, and organic EL element for blue color **210**B emits blue light.

[0052] Organic EL elements **210** (organic EL element for red color **210**R, organic EL element for green color **210**G, and organic EL element for blue color **210**B) are separated from each other by banks **220**. In this embodiment, banks **220**, each being a line bank, are formed, for example, from elongated protrusions each extending substantially in parallel to source lines **140**. It should be noted that bank **220** shall not be limited to a line bank and may be a grid-like pixel bank.

[0053] Each of organic EL elements **210** (organic EL element for red color **210**R, organic EL element for green color **210**G, and organic EL element for blue color **2105**) has: anode **211** which is the first electrode; hole injection layer **212** which is the first charge functional layer; light-emitting layer **213**; electron transport layer **214** which is the second charge functional layer; and cathode **215** which is the second electrode.

[0054] As illustrated in FIG. **4**, anode **211** is a lower electrode having a predetermined shape and is formed on TFT substrate **100**. Anode **211** is formed inside opening **220***a* of bank **220** in each pixel **110**. More specifically, anode **211** is formed in the bottom of opening **220***a* of bank **220**.

[0055] In this embodiment, anode **211** is a reflecting electrode having light-reflecting properties and has a function to reflect light generated in light-emitting layer **213**. Anode **211** includes, as a light-reflecting layer, a metallic layer composed of a metallic material such as aluminum.

[0056] In addition, anode **211** may have a structure in which a metallic layer composed of aluminum alloy and a transparent layer that is composed of oxidized tungsten and is formed on the metallic layer are laminated. In this case, the layer composed of oxidized tungsten may function not as anode **211**, but as hole injection layer **212**. The thickness of anode **211** is in the range of, for example, from 50 nm to 700 nm.

[0057] Hole injection layer (HIL) **212** is located between anode **211** and light-emitting layer **213**, and has a function to inject a hole into light-emitting layer **213**. Hole injection layer **212** is composed, for example, of an organic material including polythiophene series such as polyethylenedioxythiophene (PEDOT), phthalocyanine series, oligoamine series, dendrimeramine series, etc. Since it is desirable that hole injection layer **212** have lower resistance than light-emitting layer **213**, it is recommended to select, for the material of hole injection layer **212**, a material that has lower resistance than the material of light-emitting layer **213**.

[0058] Hole injection layer **212** is formed inside opening **220***a* of bank **220** in each pixel **110**. In this embodiment, hole injection layer **212** is disposed on anode **211** in such a manner to be surrounded by banks **220**.

[0059] More specifically, hole injection layer **212** has a thin-filmed shape and rides on bank **220**, extending from the bottom of opening **220***a* of bank **220** and along the lateral wall of bank **220**. Moreover, the thickness of hole injection layer **212** is thin and is approximately the same at the center in the bottom of opening **220***a* of bank **220**, but becomes gradually thicker toward the root of bank **220** and then becomes gradually thinner from the bottom toward the top along the lateral wall of bank **220**. The thickness at the center of hole injection layer **212** is in the range of, for example, from 5 nm to 100 nm. Hole injection layer **212** having such a shape can be formed by applying, inside opening **220***a*, an organic material composing hole injection layer **212**, and then drying the organic material applied.

[0060] Light-emitting layer **213** (EML) is located between anode **211** and cathode **215**, and has a function to emit light when a light-emitting material is excited by energy generated through the recombination of holes and electrons injected upon the application of a predetermined voltage to anode **211** and cathode **215**. In this embodiment, light-emitting layer **213** is located between hole injection layer **212** and electron transport layer **214**.

[0061] In addition, it is possible to cause light-emitting layer **213** to emit light having a predetermined color (wavelength), by selecting a material for light-emitting layer **213**. Light-emitting layer **213** is, for example, either one of a red-light emitting layer that emits red light, a green-light emitting layer that emits green light, or a blue-light emitting layer that emits blue light.

