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(54) **ORGANIC EL DISPLAY PANEL AND METHOD OF MANUFACTURING ORGANIC EL DISPLAY PANEL**

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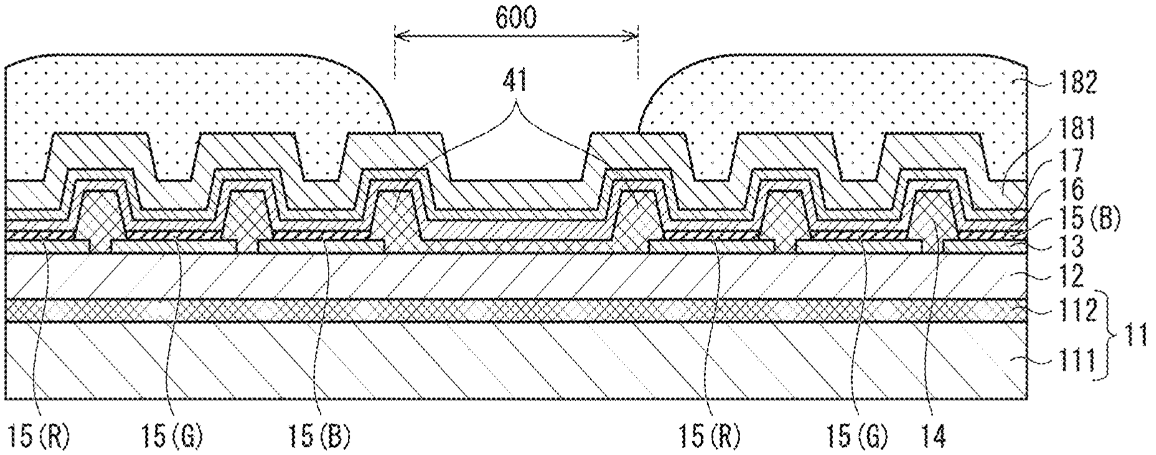
(57) **ABSTRACT**

An organic electroluminescence (EL) display panel includes a substrate; first electrodes spaced away from each other and arrayed in rows and columns above the substrate; light-emitting layers including organic light-emitting material and disposed above the first electrodes; a second electrode disposed above the light-emitting layers; a first protection layer including resin and disposed above the second electrode but not within an auxiliary region which, in plan view, extends in a column direction between ones of the first electrodes that are adjacent in a row direction across the substrate; a second protection layer including inorganic material and disposed above the first protection layer and the second electrode; and an auxiliary electrode layer extending in the column direction within the auxiliary region and electrically connecting to the second electrode through a contact opening in the first protection layer within the auxiliary region.



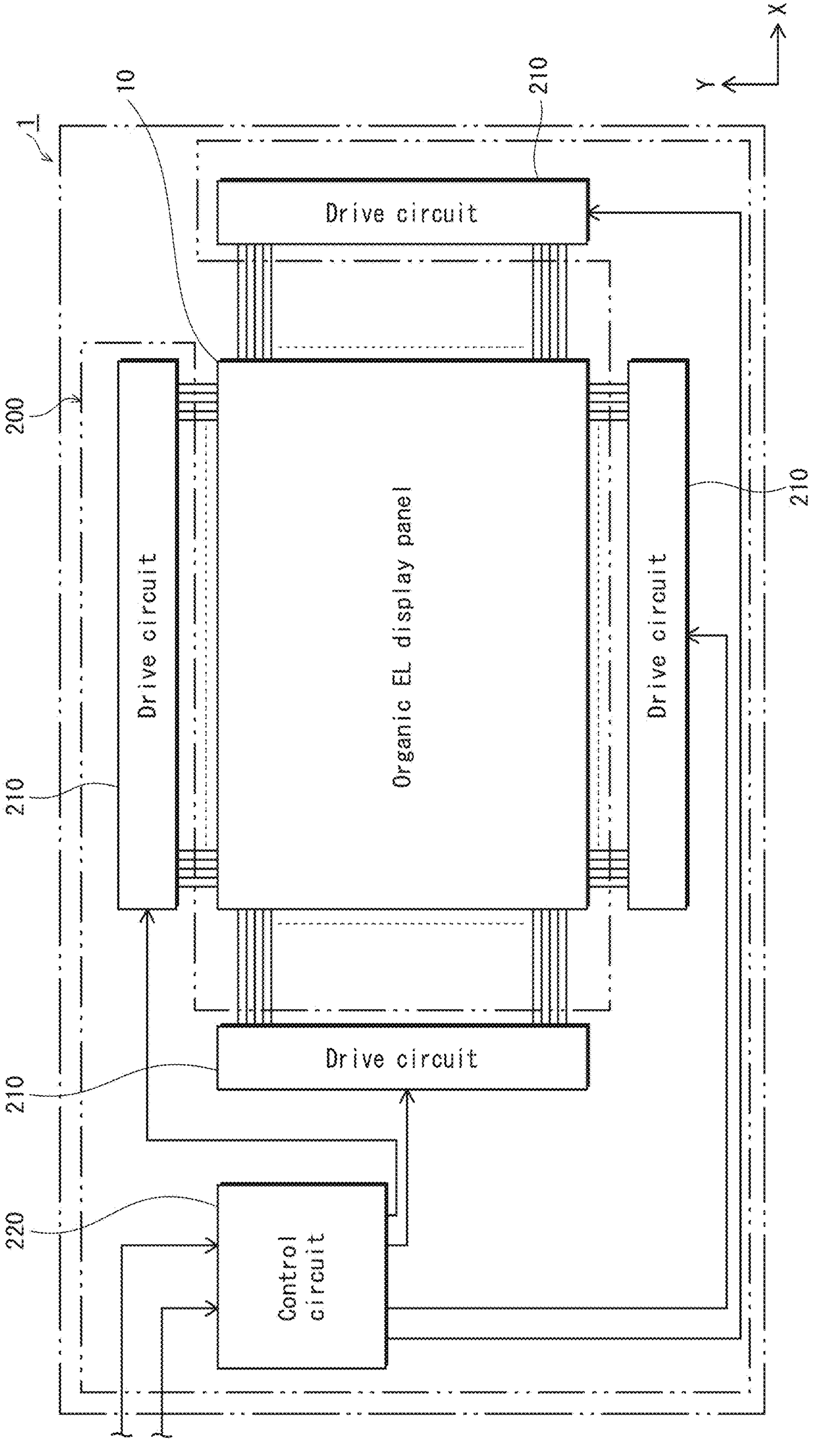
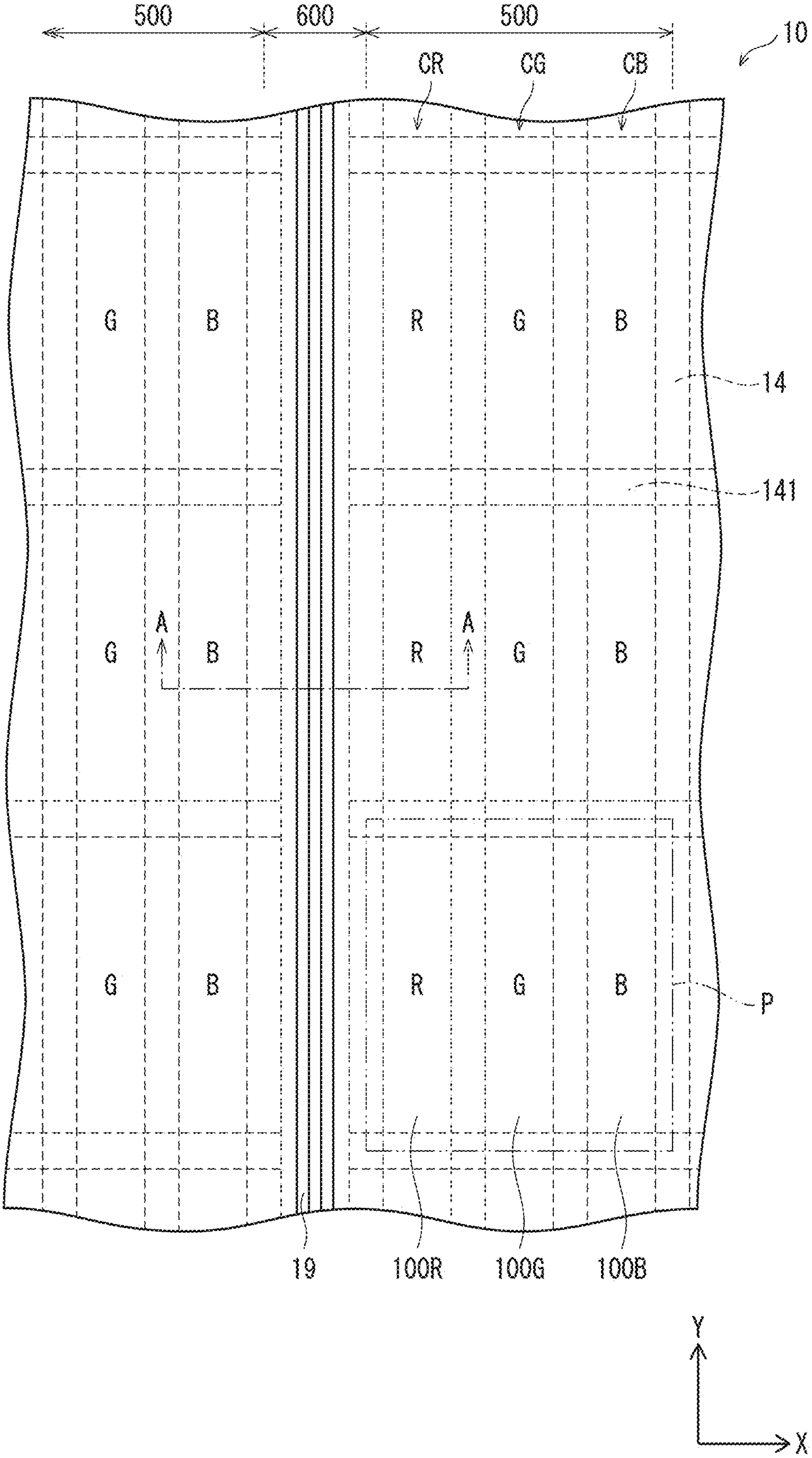

1
10
200
210
210
210
210
220
X
Y
Drive circuit
Drive circuit
Drive circuit
Drive circuit
Organic EL display panel
Control circuit

FIG. 1

FIG. 2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600
500
10
CR
CG
CB
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B
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G
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G
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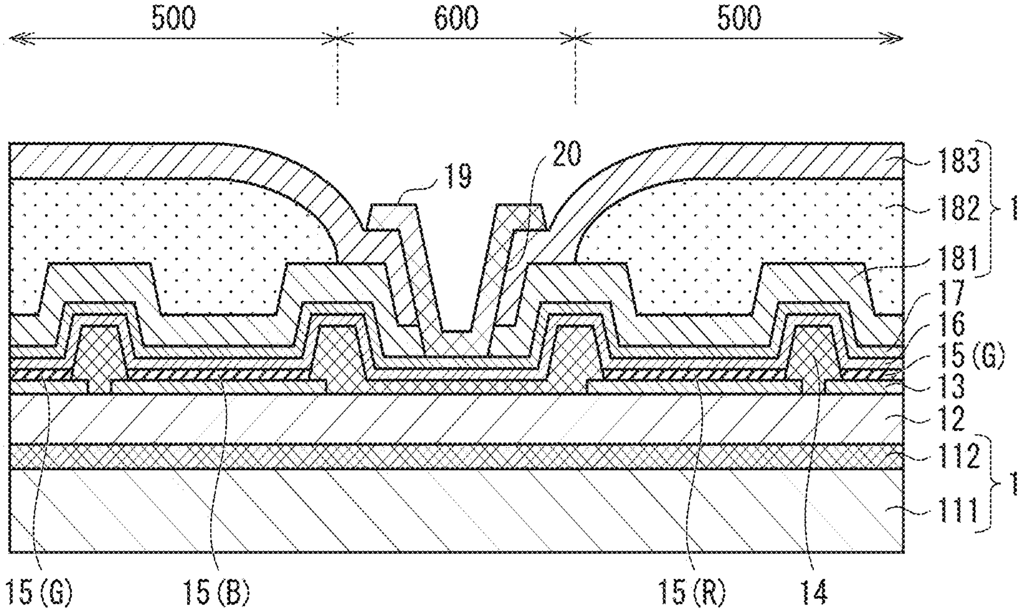
R
G
B
P
19
100R
100G
100B
Y
X