[0062] Light-emitting layer **213** is an organic light-emitting layer for which an organic light-emitting material is used. A low-molecular organic material such as aluminum-quinolinol complex (Alq3) or a high polymer organic material such as a polymer light-emitting material, e.g., polyparaphenylene vinylene (PPV) and polyfluorene, can be used as the organic light-emitting material composing light-emitting layer **213**. Since it is desirable that light-emitting layer **213** have higher liquid repellency than that of hole injection layer **212** (i.e., it is desirable that a contact angle of light-emitting layer **213** be larger than that of hole injection layer **212**), it is recommended to select, for the material of light-emitting layer **213**, a material that has higher liquid repellency than the material of hole injection layer **212**.

[0063] Light-emitting layer **213** is formed inside opening **220***a* of bank **220** in each pixel **110**. In this embodiment, light-emitting layer **213** is disposed on hole injection layer **212** in such a manner to be surrounded by banks **220**.

[0064] More specifically, light-emitting layer **213** has a thin-filmed shape and rides on bank **220**, extending from the bottom of opening **220***a* of bank **220** and along the lateral wall of bank **220**, and also along the surface of hole injection layer **212**. The thickness of light-emitting layer **213** is approximately the same at the center of the bottom of opening **220***a* of bank **220**, and becomes gradually thinner toward bank **220**. The thickness, at the center, of light-emitting layer **213** is in the range of, for example, from 30 nm to 200 nm. Light-emitting layer **213** having such a shape can be formed by applying, inside opening **220***a*, an organic material composing light-emitting layer **213** of bank **200** and then drying the organic material applied.

[0065] Electron transport layer (EFL) **214** is located between light-emitting layer **213** and cathode **215**, and has a function to transport electrons to light-emitting layer **213**. An organic material such as metallic chelate, phenanthroline, oxadiazole, or triazole series or an inorganic material such as an alkali metal compound or an alkali earth metal compound are used as the material of electron transport layer **214**.

[0066] Moreover, it is desirable that electron transport layer **214** include reducing metal. Barium, titanium, sodium, or aluminum can be used as the reducing metal for electron transport layer **214**. In this embodiment, electron transport layer **214** is composed of an organic material including barium. The concentration of barium doped in electron transport layer **214** is in the range of from 1 wt. % to 50 wt % with respect to the weight of the material used for electron transport layer **214**.

[0067] Electron transport layer **214** is formed on light-emitting layer **213** to cover opening **220***a* of bank **220**. In this embodiment, electron transport layer **214** is formed continuously on light-emitting layer **213** over all of pixels **110** across banks **220**. To be more specific, electron transport layer **214** is a thin-filmed monolayer and is formed over all of pixels **110** to cover openings **220***a* of all of banks **220** and along the surfaces of light-emitting layers **213** and banks **220**. The thickness of electron transport layer **214** is approximately the same and is in the range of, for example, from 30 nm to 100 nm. Note that electron transport layer **214** shall not be limited to a monolayer and may be formed per plural pixels **110** inside opening **220***a* of bank **220**, as is formed hole injection layer **212**.

[0068] Cathode **215** is formed on electron transport layer **214** to face anode **211**. In this embodiment, cathode **215** is formed continuously across banks **220**, as is formed electron transport layer **214**. Stated differently, cathode **215** is a common electrode commonly provided for pixels **110**. To be more specific, cathode **215** is a thin-filmed monolayer and is formed over all of pixels **110** to cover openings **220***a* of all of banks **220** and along the surface of electron transport layer **214**. The thickness of cathode **215** is approximately the same and is in the range of, for example, from 20 nm to 200 nm. Note that cathode **215** shall not be limited to a monolayer and may be formed per plural pixels **110** inside opening **220***a* of bank **220**.

[0069] Moreover, organic EL display device **1** according to this embodiment is of top emission type, and therefore, cathode **215** is composed of a material having light transmissivity. Cathode **215** is, for example, a transparent conductive layer (transparent electrode) composed of indium tin oxide (ITO) or transparent metallic oxide such as indium zinc oxide (IZO). Note that the material itself of cathode **215** need not be transparent and cathode **215** may be a metal film composed, for example, of silver (Ag) or aluminum (Al) and may be rendered thinner to transmit light.

[0070] In organic EL element **210** having the configuration as described above, when voltage is applied between anode **211** and cathode **215**, holes are injected from anode **211** to hole injection layer **212** and electrons are injected from cathode **215** to electron transport layer **214**. Then, the electrons and the holes are supplied to light-emitting layer **213** and are thus recombined in light-emitting layer **213**, as a result of which light-emitting layer **213** emits light.

[0071] Note that organic EL element **210** according to this embodiment has, as charge functional layers, hole injection layer **212** and electron transport layer **214**, but the charge functional layers shall not be limited to such. Organic EL element **210** may include a different charge functional layer such as a hole transport layer, an electron injection layer, or an electron barrier layer.

[0072] Bank **220** is a barrier for partitioning each light-emitting layer **213** in organic EL element **210**, and has opening **220***a* that surrounds light-emitting layer **213**. Hole injection layer **212** and light-emitting layer **213** are formed inside opening **220***a* of bank **220**. In this embodiment, hole injection layer **212** and light-emitting layer **213** ride on the lateral wall (lateral face) which constitutes the surface of bank **220**.

[0073] At the lateral wall of bank **220**, the ends of light-emitting layer **213** are located in the vicinity of but do not extend beyond the ends of hole injection layer **212**. In other words, the tips of the ends of hole injection layer **212** are located as high as or higher than the tips of the ends of light-emitting layer **213**.

[0074] Accordingly, in the location near the tips of the ends of both hole injection layer **212** and light-emitting layer **213** (region A enclosed by a dashed circle in FIG. **4**), hole injection layer **212** and electron transport layer **214** are either close to or in contact with each other. In other words, light-emitting layer **213** which is located between hole injection layer **212** and electron transport layer **214** is formed, leaving the portions where the ends of hole injection layer **212** that rides on the lateral wall of bank **220** and electron transport layer **214** are close to or in contact with each other. In this embodiment, the ends of hole injection layer **212** are in contact with electron transport layer **214** in region A without having light-emitting layer **213** in between. In the portion at which hole injection layer **212** and electron transport layer **214** are close to or in contact with each other, the same resistance behavior as exhibited by one resistance element having electrical resistance properties can be observed.

[0075] Thus, resistance element **10** is formed as a resistance circuit connected in parallel to a main light-emitting portion of organic EL element **210** in the center of bank **220**, in the state where a portion of hole injection layer **212** on the lateral wall of bank **220** and electron transport layer **214** are close to or in contact with each other. In other words, resistance element **10** is a portion at which hole injection layer **212** and electron transport layer **214** are close to or in direct contact with each other without having light-emitting layer **213** in between (i.e., a boundary between hole injection layer **212** and electron transport layer **214**), and is formed using one or more components making up organic EL element **210**. The portion at which hole injection layer **212** and electron transport layer **214** are close to or in contact with each other is not necessary as a matter of fact, but by intentionally forming such a portion, resistance element **10**, which is connected in parallel to organic EL element **210**, is formed in each bank **220**.

[0076] Resistance element **10** having the configuration as described above is formed using one or more materials composing organic EL element **210**, and therefore, the resistance of resistance element **10** becomes higher due to the deterioration caused by the energization of resistance element **10**, and resistance gradually increases over time.

[0077] In this case, by using, as the material of hole injection layer **212**, a material having lower resistance than the material of light-emitting layer **213**, it is possible to easily increase, for resistance element **10** than for organic EL element **210**, the rate at which resistance increases (resistance increase rate) due to deterioration after energization.

[0078] Bank **220** may be composed of an organic material such as resin or of an inorganic material. The organic material is, for example, acrylic resin, polyimide, or novorak phenol resin. The inorganic material is, for example, silicon oxide (SiO_2) or silicon nitride (Si_3N_4). Note that it is desirable that bank **220** be formed using a material having organic solvent tolerance and insulating properties. Moreover, since etching and bake processes may possibly be performed, it is also desirable that bank **220** be formed using a material having high tolerance against these processes.