FIG. 3


500
600
500
19
20
183
182
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16
15(G)
13
12
112
11
111
15(G)
15(B)
15(R)
14

FIG. 4

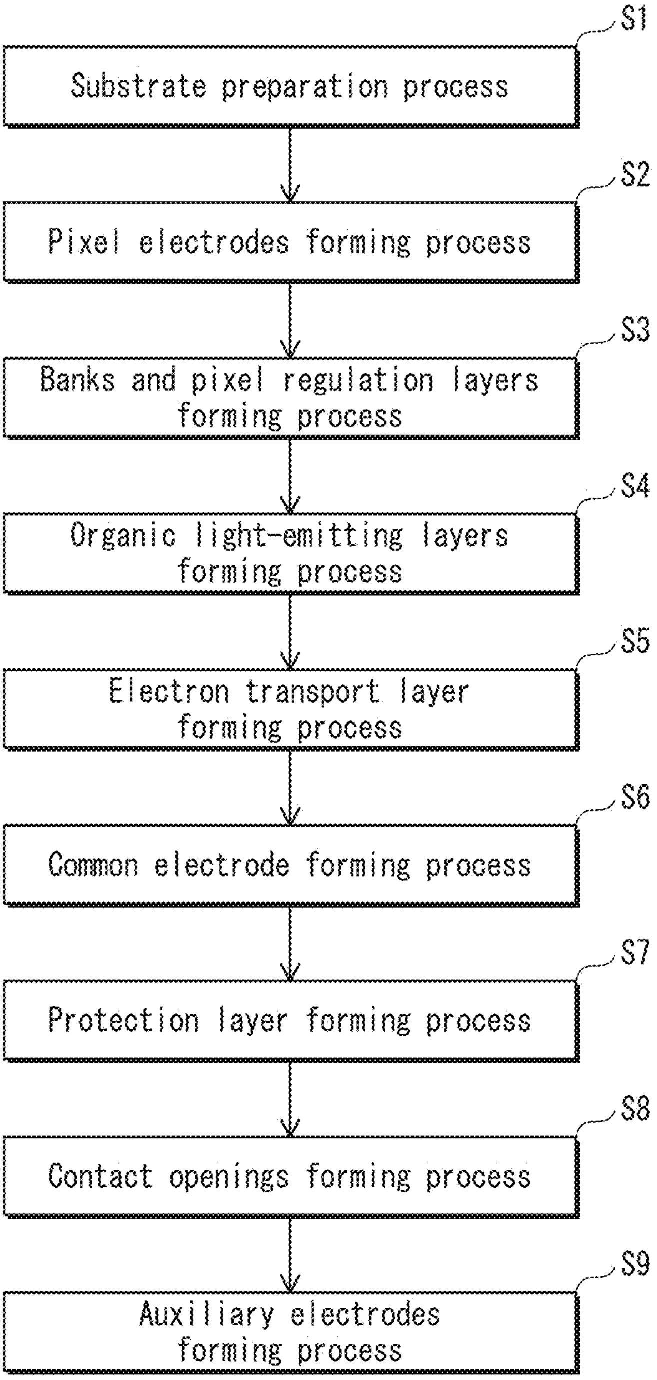

S1
Substrate preparation process
S2
Pixel electrodes forming process
S3
Banks and pixel regulation layers forming process
S4
Organic light-emitting layers forming process
S5
Electron transport layer forming process
S6
Common electrode forming process
S7
Protection layer forming process
S8
Contact openings forming process
S9
Auxiliary electrodes forming process