[0079] Additionally, it is recommended that the surface of bank **220** be liquid-repellent. By applying liquid-repellent treatment such as fluorine-plasma treatment to bank **220**, for example, it is possible to give bank **220** liquid repellency and render the surface of bank **220** to be liquid-repellent. Note that the surface of bank **220** may be rendered liquid-repellent by forming bank **220** using an organic material that has liquid repellency, instead of applying liquid-repellent treatment to bank **220**. For example, a material including a fluorine resin such as a fluoridated polyolefin resin, a fluoridated polyimide resin, a fluoridated poly-acryl resin can be used as the organic material that has liquid repellency.

[0080] A sealing layer is formed to cover cathode **215** although not shown in the diagram. For example, an organic material such as a fluorine resin, an oxide material such as oxide silicon (SiO_2), oxide germanium (GeO), or oxide aluminum (Al_2O_3), or a nitride material such as oxynitride silicon (SiON) or nitride silicon (SiN) may be used as the material of the sealing layer. Note that, since organic EL display device **1** according to this embodiment is of top emission type, a light transmissive material is used as the material of the sealing layer.

[0081] Next, advantageous effects of organic EL display device **1** according to this embodiment will be described with reference to FIG. **5** and FIG. **6** in comparison with a conventional organic EL display device. FIG. **5** is a diagram illustrating a change in the amount of current when organic EL element **210**X in a conventional organic EL display device deteriorates. FIG. **6** is a diagram illustrating a change in the amount of current when organic EL element **210** and resistance element **10** in organic EL display device **1** according to the embodiment deteriorate.

[0082] With a conventional organic EL display device, after the energization of organic EL element **210**X by means of pixel circuit **120** which is a constant current circuit, the current flows to organic EL element **210**X and organic EL element **210**X emits light, as illustrated in (a) in FIG. **5**.

[0083] Here, a light-emitting layer or a charge functional layer of organic EL element **210**X deteriorates over time after energization etc. Therefore, the resistance of organic EL element **210**X gradually increases over time due to the deterioration caused by the energization of organic EL element **210**X. In other words, the resistance of organic EL element **210**X becomes higher over time after energization during normal operation.

[0084] As a result, the amount of current that flows from pixel circuit **120**, which is a constant current circuit, to organic EL element **210**X remains unchanged, but the luminance of organic EL element **210**X gradually decreases because resistance in organic EL element **210**X becomes higher over time. This causes screen burn-in in white display pixels displaying, for example, a menu screen.

[0085] In contrast, in organic EL display device **1** according to this embodiment, resistance element **10**, having resistance that increases at a higher rate than that of organic EL element **210** due to energization, is connected in parallel to organic EL element **210**.

[0086] With this, after the energization of organic EL element **210** by means of pixel circuit **120** which is a constant current circuit, the current which is supplied from pixel circuit **120** in accordance with the resistance ratio between organic EL element **210** and resistance element **10** is split, and a predetermined amount of current flows to organic EL element **210** and resistance element **10**, respectively. Accordingly, organic EL element **210** emits light.

[0087] Here, the resistance of organic EL element **210** and the resistance of resistance element **10** become higher as the resistance values thereof gradually increase over time due to deterioration after energization during normal operation, but the resistance of resistance element **10** increases, due to energization, at a higher rate than the resistance of organic EL element **210**. The resistance ratio between organic EL element **210** and resistance element **10** therefore automatically changes so that the resistance of resistance element **10** is higher than the resistance of organic EL element **210**. As a result, it is possible to increase a relative amount of energization for organic EL element **210** with respect to the amount of energization for resistance element **10**, as illustrated in (b) in FIG. **6**. With this, it is possible to prevent luminance decrease caused by the deterioration of organic EL element **210**. It is therefore possible to prevent screen burn-in due to the deterioration of organic EL elements **210**.

[0088] In particular, in organic EL display device **1** according to this embodiment, resistance element **10** is formed using one or more components that make up organic EL element **210** instead that a circuit element such as a resistor is separately mounted on organic EL display device **1**. More specifically, resistance element **10** is formed in the state where hole injection layer **212** and electron transport layer **214** are made close to or in contact with each other at the lateral wall of bank **220** in EL portion **200**.