FIG. 5A

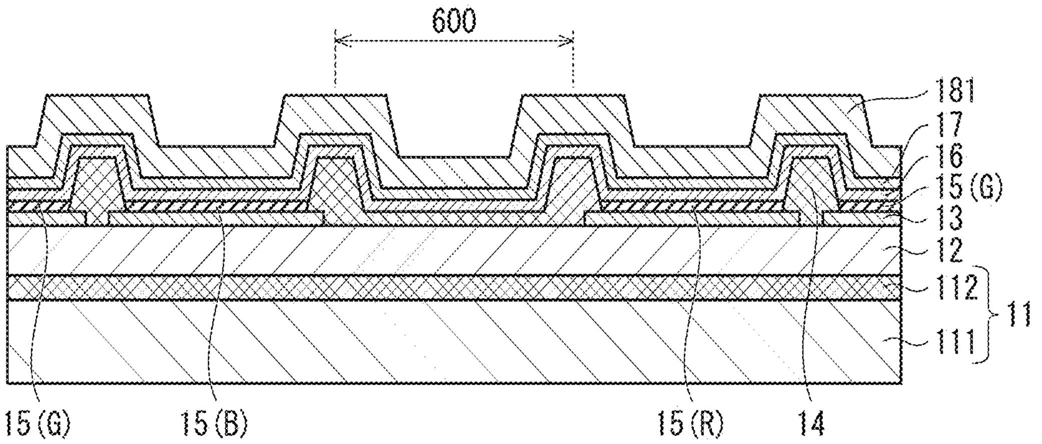


FIG. 5B

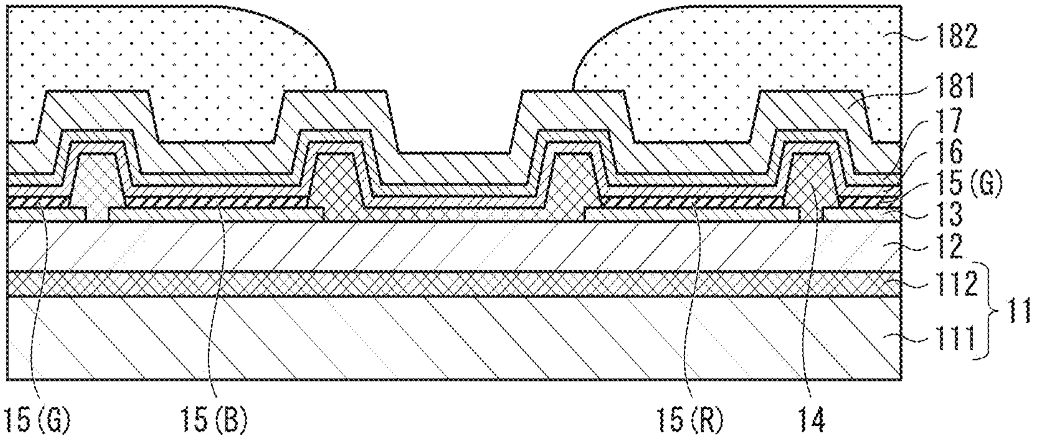


FIG. 5C

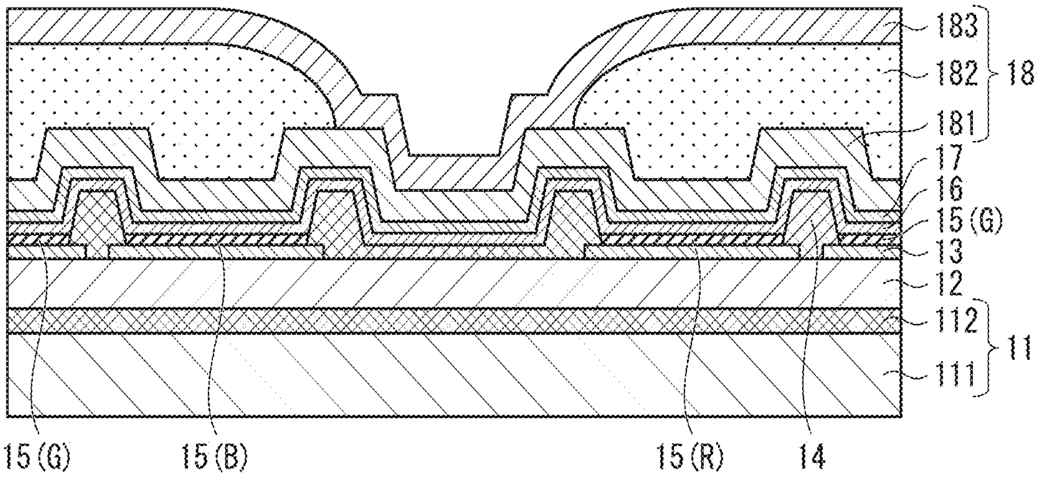


FIG. 6A

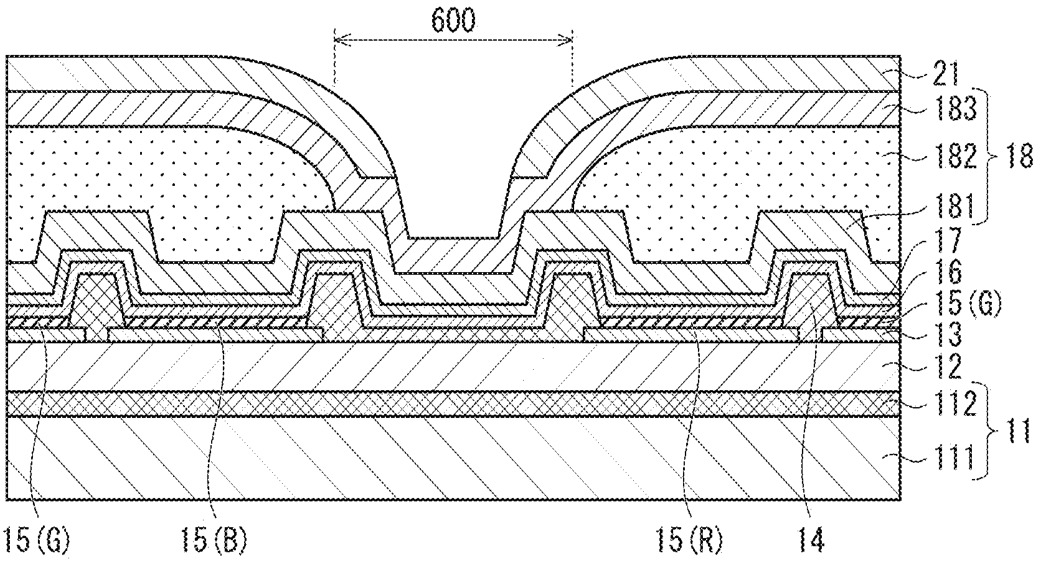


FIG. 6B

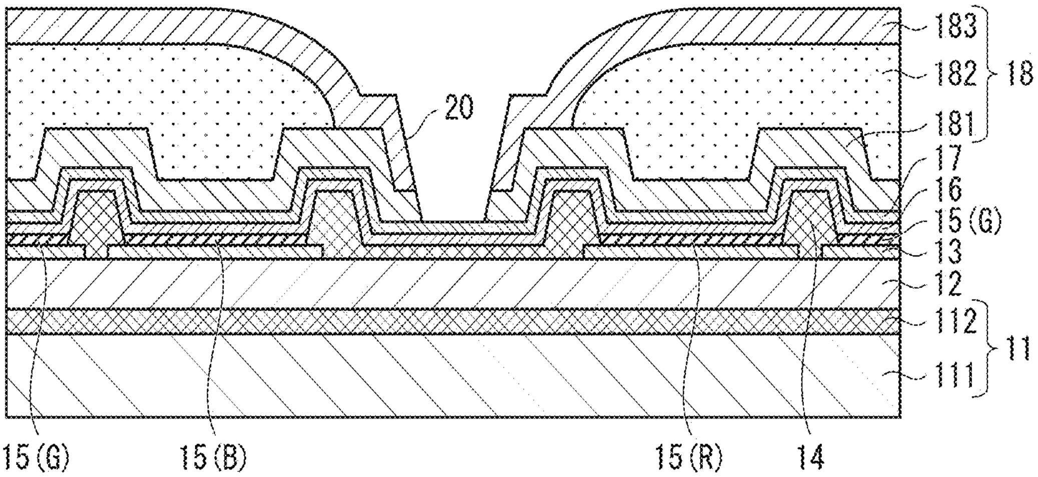


FIG. 6C

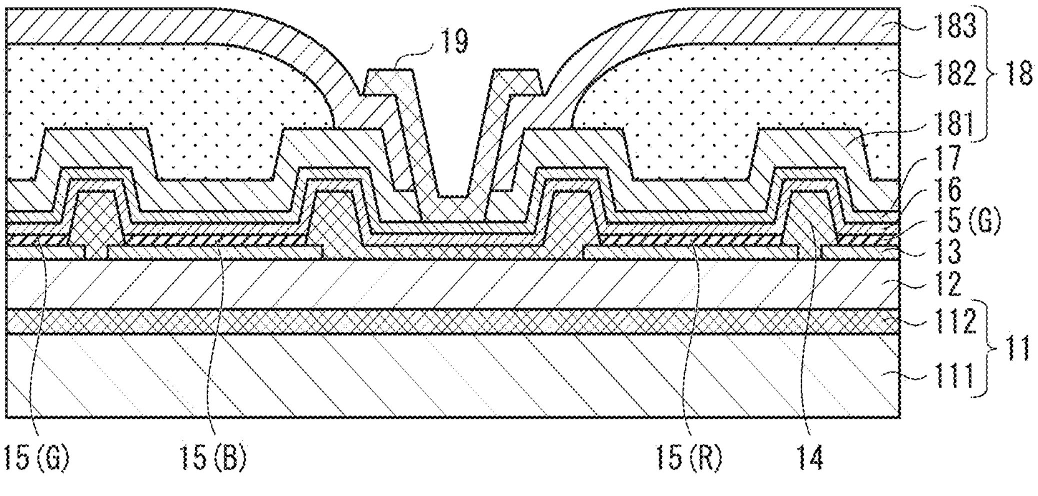


FIG. 7A

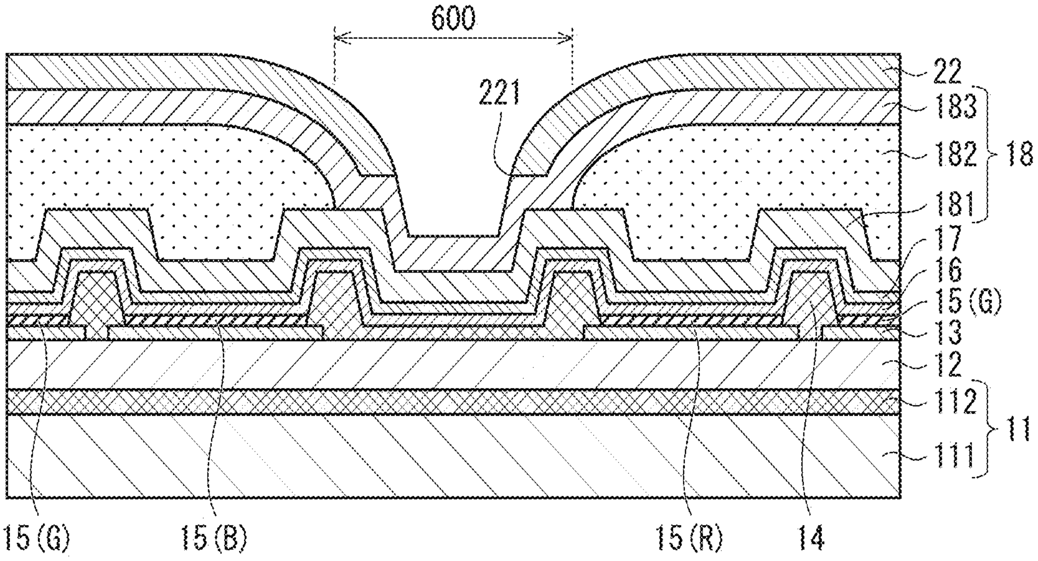


FIG. 7B

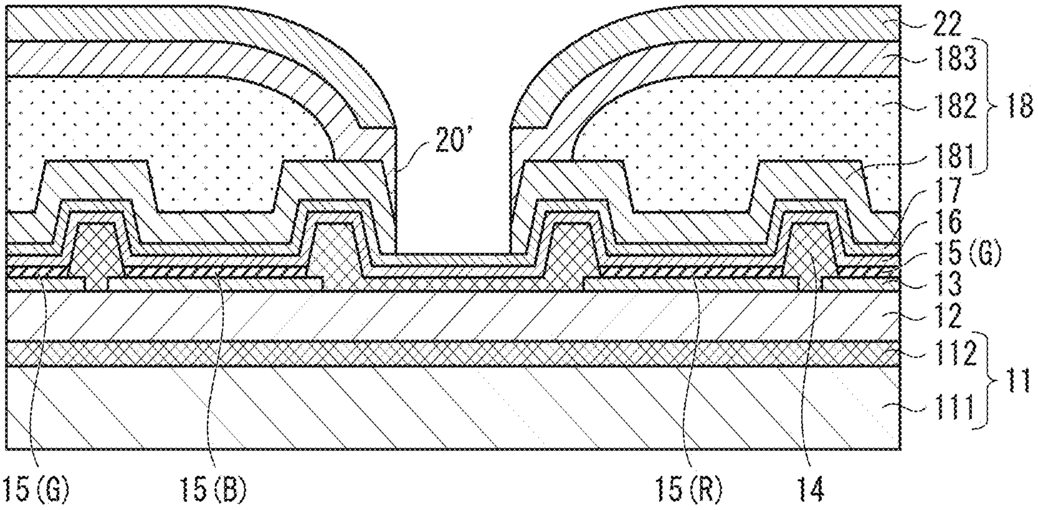
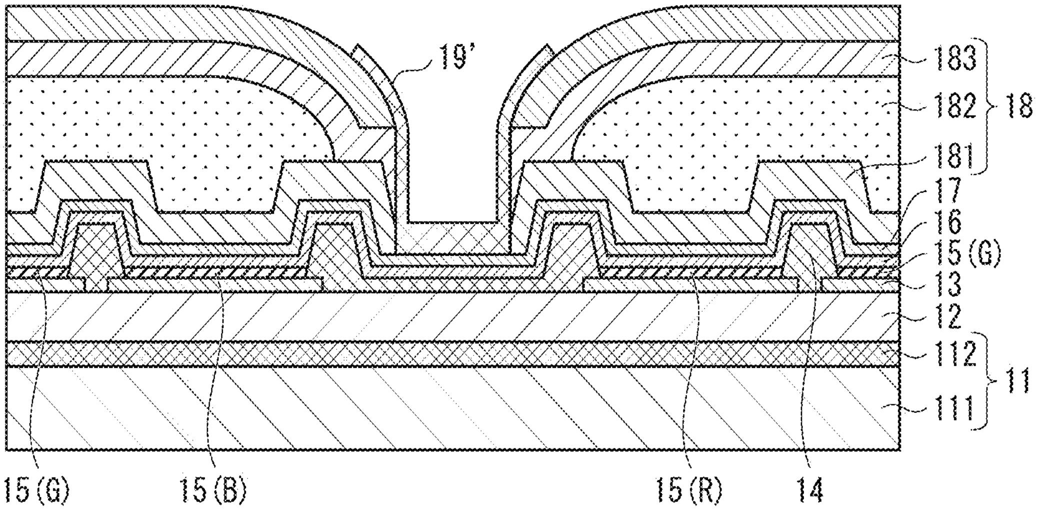
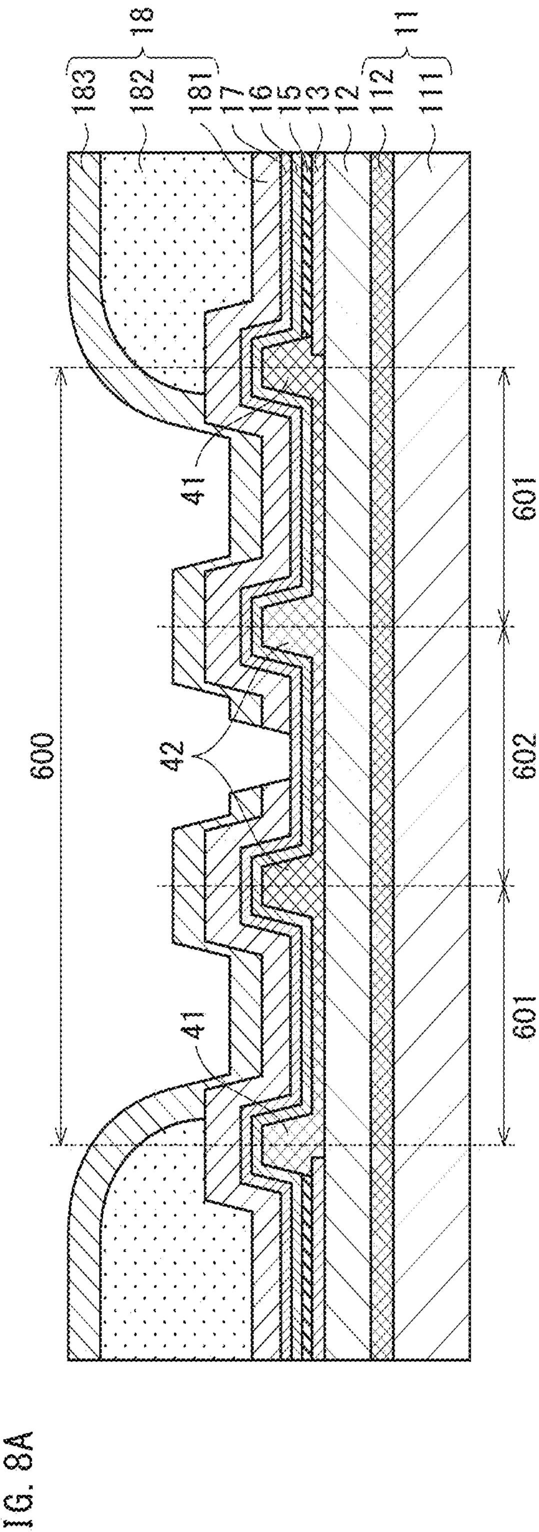


FIG. 7C




183
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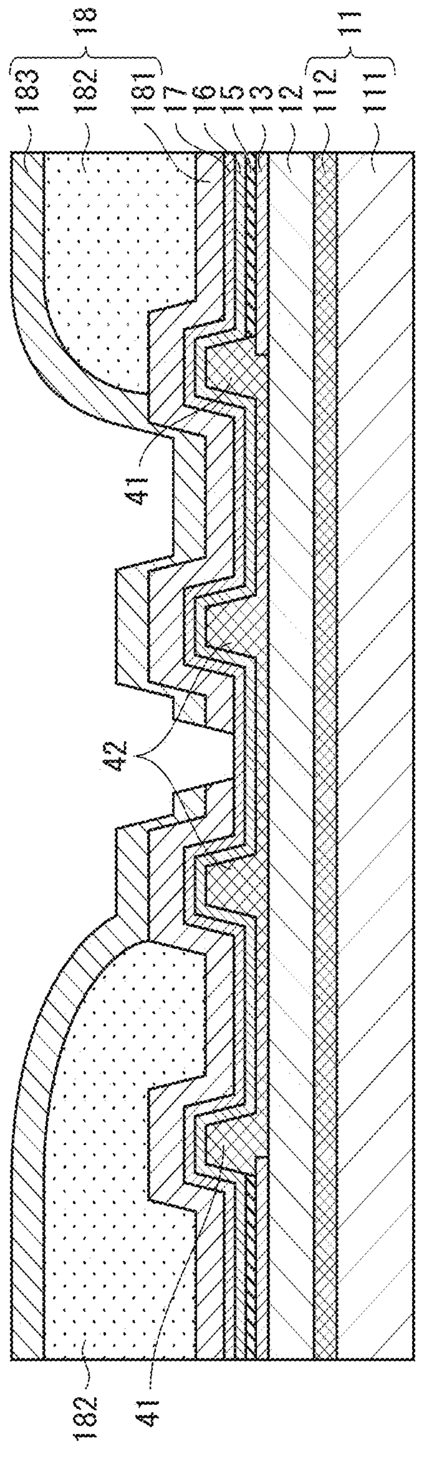
601
602
601

FIG. 8A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112
111
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182
41

FIG. 8B

FIG. 9A

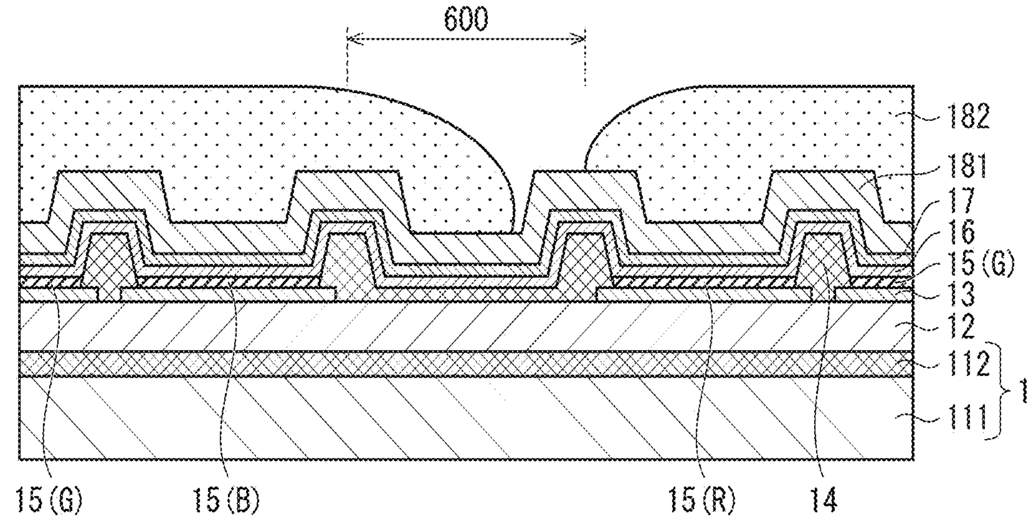

600
182
181
17
16
15(G)
13
12
112
11
111
15(G)
15(B)
15(R)
14

FIG. 9B

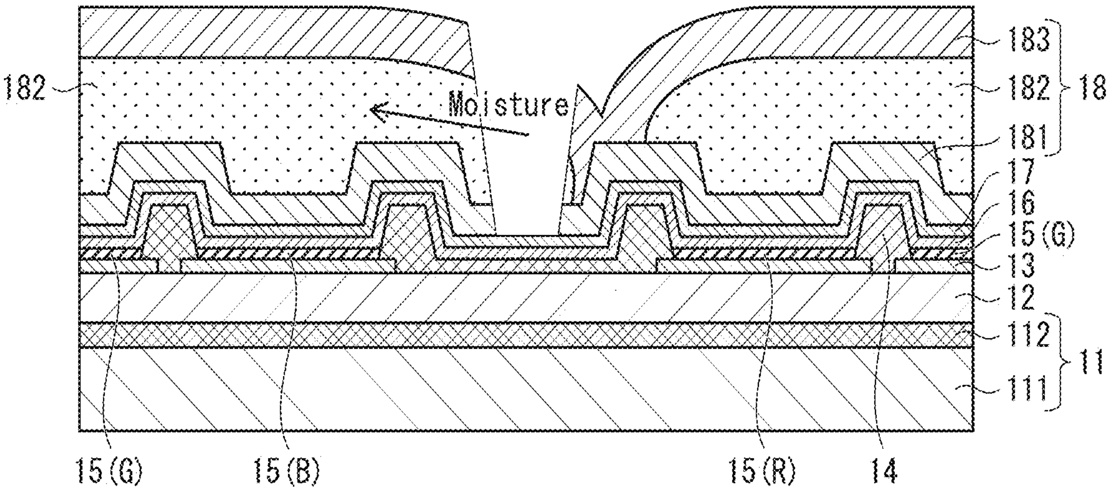

183
182
18
181
182
Moisture
17
16
15(G)
13
12
112
11
111
15(G)
15(B)
15(R)
14

FIG. 10

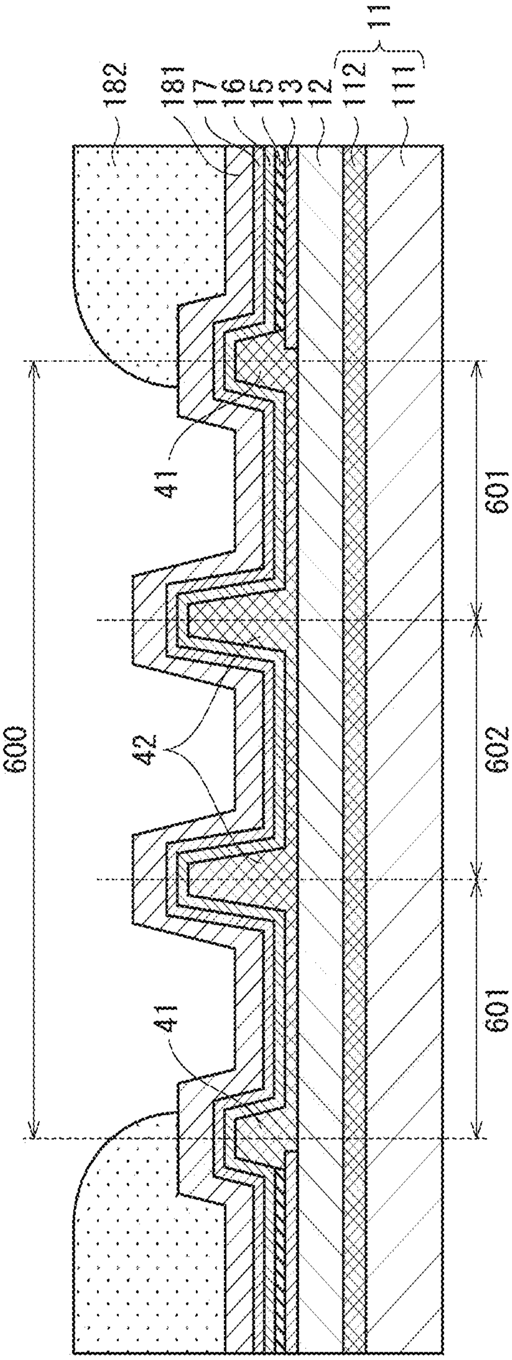
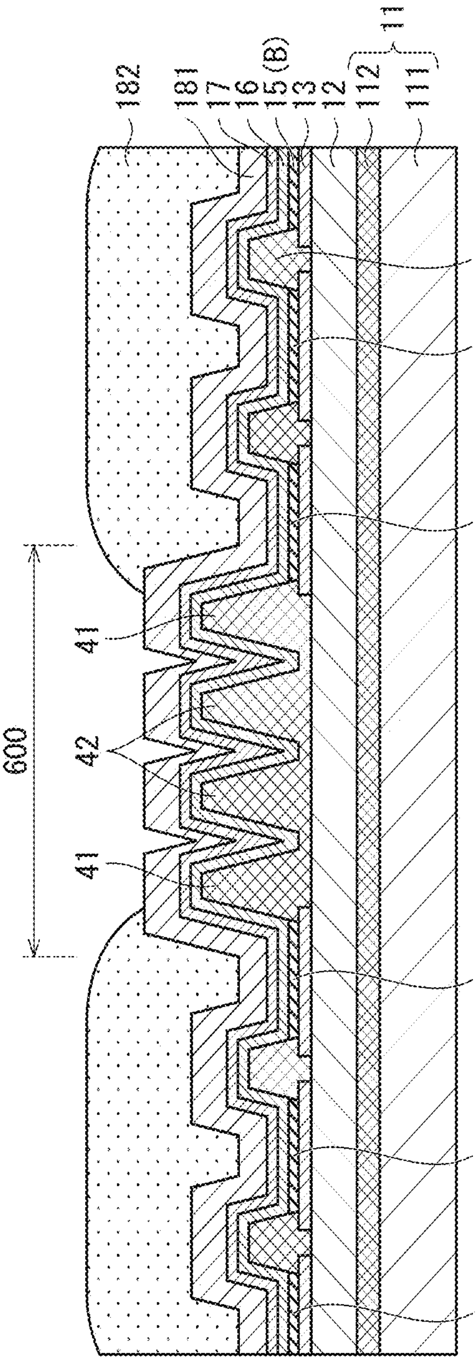


FIG. 11


182
181
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15(B)
13
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112
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15(G)
15(R)
41
42
600
41
15(B)
15(G)
15(R)