[0089] This can achieve a small organic EL display device compared to the case of separately mounting a circuit element such as a resistor to be connected in parallel to organic EL element **210** in each pixel **110**.

[0090] Moreover, the amount of current that relatively flows to resistance element **10** connected in parallel to organic EL element **210** can be controlled by the concentration of barium doped in electron transport layer **214** in organic EL element **210**. This point will be described with reference to FIG. **7**. FIG. **7** is a diagram illustrating a change in the luminance of organic EL element **210** with respect to a period of energization time. In addition, FIG. **7** illustrates a change in luminance when the concentration of barium doped in electron transport layer **214** of organic EL element **210** is 5%, 20%, and 40%. Note that FIG. **7** shows experimental values.

[0091] As illustrated in FIG. **7**, the higher the concentration of barium doped in electron transport layer **214** of organic EL element **210** gets, the lower the luminance of organic EL element **210** becomes in a short period of energization time. In other words, organic EL element **210** can easily deteriorate as the concentration of barium doped in electron transport layer **214** of organic EL element **210** gets higher. That is to say that resistance easily becomes higher. This is because resistance change rate of electron transport layer **214** changes because of deterioration after energization, depending on the concentration of barium doped in electron transport layer **214**. Thus, it is possible to control the amount of current that relatively flows to resistance element **10**, by changing the concentration of barium doped in electron transport layer **214**.

[0092] Next, a method for manufacturing organic EL display device **1** according to this embodiment will be described with reference to FIG. **8**A through FIG. **8**L. FIG. **8**A through FIG. **8**L are each a cross-sectional view of a process in the method for manufacturing organic EL display device **1** according to this embodiment.

[0093] First, TFT substrate **100** is prepared, as illustrated in FIG. **8**A. TFT substrate **100** can be created, for example, by forming, on a substrate such as a glass substrate, circuit elements such as TFTs included in pixel circuit **120** and wirings, and covering the substrate with a planarization layer. Note that a contact hole is formed in a portion of the planarization layer. Through this contact hole, source electrode S2 of driving transistor DrTr in pixel circuit **120** of TFT substrate **100** is electrically connected to anode **211** of organic EL element **210**.

[0094] Next, anode **211** of organic EL element **210** is formed on TFT substrate **100**, as illustrated in FIG. **8**B. For example, an aluminum alloy film is formed on TFT substrate **100** by means of sputtering and anode **211** that is composed of aluminum alloy and has a predetermined shape can be formed through photolithograpy and etching

[0095] Next, bank **220** having opening **220***a* is formed, as illustrated in FIG. **8**C through FIG. **8**F. More specifically, bank **220** is formed to surround the region where anode **211** has been formed.

[0096] In this case, the entire surface of TFT substrate **100** is coated, for example, by applying resist film **220**M (e.g., a photosensitive resin) including a photoresist material, as the material of bank **220** to cover anode **211**, as illustrated in FIG. **8**C. Then, mask **230** having an opening is formed on resist film **220**M, resist film **220**M is subsequently exposed to light via mask **230**, and then, a predetermined portion of resist film **220**M is removed in a developing process using a developer so that anode **211** is exposed. Subsequently, heat treatment (e.g., bake process) of heating with the temperature ranging from 150 to 250 degrees Celsius is applied. With this heat treatment, the solvent remaining in resist film **220**M vaporizes. Thus, it is possible to form bank **220** having opening **220***a* that allows anode **211** to be exposed, as illustrated in FIG. **8**E. After that, mask **230** is removed as illustrated in FIG. **8**F. Note that liquid-repellent treatment may be applied on the surface of bank **220** where necessary.