FIG. 12

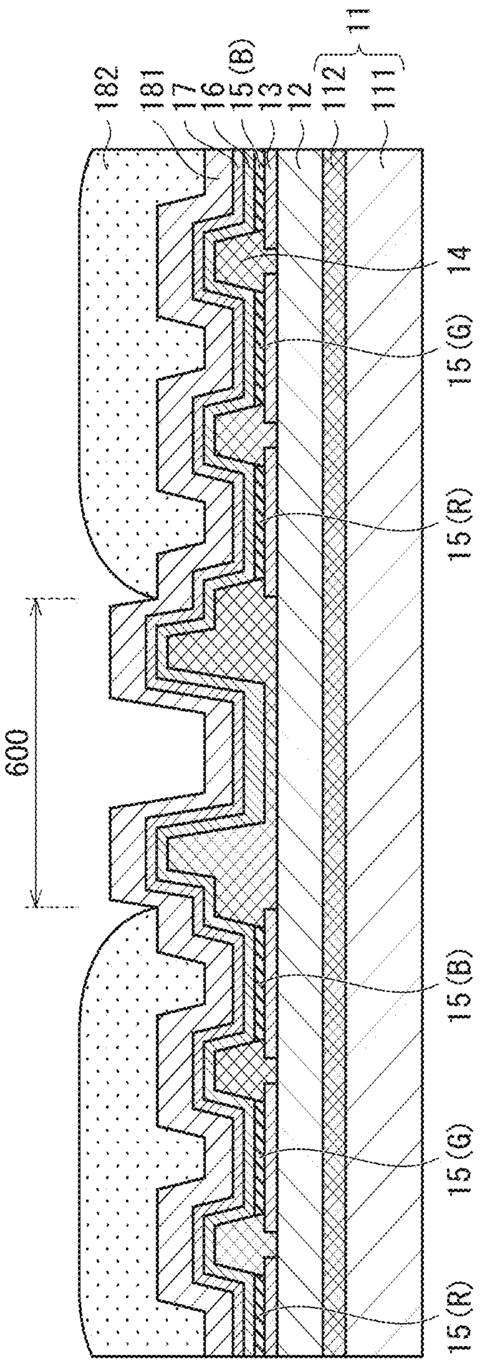


FIG. 13

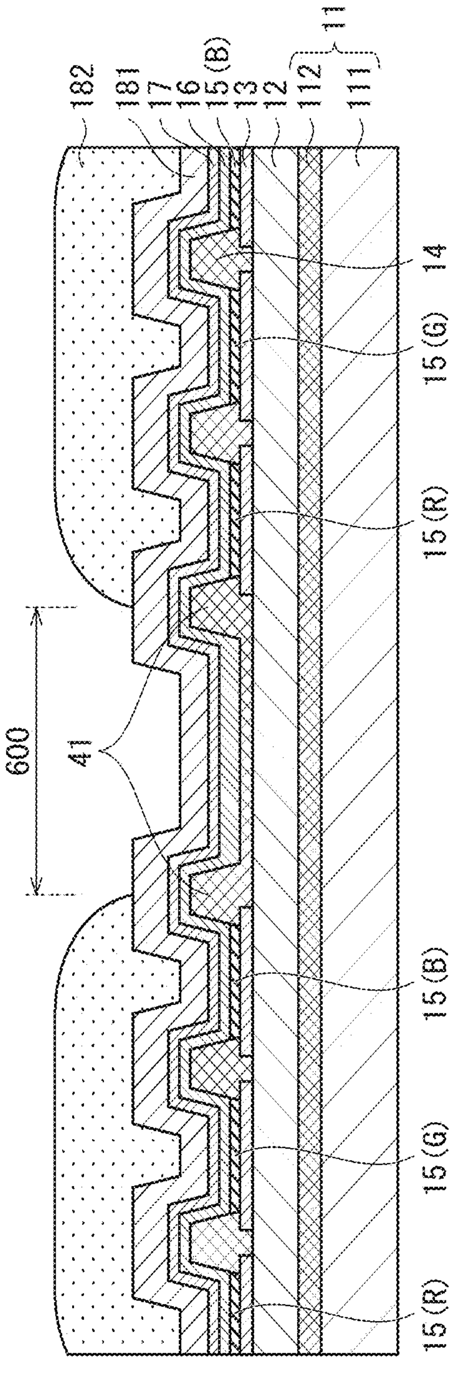


FIG. 14

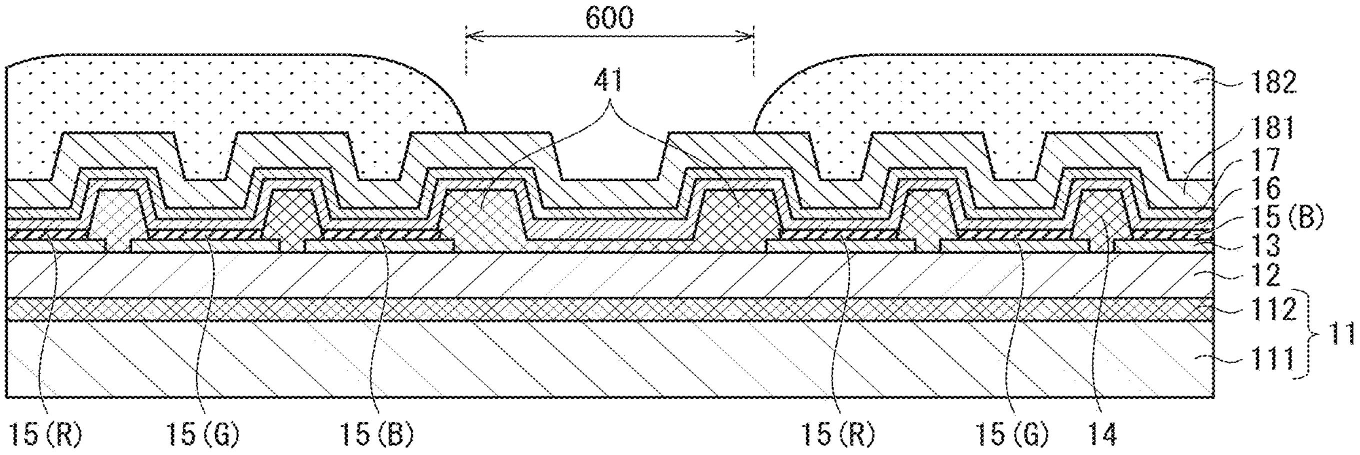


FIG. 15

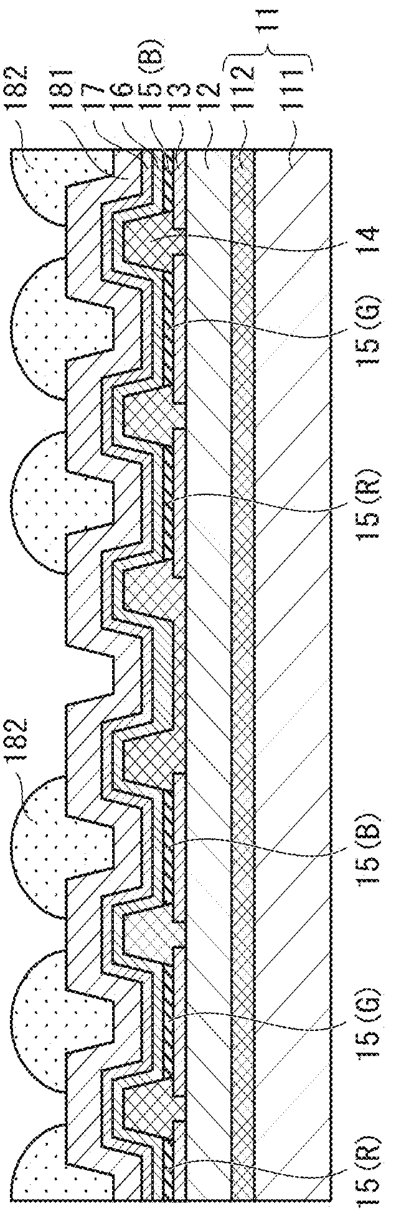
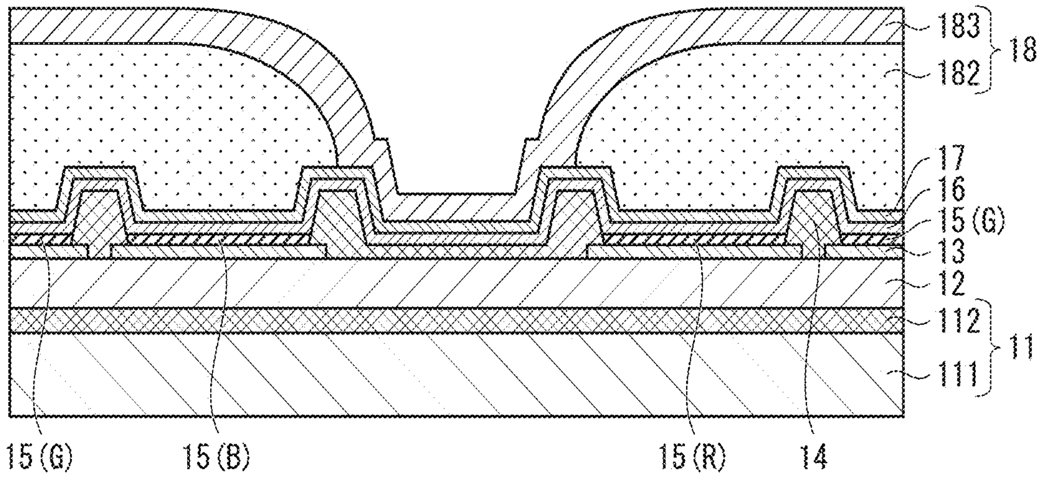


FIG. 16


183
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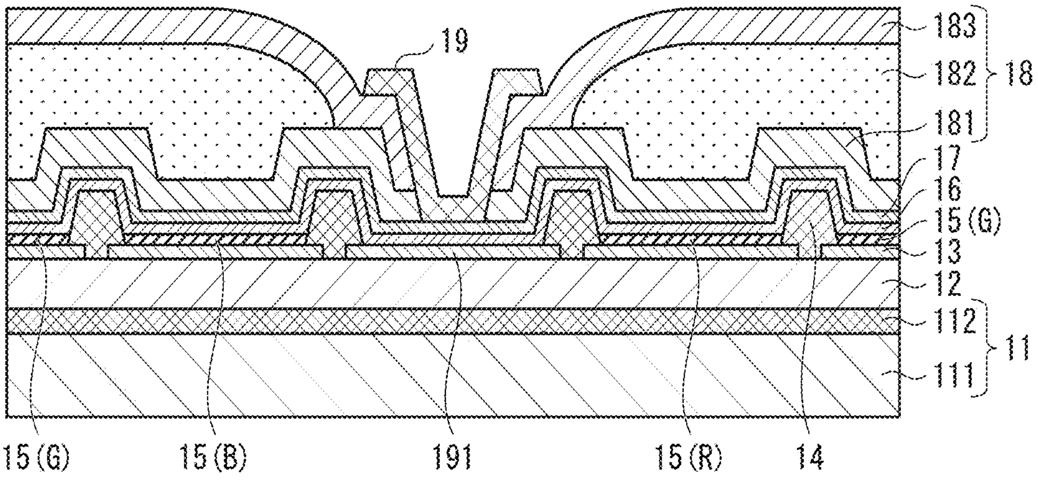
15(G)
15(B)
15(R)
14

FIG. 17


19
183
182
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15(G)
15(B)
191
15(R)
14