[0097] Moreover, when a portion of resist film **220**M is removed using a developer so that opening **220***a* is formed, it is recommended that the portion of resist film **220**M be removed so that angle θ (taper angle) between the bottom plane of opening **220***a* (surface of anode **211**) and the lateral wall of bank **220** is greater than 90 degrees. In other words, it is recommended to make the lateral wall of bank **220** tilted so that the root of the lateral wall of bank **220** recedes more than the upper part of the lateral wall, by relatively increasing the amount of the portion to be removed from the root of bank **220**. Taper angle θ (tilt angle) of the lateral wall of bank **220** can be controlled, for example, by adjusting the conditions under which resist film **220**M is exposed to light.

[0098] Next, hole injection layer **212** is formed inside opening **220***a* of bank **220**. In this embodiment, hole injection layer **212** is formed on anode **211** by applying, inside opening **220***a* of bank **220**, first organic solvent **212**M that includes an organic material composing hole injection layer **212**, and then drying first organic solvent **212**M, as illustrated in FIG. **8**G and FIG. **8**H.

[0099] In this case, first organic solvent **212**M, in which the organic material composing hole injection layer **212** is dispersed, is firstly applied, as ink for printing and using inkjet printing method, inside opening **220***a* of bank **220**, where anode **211** is exposed, as illustrated in FIG. **8**G. Here, the surface of first organic solvent **212**M bulges from opening **220***a* of bank **220** and forms a spherical shape due to surface tension.

[0100] Note that the method of applying first organic solvent **212**M shall not be limited to inkjet printing method, and may be dispenser printing, nozzle coating, spin coating, letterpress printing, or intaglio printing method.

[0101] After that, first organic solvent **212**M is dried. It is possible to dry first organic solvent **212**M, for example, by applying heat treatment. With this, a solvent composition in first organic solvent **212**M vaporizes, and it is thus possible to form thin-filmed hole injection layer **212** along the inner surface of opening **220***a* of bank **220**, as illustrated in FIG. **8**H. More specifically, it is possible to form hole injection layer **212** that rides on bank **220**, extending from the bottom of opening **220***a* of bank **220** and along the lateral wall of bank **220**. Note that by controlling temperature or time when heat treatment is applied, or by controlling pressure inside a chamber in the case of applying heat treatment in the chamber, it is possible to transform bulging first organic solvent **212**M into hole injection layer **212** having desired thickness and shape.

[0102] Next, light-emitting layer **213** is formed inside opening **220***a* of bank **220**. In this embodiment, light-emitting layer **213** is formed on hole injection layer **212** by applying, inside opening **220***a* of bank **220**, second organic solvent **213**M that includes an organic material (light-emitting material) composing light-emitting layer **213**, and then drying second organic solvent **213**M, as illustrated in FIG. **8**I and FIG. **8**J.

[0103] In this case, second organic solvent **213**M, in which an organic material composing light-emitting layer **213** is dispersed, is applied, as ink for printing and using an inkjet printing method, inside opening **220***a* of bank **220**, where hole injection layer **212** has been formed. Here, the surface of second organic solvent **213**M bulges from opening **220***a* of bank **220** and forms a spherical shape due to surface tension.

[0104] Here, since the liquid repellency of second organic solvent **213**M for forming light-emitting layer **213** is higher than that of first organic solvent **212**M for forming hole injection layer **212**, curvature is greater in the surface of second organic solvent **213**M than in the surface of first organic solvent **212**M.

[0105] Moreover, although second organic solvent **213**M for forming light-emitting layer **213** (red-light emitting layer) of organic EL element for red color, second organic solvent **213**M for forming light-emitting layer **213** (green-light emitting layer) of organic EL element for green color, and second organic solvent **213**M for forming light-emitting layer **213** (blue-light emitting layer) of organic EL element for blue color are applied separately, it is also possible to apply these second organic solvents **213**M at the same time by using an ink-jet apparatus having plural heads,

[0106] Note that the method of applying second organic solvent **213**M shall not be limited to ink-jet printing method and may be dispenser printing, nozzle coating, spin coating, letterpress printing, or intaglio printing method.

[0107] After that, second organic solvent **213**M is dried. It is possible to dry second organic solvent **213**M, for example, by applying heat treatment. With this, a solvent composition in second organic solvent **213**M vaporizes and it is thus possible to form a thin-filmed light-emitting layer **213**, as illustrated in FIG. **8**J. More specifically, it is possible to form light-emitting layer **213** that rides on bank **220**, extending from the bottom of opening **220***a* of bank **220** and along the lateral wall of bank **220**, as is formed hole injection layer **212**. Note that by controlling temperature or time when heat treatment is applied, or by controlling pressure inside a chamber in the case of applying heat treatment in the chamber, it is possible to transform bulging second organic solvent **213**M into light-emitting layer **213** having desired thickness and shape.

[0108] Here, in this embodiment, light-emitting layer **213** is formed so that the ends of light-emitting layer **213** do not extend beyond the ends of hole injection layer **212**. More specifically, the tips of the ends of hole injection layer **212** either coincide with or are exposed from the tips of the ends of light-emitting layer **213**. It is possible to easily form such a structure by causing taper angle θ at the lateral wall of bank **220** illustrated in FIG. **8**F to be greater than 90 degrees. Moreover, as has already been mentioned above, by increasing the liquid repellency of second organic solvent **213**M for forming light-emitting layer **213** more than that of first organic solvent **212**M for forming hole injection layer **212**, it is possible to easily cause the tips of the ends of hole injection layer **212** to either coincide with or be exposed from the tips of the ends of light-emitting layer **213**.

[0109] Next, electron transport layer **214** is formed on light-emitting layer **213** to cover opening **220***a* of bank **220**, as illustrated in FIG. **8**K. An organic material made by adding barium to a low-molecular material can be used as the material of electron transport layer **214**. Electron transport layer **214** is formed on the entire surface covering light-emitting layer **213** and bank **220**, for example, using an evaporation method.

[0110] Here, since the tips of the ends of hole injection layer **212** either coincide with or are exposed from the tips of the ends of light-emitting layer **213**, hole injection layer **212** and electron transport layer **214** are close to or in contact with each other at the lateral wall of bank **220**. Thus, resistance element **10** is formed near a boundary between hole injection layer **212** and electron transport layer **214**.

[0111] Next, cathode **215** is formed on electron transport layer **214**, as illustrated in FIG. **8**L. It is possible to form cathode **215** composed of ITO film, for example, by forming ITO on electron transport layer **214** by means of sputtering.

[0112] In this way, it is possible to form organic EL element **210** having anode **211**, hole injection layer **212**, light-emitting layer **213**, electron transport layer **214**, and cathode **215**. Note that a sealing layer may be subsequently formed to cover the entire surface of cathode **215**. With this, it is possible to form EL portion **200** on TFT substrate **100**.

[0113] Note that organic EL display device **1** can be achieved by attaching, to EL portion **200** with an attaching layer, color-filter substrate **300** that has separately been created.

[0114] As has been described above, organic EL display device **1** according to this embodiment has, in each of pixels **110**, organic EL element **210** and resistance element **10** that is connected in parallel to organic EL element **210**. In addition, organic EL element **210** and resistance element **10** have properties such that resistance gradually increases over time after the energization of these elements. Moreover, the resistance of resistance element **10** changes at a rate higher than the resistance of organic EL element **210**.

[0115] With the configuration as described above, it is possible to automatically increase the amount of energization provided for organic EL element **210** as the deterioration of organic EL element **210** progresses due to the energization of organic EL element **210** during normal operation. Thus, it is possible to prevent luminance decrease caused by the deterioration of organic EL element **210**. As a result, it is possible to prevent screen burn-in caused by the deterioration of organic EL elements **210**.

Variations Etc.

[0116] Although a display device and a method for manufacturing the display device have been described based on the embodiment so far, the technology disclosed in the present disclosure shall not be limited to the aforementioned embodiment.

[0117] In the aforementioned embodiment, resistance element **10** is formed from one or more components making up organic EL element **210**, but shall not be limited to such. Resistance element **10** needs to be a variable resistance which increases over time. In this case, resistance element **10** shall not be limited to one whose resistance increases due to the deterioration of the material of organic EL element **210**.