FIG. 18A

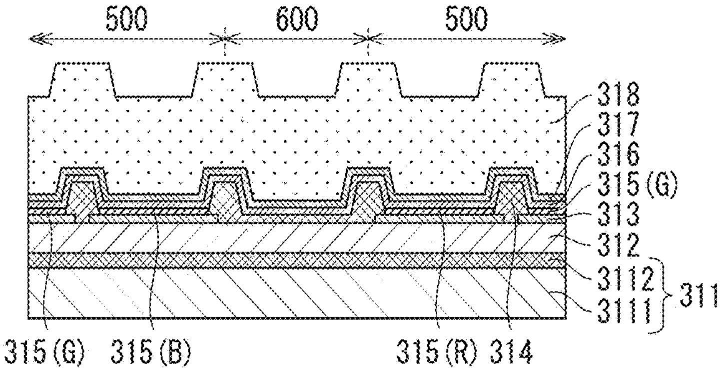


FIG. 18B

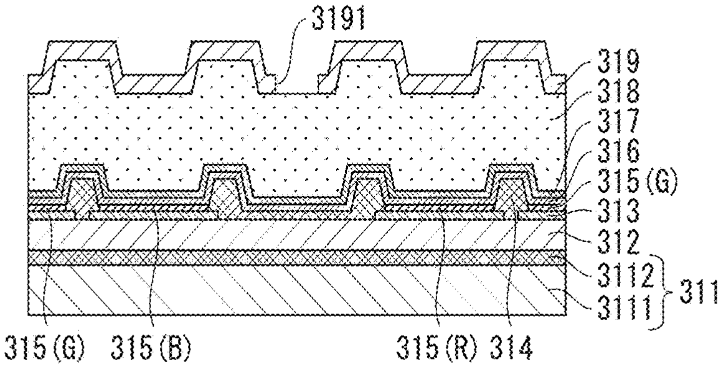


FIG. 18C

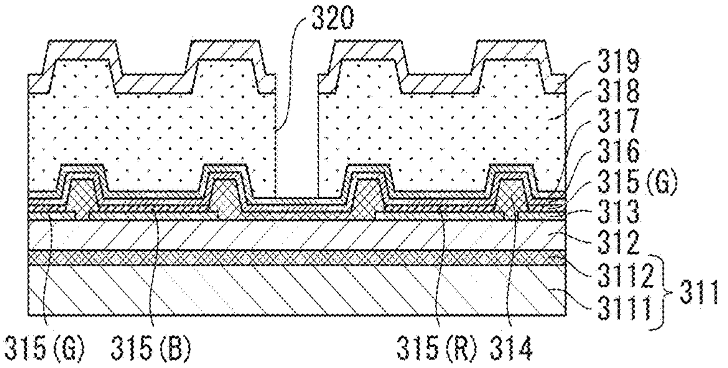


FIG. 18D

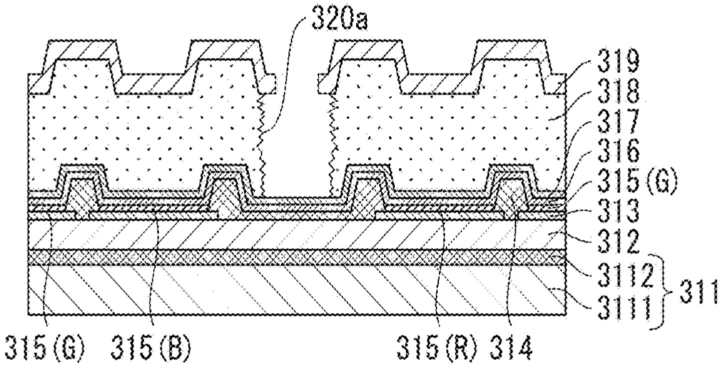
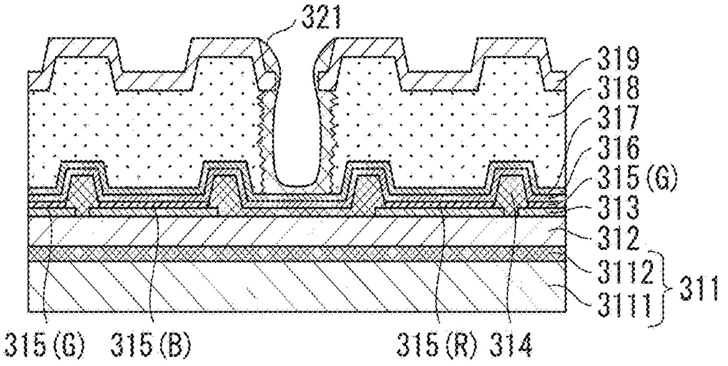


FIG. 18E



ORGANIC EL DISPLAY PANEL AND METHOD OF MANUFACTURING ORGANIC EL DISPLAY PANEL

[0001] This application claims priority to Japanese Patent Application No. 2018-098836 filed May 23, 2018, the contents of which are hereby incorporated by reference in its entirety.

BACKGROUND

Technical Field

[0002] The present disclosure relates to an organic electroluminescence (EL) display panel that makes use of electroluminescence of an organic material and a method of manufacturing such an organic EL display panel.

Description of Related Art

[0003] Recently, as display panels used for display devices such as digital televisions, organic EL display panels in which a plurality of organic EL elements are arranged in a matrix on a substrate are in practical use.

[0004] In a typical organic EL display panel, light-emitting layers of the organic EL elements are partitioned from adjacent organic EL elements by banks made of an electrically-insulating material. In an organic EL display panel for color display, the organic EL elements form subpixels each emitting light of one of red (R), green (G), and blue (B) (hereinafter simply referred to as R, G, and B), and each combination of adjacent ones of the subpixels of R, G, and B forms a unit pixel in color display.

[0005] The organic EL elements each have a basic structure in which a light-emitting layer including an organic light-emitting material (organic light-emitting layer) between a pair of electrodes, and when driven, a voltage is applied between the pair of electrodes and light emission is achieved in accordance with recombination of holes and electrons injected into the light-emitting layer.

[0006] A top-emission type organic EL element has an element structure in which a pixel electrode, organic layers (including the light-emitting layer), and a common electrode are disposed in this order on the substrate. Light emitted from the light-emitting layer is reflected at the pixel electrode made of a light-reflective material and is emitted upwards from the common electrode made of a light-transmissive material. The common electrode often spans over an entire surface of an image display region on the substrate.

[0007] In accordance with development of organic EL display panels of greater sizes for use in large-screen display devices such as televisions, electrical resistance of the common electrode may become greater and light-emitting efficiency may deteriorate in portions that are distant from an electric power supply portion because of insufficient supply of current due to voltage decline, and consequently luminance unevenness may occur.

[0008] In view of this, for example, in Japanese Patent Application Publication No. 2006-261058, an electrically-conductive electrode (auxiliary electrode) is disposed on a protection layer on the common electrode and suppresses voltage decline in the common electrode by electrically connecting the auxiliary electrode and the common electrode through a contact hole in the protection layer.

[0009] However, the protection layer typically is made of an inorganic material such as silicon nitride (SiN). Such inorganic materials have a great light-transmittance, moisture tolerance, and electrically-insulating property, but also have a disadvantage that cracks appear easily. Accordingly, in order to sufficiently protect the organic EL elements, the protection layer needs to have a relatively great film thickness.

[0010] Due to this, a time period required for forming the contact holes (task time) is long, and consequently states of inner side surfaces of the contact holes deteriorate and even when a metal for the auxiliary electrodes is vapor-deposited, sufficient coverage (covered area) of a metal layer cannot be obtained. As a result, the auxiliary electrodes have great electrical resistance and insufficient electrical connection to the common electrode.

SUMMARY

[0011] An organic EL display panel pertaining to at least one embodiment of the present disclosure includes a substrate. the organic EL display panel further includes a plurality of first electrodes that are spaced away from each other and are arrayed in rows and columns above the substrate. The organic EL display panel further includes a plurality of light-emitting layers that include organic light-emitting material and are disposed above the first electrodes. The organic EL display panel further includes a second electrode that is disposed above the light-emitting layers. The organic EL display panel further includes a first protection layer that includes resin and is disposed above the second electrode and is not disposed within an auxiliary region which, in plan view, extends in a column direction between ones of the first electrodes that are adjacent in a row direction across the substrate. The organic EL display panel further includes a second protection layer that includes inorganic material and is disposed above the first protection layer and the second electrode. The organic EL display panel further includes an auxiliary electrode layer that extends in the column direction within the auxiliary region and is electrically connected to the second electrode through a contact opening in the first protection layer within the auxiliary region.

[0012] An organic EL display panel manufacturing method pertaining to at least one embodiment of the present disclosure includes preparing a substrate. The method further includes forming a plurality of first electrodes that are spaced away from each other and are arrayed in rows and columns above the substrate. The method further includes forming a plurality of light-emitting layers that include organic light-emitting material above the first electrodes. The method further includes forming a second electrode above the light-emitting layers. The method further includes forming a first protection layer through applying resin material above the second electrode excluding an auxiliary region which, in plan view, extends in a column direction between ones of the first electrodes that are adjacent in a row direction across the substrate. The method further includes forming a second protection layer through applying inorganic material above the first protection layer and the second electrode. The method further includes forming a contact opening in the second protection layer within the auxiliary region. The method further includes forming an auxiliary electrode layer within the auxiliary region in the column direction, the auxiliary electrode layer electrically connecting to the second electrode through the contact opening.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] These and other objects, advantages, and features of the technology pertaining to the present disclosure will become apparent from the following description thereof taken in conjunction with the accompanying drawings, which illustrate at least one embodiment of the technology pertaining to the present disclosure. In the drawings:

[0014] FIG. **1** is a block diagram of an overall structure of an organic EL display device **1** pertaining to at least one embodiment;

[0015] FIG. **2** is a schematic plan diagram in which a part of an image display surface of an organic EL display panel pertaining to at least one embodiment is enlarged;

[0016] FIG. **3** is a schematic cross-sectional diagram of the organic EL display panel pertaining to at least one embodiment, taken along line A-A in FIG. **2**;

[0017] FIG. **4** is a flowchart of processes of manufacturing the organic EL display panel pertaining to at least one embodiment;

[0018] FIG. **5**A, FIG. **5**B, and FIG. **5**C are each a partial cross-sectional diagram schematically illustrating a part of processes of manufacturing organic EL elements pertaining to at least one embodiment;

[0019] FIG. **6**A, FIG. **6**B, and FIG. **6**C are each a partial cross-sectional diagram schematically illustrating a part of processes of manufacturing the organic EL elements pertaining to at least one embodiment, continuing from FIG. **5**C;

[0020] FIG. **7**A, FIG. **7**B, and FIG. **7**C are each a partial cross-sectional diagram schematically illustrating a part of processes of manufacturing contact openings in organic EL elements pertaining to at least one embodiment;

[0021] FIG. **8**A and FIG. **8**B are schematic cross-sectional diagrams illustrating a partition structure of auxiliary electrode forming regions pertaining to at least one embodiment;

[0022] FIG. **9**A and FIG. **9**B are schematic cross-sectional diagrams illustrating risks that may occur when dam banks in FIG. **8**A and FIG. **8**B pertaining to at least one embodiment are not present;

[0023] FIG. **10** is a schematic cross-sectional diagram illustrating a partition structure of auxiliary electrode forming regions pertaining to at least one embodiment;

[0024] FIG. **11** is a schematic cross-sectional diagram illustrating a partition structure of auxiliary electrode forming regions pertaining to at least one embodiment;

[0025] FIG. **12** is a schematic cross-sectional diagram illustrating a partition structure of auxiliary electrode forming regions pertaining to at least one embodiment;

[0026] FIG. **13** is a schematic cross-sectional diagram illustrating a partition structure of auxiliary electrode forming regions pertaining to at least one embodiment;

[0027] FIG. **14** is a schematic cross-sectional diagram illustrating a partition structure of auxiliary electrode forming regions pertaining to at least one embodiment;

[0028] FIG. **15** is a schematic cross-sectional diagram illustrating second protection sublayers in a protection layer pertaining to at least one embodiment;

[0029] FIG. **16** is a schematic cross-sectional diagram illustrating at least one embodiment in a case where the protection layer does not include a first protection sublayer;

[0030] FIG. **17** is a schematic cross-sectional diagram illustrating at least one embodiment in a case where second auxiliary electrodes are disposed below an electron transport layer; and

[0031] FIG. **18**A, FIG. **18**B, FIG. **18**C, FIG. **18**D, and FIG. **18**E are each a schematic cross-sectional diagram of a part of processes of forming a hypothetical organic EL display panel for describing circumstances leading to an embodiment of the present disclosure.

DETAILED DESCRIPTION

<<Circumstances Leading to Embodiments of Present Disclosure>>

[0032] FIG. **18**A, FIG. **18**B, FIG. **18**C, FIG. **18**D, and FIG. **18**E are schematic cross-sectional diagrams of processes of manufacturing auxiliary electrodes in a hypothetical organic EL display panel.

[0033] FIG. **18**A is a schematic cross-sectional diagram of a portion of an organic EL display panel before forming of the auxiliary electrodes. In FIG. **18**A, an interlayer insulating layer **312** is formed on a substrate **311** including a base member **3111** and a thin film transistor (TFT) layer **3112**, a plurality of banks **314** are formed on the interlayer insulating layer **312**, and pixel electrodes **313** and light-emitting layers **315** are formed in regions between adjacent banks **314** excluding auxiliary electrode forming regions **600** to form light-emitting regions **500**.