[0118] Forms obtained by various modifications to the foregoing embodiment that can be conceived by a person skilled in the art as well as forms realized by arbitrarily combining components and functions in the embodiment within the scope of the essence of the present disclosure are included in the present disclosure.

[0119] Although only an exemplary embodiment of the present disclosure has been described in detail above, those skilled in the art will readily appreciate that many modifications are possible in the exemplary embodiments without materially departing from the novel teachings and advantages of the present disclosure. Accordingly, all such modifications are intended to be included within the scope of the present disclosure.

INDUSTRIAL APPLICABILITY

[0120] The present disclosure can be widely utilized for various electronic appliances such as a TV set, a personal computer, or a cell phone equipped with a display device (display panel) such as an organic EL display device.

1. A display device comprising:
a light-emitting element that is provided in each of pixels and emits light according to flow of current; and
a resistance element that is provided in each of the pixels and is connected in parallel to the light-emitting element, wherein
resistance of the light-emitting element and resistance of the resistance element increase over time after energization of the light-emitting element and the resistance element, and
the resistance of the resistance element changes at a higher rate than the resistance of the light-emitting element.

2. The display device according to claim **1**, wherein
the light-emitting element includes a first charge functional layer, a light-emitting layer disposed on the first charge functional layer, and a second charge functional layer disposed on the light-emitting layer, and
the resistance element is formed in a state where the first charge functional layer and the second charge functional layer are close to or in contact with each other.

3. The display device according to claim **2**, further comprising:
a bank that has an opening, wherein
the first charge functional layer and the light-emitting layer ride on the bank, extending from a bottom of the opening and along a lateral wall of the bank,
the second charge functional layer covers the opening, and
the resistance element is formed in a state where a portion of the first charge functional layer on the lateral wall of the bank and the second charge functional layer are close to or in contact with each other.

4. The display device according to claim **3**, wherein
an angle between a bottom plane of the opening and the lateral wall of the bank is greater than 90 degrees.

5. The display device according to claim **2**, wherein
resistance of the first charge functional layer is lower than the resistance of the light-emitting layer.

6. The display device according to claim **2**, wherein
the light-emitting layer has higher liquid repellency than liquid repellency of the first charge functional layer.

7. The display device according to claim **2**, wherein
the second charge functional layer includes barium.

8. The display device according to claim **2**, wherein
the first charge functional layer is a hole injection layer, and
the second charge functional layer is an electron transport layer.

9. The display device according to claim **1**, further comprising:
a constant current circuit that supplies current to the light-emitting element in each of the pixels.

10. The display device according to claim **9**, wherein
the constant current circuit has a driving transistor that controls current that flows to the light-emitting element, and a switching transistor that is connected to a control terminal of the driving transistor and controls conduction and non-conduction of the driving transistor.

11. The display device according to claim **1**, wherein
the light-emitting element is an organic electroluminescent (EL) element.

12. A method of manufacturing a display device, the method comprising:
forming a bank that has an opening;
forming a first charge functional layer by applying a first material inside the opening and drying the first material applied;
forming a light-emitting layer on the first charge functional layer by applying a second material inside the opening and drying the second material applied; and
forming a second charge functional layer on the light-emitting layer to cover the opening, wherein
the first charge functional layer and the second charge functional layer are close to or in contact with each other at a lateral wall of the bank.

* * * * *

patsnap

专利名称(译)	显示装置和制造显示装置的方法
公开(公告)号	US20190088725A1
公开(公告)日	2019-03-21
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申请(专利权)人(译)	JOLED INC.
当前申请(专利权)人(译)	JOLED INC.
[标]发明人	YAMAMOTO HIROKI
发明人	YAMAMOTO, HIROKI
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摘要(译)

一种显示装置，包括：有机EL元件，设置在每个像素中并根据电流流动发光;电阻元件设置在每个像素中并且与有机EL元件并联连接。在发光元件和电阻元件通电之后，发光元件的电阻和电阻元件的电阻随时间增加。电阻元件的电阻高于有机EL元件的电阻。