[0034] An electron transport layer **316** and a common electrode **317** are laminated to span over the auxiliary electrode forming regions **600** and the light-emitting regions **500**, and a protection layer **318** is formed above the common electrode **317** to protect organic EL elements below the protection layer **318**.

[0035] Typically, the protection layer **318** has a single-layered or multi-layered structure in which an inorganic material such as silicon nitride are deposited through vapor deposition or sputtering. Cracks easily appear in such an inorganic layer, and such an inorganic layer needs to have a relatively great film thickness (for example, a film thickness from 2 μm to 10 μm) such that the inorganic layer is laminated to cover any minute impurity on the common electrode **317** and the protection layer has a sufficient liquid proofing.

[0036] When forming the contact holes in the auxiliary electrode forming regions **600** of the protection layer **318**, first, a mask **319** having a resistance against etching (hereinafter referred to as “hard mask”; mainly an ITO film) is formed on an upper surface of the protection layer **318**, and the hard mask is patterned through photolithography to form openings **3191** in regions of the hard mask **319** where the contact holes are to be formed (FIG. **18**B).

[0037] Then, the contact holes **320** are bored in the protection layer **318** through anisotropic dry etching (FIG. **18**C). However, the protection layer **318** has a relatively great film thickness as described above, and therefore takt time until boring of the contact holes **320** is fully completed is long. Further, even when performing anisotropic etching, performing etching for a long time period often yields side etching **320***a* on the inner side surfaces of the contact holes **320**, and consequently inner surfaces of the contact holes **320** have bad surface states (FIG. **18**D).

[0038] Even if the auxiliary electrodes **321** made of metal are formed in the contact holes **320** in such states through vapor deposition or sputtering, coverage (covered area) of the metal film relative to the inner side surfaces of the contact holes **320** may be bad, and the auxiliary electrodes **321** may have great electrical resistance. Consequently, the effect of suppressing voltage decline of the common electrode **317** that is expected for the auxiliary electrodes **321** may not be sufficiently obtained.

[0039] In view of this, the inventors of the present disclosure conducted research to develop a structure in which protection by the protection layer of the organic EL elements is sufficiently ensured, task time for forming the contact holes is shortened, and good electrical conductivity of the auxiliary electrodes and electrical connection of the auxiliary electrodes to the common electrode is maintained, and arrived at an embodiment of the present disclosure.

<<Overview>>

[0040] An organic EL display panel pertaining to at least one embodiment of the present disclosure includes a substrate. the organic EL display panel further includes a plurality of first electrodes that are spaced away from each other and are arrayed in rows and columns above the substrate. The organic EL display panel further includes a plurality of light-emitting layers that include organic light-emitting material and are disposed above the first electrodes. The organic EL display panel further includes a second electrode that is disposed above the light-emitting layers. The organic EL display panel further includes a first protection layer that includes resin and is disposed above the second electrode and is not disposed within an auxiliary region which, in plan view, extends in a column direction between ones of the first electrodes that are adjacent in a row direction across the substrate. The organic EL display panel further includes a second protection layer that includes inorganic material and is disposed above the first protection layer and the second electrode. The organic EL display panel further includes an auxiliary electrode layer that extends in the column direction within the auxiliary region and is electrically connected to the second electrode through a contact opening in the first protection layer within the auxiliary region.

[0041] This structure helps to ensure electrical conductivity of the auxiliary electrode layer, to improve electrical connection of the auxiliary electrode layer with the second electrode that is a common electrode, to improve light-emitting efficiency of the organic EL display panel, and to suppress luminance unevenness of the organic EL display panel.

[0042] An organic EL display panel pertaining to at least one embodiment of the present disclosure further includes partition walls. In plan view of the substrate, the partition walls extend in the column direction and are disposed between the auxiliary region and regions where the light-emitting layers are disposed.

[0043] This embodiment helps to prevent, when forming the first protection layer made of a resin material through a wet process, the resin material from flowing into the auxiliary region within which the auxiliary electrode layer is formed.

[0044] An organic EL display panel pertaining to at least one embodiment of the present disclosure further includes second partition walls. The partition walls are first partition walls. In plan view of the substrate, the second partition walls extend in the column direction and are disposed between the first partition walls and the auxiliary electrode layer.

[0045] This helps to further suppress flowing of the resin material into the auxiliary region within which the auxiliary electrode layer is formed.

[0046] According to an organic EL display panel pertaining to at least one embodiment of the present disclosure, the second partition walls have a greater height than the first partition walls.

[0047] An organic EL display panel pertaining to at least one embodiment of the present disclosure further includes banks extending in the column direction and partitioning the organic light-emitting layers arrayed in the column direction. The first partition walls and the second partition walls have greater heights than the banks.

[0048] These embodiments help to further suppress flowing of the resin material into the auxiliary region within which the auxiliary electrode layer is formed.

[0049] An organic EL display panel pertaining to at least one embodiment of the present disclosure further includes banks extending in the column direction and partitioning the organic light-emitting layers arrayed in the column direction. The partition walls are ones of the banks that are closest to the auxiliary region.

[0050] According to this, non-light-emitting columns have a small width in the row direction, and such a structure is appropriate for obtaining improved definition.

[0051] According to an organic EL display panel pertaining to at least one embodiment of the present disclosure, a width of the partition walls in the row direction is greater than a width of the banks, excluding the partition walls, in the row direction.

[0052] According to an organic EL display panel pertaining to at least one embodiment of the present disclosure, a distance between the partition walls in the auxiliary region in the row direction is greater than a distance between each pair of adjacent ones of the banks, excluding the partition walls, in the row direction.

[0053] Any of these embodiments helps to suppress flowing of the resin material into the auxiliary region within which the auxiliary electrode layer is formed.

[0054] An organic EL display panel pertaining to at least one embodiment of the present disclosure further includes an electric charge movement facilitating layer below the second electrode and above the light-emitting layers and the auxiliary region. The organic EL display panel further includes a second auxiliary electrode layer extending in the column direction and electrically contacting a surface of the electric charge movement facilitating layer opposite the second electrode within the auxiliary region. The auxiliary electrode layer is referred to as a first auxiliary electrode layer.

[0055] This further helps to suppress voltage decline of the second electrode and to display images having good light-emitting efficiency and without luminance unevenness.

[0056] According to an organic EL display panel pertaining to at least one embodiment of the present disclosure, the second auxiliary electrode layer includes the same material as the first electrodes and is in the same layer as the first electrodes.

[0057] According to this embodiment, the second auxiliary electrode layer is formed simultaneously with the first electrodes during the process of forming the first electrodes. This has an effect of helping to suppress manufacturing costs.

[0058] An organic EL display panel pertaining to at least one embodiment of the present disclosure further includes a third protection layer that includes inorganic material and is disposed between the second electrode and the first protection layer.

[0059] This embodiment further helps to improve a sealing property of the protection layer.

[0060] According to an organic EL display panel pertaining to at least one embodiment of the present disclosure, the second protection layer is disposed between the auxiliary electrode layer and the first protection layer.

[0061] An organic EL display panel manufacturing method pertaining to at least one embodiment of the present disclosure includes preparing a substrate. The method further includes forming a plurality of first electrodes that are spaced away from each other and are arrayed in rows and columns above the substrate. The method further includes forming a plurality of light-emitting layers that include organic light-emitting material above the first electrodes. The method further includes forming a second electrode above the light-emitting layers. The method further includes forming a first protection layer through applying resin material above the second electrode excluding an auxiliary region which, in plan view, extends in a column direction between ones of the first electrodes that are adjacent in a row direction across the substrate. The method further includes forming a second protection layer through applying inorganic material above the first protection layer and the second electrode. The method further includes forming a contact opening in the second protection layer within the auxiliary region. The method further includes forming an auxiliary electrode layer within the auxiliary region in the column direction, the auxiliary electrode layer electrically connecting to the second electrode through the contact opening.

[0062] The manufacturing method pertaining to the above embodiment helps to manufacture an organic EL display panel that efficiently suppresses voltage decline of the second electrode that is the common electrode to display images having good light-emitting efficiency and little luminance unevenness.

EMBODIMENT

[0063] The following describes an organic EL display panel pertaining to at least one embodiment of the present disclosure, with reference to the drawings. Note that the drawings may be schematic for convenience of explanation, and dimensions, an aspect ratio, or the like of components may differ from the actual dimensions, aspect ratio, or the like.

1. Overall Structure of Organic EL Display Device **1**

[0064] FIG. **1** is a block diagram of an overall structure of an organic EL display device **1** pertaining to at least one embodiment. The organic EL display device **1** is, for example, a display device used for a television, a personal computer, a portable terminal, a commercial display (an electronic signage or a large-sized screen for installment in a commercial facility), or the like.

[0065] The organic EL display device **1** includes an organic EL display panel **10** and a drive control unit **200** electrically connected to the organic EL display panel **10**.

[0066] In the present embodiment, the organic EL display panel **10** is a top-emission type display panel whose upper surface is a rectangular image display surface. In the organic EL display panel **10**, a plurality of organic EL elements (not illustrated) are arrayed along the image display surface, and an image is displayed with use of a combination of light emitted from the organic EL elements. Note that the organic EL display panel **10** is, for example, an active matrix type of panel.

[0067] The drive control unit **200** includes drive circuits **210** connected to the organic EL display panel **10** and a control circuit **220** connected to an external device such as a calculator or a receiving device such as an antenna. The drive circuits **210** each include a power supply circuit that supplies electric power to the organic EL elements, a signal circuit that applies a voltage signal controlling electric power supplied to the organic EL elements, and a scanning circuit that switches, at defined intervals, a position to which the voltage signal is applied.

[0068] The control circuit **220** controls operations of the drive circuits **210** in accordance with data including image information inputted from the external device or the receiving device.

[0069] FIG. **1** shows an example in which four drive circuits **210** are arranged around the organic EL display panel **10**, but note that the structure of the drive control unit **200** is not limited to this; the number and positions of the drive circuits **210** can be appropriately changed. Further, in the following, as in FIG. **1**, a direction along a longer side of the upper surface of the organic EL display panel **10** is referred to as an X direction, and a direction along a shorter side of the upper surface of the organic EL display panel **10** is referred to as a Y direction for convenience of explanation.

2.2. Structure of Organic EL Display Panel **10**

(A) Structure in Plan View

[0070] FIG. **2** is a schematic plan diagram in which a part of the image display surface of the organic EL display panel **10** pertaining to at least one embodiment is enlarged. In the organic EL display panel **10**, for example, subpixels **100**R emitting light of the color R, subpixels **100**G emitting light of the color G, and subpixels **100**B emitting light of the color B are arranged in a matrix. The subpixels **100**R, the subpixels **100**G, and the subpixels **100**B are arranged alternatingly in the X direction, and each set of a subpixel **100**R, a subpixel **100**G, and a subpixel **100**B that are arrayed in the X direction forms a pixel P.

[0071] The subpixels **100**R each include an organic EL element **2** emitting light of the color R, the subpixels **100**G each include an organic EL element **2** emitting light of the color G, and the subpixels **100**B each include an organic EL element **2** emitting light of the color B (see FIG. **3**). Through combining luminance of the subpixels **100**R, **100**G, and **100**B that are subjected to a gradation control, a full-color representation is achieved.

[0072] In the Y direction, the subpixels **100**R are arrayed to form subpixel arrays CR, the subpixels **100**G are arrayed to form subpixel arrays CG, and the subpixels **100**B are arrayed to form subpixel arrays CB. Due to this, the pixels P are arranged in a matrix along the X direction and the Y direction in an entirety of the organic EL display panel **10**, and an image is displayed in the image display surface through combining color emission from the pixels P, which are arranged in a matrix.

[0073] The organic EL display panel **10** pertaining to the present embodiment employs a so-called line bank structure. That is, a plurality of banks **14** that partition the subpixel arrays CR, CG, and CB into columns are arranged in the X direction at intervals, and in each of the subpixel arrays CR, CG, and CB, an organic light-emitting layer spans over the subpixels **100**R in the subpixel arrays CR, the subpixels **100**G in the subpixel arrays CG, or the subpixels **100**B in the subpixel arrays CB, respectively.

[0074] In each of the subpixel arrays CR, CG, and CB, a plurality of pixel regulation layers **141** that electrically insulate between the subpixels **100**R, the subpixels **100**G; or the subpixels **100**B are arranged at intervals in the Y direction, and each of the subpixels **100**R, **100**G, and **100**B is configured to emit light independently from one another.

[0075] The pixel regulation layers **141** have a height lower than surfaces of the light-emitting layers. The banks **14** and the pixel regulation layers **141** are illustrated by broken lines in FIG. **2**. This is because the pixel regulation layers **141** and the banks **14** are not exposed at a surface of the image display surface and are arranged inside the image display surface.

[0076] Here, when referring to each region formed by a set of a subpixel array CR, a subpixel array CG, and a subpixel array CB as a light-emitting region **500** (light-emitting portion), between each pair of adjacent ones of the light-emitting regions **500**, an auxiliary electrode forming region **600** (non-light-emitting portion) extending in parallel with the subpixel arrays is disposed.

[0077] In the auxiliary electrode forming regions **600**, no organic EL element is disposed, and approximately at centers of the auxiliary electrode forming regions **600** in the X direction, elongated auxiliary electrodes **19** extending in the Y direction are disposed.

(B) Cross-Sectional Structure of Organic EL Elements

[0078] As described above, in the organic EL display panel **10**, a pixel includes three subpixels each emitting light of a different one of the colors R, G, and B. Each of the subpixels include an organic EL element emitting light of a corresponding color.

[0079] Structures of the organic EL elements of the three colors are substantially the same as one another, and therefore are simply referred to as the organic EL elements **2** when they are not distinguished from one another.

[0080] FIG. **3** is a schematic cross-sectional diagram taken along line A-A in FIG. **2**.

[0081] In FIG. **3**, in the present embodiment, the organic EL elements **2** each include a substrate **11**, an interlayer insulating layer **12**, a pixel electrode **13**, a bank **14**, a light-emitting layer **15**, an electron transport layer **16**, a common electrode **17**, a protection layer **18**, and an auxiliary electrode **19**.

[0082] The substrate **11**, the interlayer insulating layer **12**, the electron transport layer **16**, the common electrode **17**, and the protection layer **18** are not in one-to-one correspondence with the pixels but each spans over the plurality of organic EL elements **2** of the organic EL display panel **10**.

(1) Substrate

[0083] The substrate **11** includes: a base member **111** that is made of an electrically-insulating material; and a thin film transistor (TFT) layer **112**. The TFT layer **112** includes drive circuits corresponding one-to-one with the subpixels. The base member **111** may be, for example, a glass substrate; a silica glass substrate; a silicon substrate; a metal substrate of a metal such as molybdenum sulfide, copper, zinc, aluminum, stainless steel, magnesium, iron, nickel, gold, silver, or the like; a semiconductor substrate such as gallium arsenide; a plastic substrate, or similar.

[0084] For a plastic material for the plastic substrate, a thermoplastic resin or a thermosetting resin may be used. For example, polyethylene; polypropylene;

[0085] polyamide; polyimide (PI); polycarbonate; an acrylic resin; polyethylene terephthalate (PET); polybutylene terephthalate; polyacetal; other fluorine-based resins; thermoplastic elastomer such as styrenic elastomer, polyolefin elastomer, polyvinyl chloride elastomer, polyurethane elastomer, fluorine rubber elastomer, and chlorinated polyethylene elastomer; an epoxy resin; an unsaturated polyester; a silicone resin; polyurethane, or the like, or copolymer, blend, polymer alloy or the like mainly including such a material, primarily consisting of one of the above, or a layered body including layers of one or more of the above can be used.

(2) Interlayer Insulating Layer

[0086] The interlayer insulating layer **12** is disposed on the substrate **11**. The interlayer insulating layer **12** is made of a resin material and planarizes unevenness of an upper surface of the TFT layer **112**. For the resin material, for example, a positive photosensitive material is used. Examples of such a photosensitive material are an acrylic resin, a polyimide resin, a siloxane resin, and a phenolic resin. Further, although not illustrated in the cross-sectional diagram of FIG. **3**, the interlayer insulating layer **12** has contact holes corresponding one-to-one with the subpixels.

(3) Pixel Electrodes

[0087] The pixel electrodes **13** each include a metal layer made of a light-reflective metal material and are disposed on the interlayer insulating layer **12**. The pixel electrodes **13** correspond one-to-one with the subpixels and are electrically connected to the TFT layer **112** through the contact holes (not illustrated).

[0088] In the present embodiment, the pixel electrodes **13** function as anodes.

[0089] Specific examples of a metal material having light-reflectivity are silver (Ag); aluminum (Al); an aluminum alloy; molybdenum (Mo); a silver, palladium, and copper alloy (APC); a silver, rubidium, gold alloy (ARA); a molybdenum chromium alloy (MoCr); a molybdenum tungsten alloy (MoW); a nickel chromium alloy (NiCr), and the like.

[0090] The pixel electrodes **13** may each be a single metal layer or may each have a layered structure in which a layer made of a metal oxide such as indium tin oxide (ITO) or indium zinc oxide (IZO) is laminated on a metal layer.

(4) Banks and Pixel Regulation Layers

[0091] The banks **14** partition the pixel electrodes **13**, which are arranged above the substrate **11** in one-to-one correspondence with the subpixels, in the X direction (see FIG. **2**) into columns. The banks **14** each have a shape of a line bank extending in the Y direction between the subpixel arrays CR, CG, and CB, which are arrayed in the X direction.

[0092] The banks **14** are made using an electrically-insulating material. Specific examples of the electrically-insulating material are electrically-insulating organic materials (such as an acrylic resin, a polyimide resin, a novolac resin, a phenolic resin, and the like).

[0093] The banks **14** function as a structure for preventing, when the light-emitting layers **15** are formed through an application process, the applied ink of each color from flowing out and mixing.

[0094] When a resin material is used, the resin material beneficially has photosensitivity from the perspective of workability. The resin material may have positive photosensitivity or negative photosensitivity.

[0095] The banks **14** beneficially have a tolerance for organic solvents and heat. Further, in order to suppress flowing out of the ink, surfaces of the banks **14** beneficially have defined liquid repellency.

[0096] In portions where the pixel electrodes **13** are not disposed, bottom surfaces of the banks **14** are in contact with an upper surface of the interlayer insulating layer **12**.

[0097] The pixel regulation layers **141** are made of an electrically-insulating material, cover edges of the pixel electrodes **13** that are adjacent in the Y direction (FIG. **2**) in each of the subpixel arrays, and partition the pixel electrodes **13** that are adjacent in the Y direction.

[0098] The pixel regulation layers **141** are designed to have a film thickness slightly greater than the film thickness of the pixel electrodes **13** but smaller than the thickness of the light-emitting layers **15** up to their upper surfaces. Due to this, in each of the subpixel arrays CR, CG, and CB, the light-emitting layer **15** is not partitioned by the pixel regulation layers **141**. Accordingly, flow of the ink is not prevented when forming the light-emitting layers **15**. Due to this, in each of the subpixel arrays, the light-emitting layer **15** easily has a uniform thickness.

[0099] Due to the above-described structure, the pixel regulation layers **141** improve an electrically-insulating property of the pixel electrodes **13** that are adjacent in the Y direction and play the roles of preventing, in each of the subpixel arrays CR, CG, and CB, the organic light-emitting layer **15** from being discontinuous due to height differences, improving the electrically-insulating property between the pixel electrodes **13** and the common electrode **17**, and the like.

[0100] Specific examples of the electrically-insulating material used for the pixel regulation layers **141** are resin materials, inorganic materials, and the like that are exemplified as a material of the banks **14** described above. Further, surfaces of the pixel regulation layers **141** beneficially have a lyophilic property for inks such that wet-spreading of inks is good when forming the light-emitting layers **15**, which are layers on the pixel regulation layers **141**.

[0101] Note that the pixel regulation layers **141** are not disposed in the auxiliary electrode forming regions **600**.

(5) Light-Emitting Layers

[0102] The light-emitting layers **15** are disposed between the banks **14** in the light-emitting regions **500**, and have a function of emitting light of the colors R, G, or B through recombination of holes and electrons. Note that the light-emitting layers **15** are referred to as the light-emitting layers **15**(R), the light-emitting layers **15**(G), and the light-emitting layers **15**(B) when it is necessary to specify their light-emission colors.

[0103] For a material of the light-emitting layers **15**, a publicly known material can be used. Specifically, for example, the light-emitting layers **15** are beneficially made of a fluorescent substance such as an oxynoid compound, perylene compound, coumarin compound, azacoumarin compound, oxazole compound, oxadiazole compound, perinone compound, pyrrolo-pyrrole compound, naphthalene compound, anthracene compound, fluorene compound, fluoranthene compound, tetracene compound, pyrene compound, coronene compound, quinolone compound and azaquinolone compound, pyrazoline derivative and pyrazolone derivative, rhodamine compound, chrysene compound, phenanthrene compound, cyclopentadiene compound, stilbene compound, diphenylquinone compound, styryl compound, butadiene compound, dicyanomethylene pyran compound, dicyanomethylene thiopyran compound, fluorescein compound, pyrylium compound, thiapyrylium compound, selenapyrylium compound, telluropyrylium compound, aromatic aldadiene compound, oligophenylene compound, thioxanthene compound, cyanine compound, acridine compound, metal complex of an 8-hydroxyquinoline compound, metal complex of a 2-bipyridine compound, complex of a Schiff base and a group III metal, metal complex of oxine, or rare earth metal complex.

(6) Electron Transport Layer

[0104] The electron transport layer **16** has a function of transporting electrons from the common electrode **17** to the light-emitting layers **15**. The electron transport layer **16** is made of an organic material having a high electron transport property, and includes neither alkali metals nor alkaline earth metals.

[0105] For the organic material of the electron transport layer **16**, for example, a π electron system small-molecule organic material such as an oxadiazole derivative (OXD), a triazole derivative (TAZ), a phenanthroline derivative (BCP, Bphen), or the like can be used.

(7) Common Electrode

[0106] The common electrode **17** is made of a light-transmissive electrically-conductive material and is disposed on the electron transport layer **16**. The common electrode **17** functions as a cathode.

[0107] For a material of the common electrode **107**, ITO; IZO; a metal such as silver, a silver alloy, aluminum, an aluminum alloy; or the like is beneficially used. When forming the common electrode **17** using a metal, the common electrode **17** is formed as a thin film having a film thickness of approximately 20 nm or less, such that the common electrode **17** has a light-transmittance.

(8) Protection Layer

[0108] The protection layer **18** is disposed in order to prevent the components of the organic EL elements below the protection layer **18**, specifically organic layers such as the light-emitting layers **15**, the electron transport layer **16**, or the like from deteriorating due to exposure to moisture or other liquids or to air.

[0109] In the present embodiment, in the light-emitting regions **500**, the protection layer **18** includes a first protection sublayer **181** (third protection layer), second protection sublayers **182** (first protection layer), and a third protection sublayer **183** (second protection layer) that are light-transmissive.

[0110] The first protection sublayer **181** is a thin film of silicon nitride (SiN) and covers an upper surface of the common electrode **17**.

[0111] The second protection sublayers **182** are made of resin and cover an upper surface of the first protection sublayer **181** excluding the auxiliary electrode forming regions **600** and regions surrounding the auxiliary electrode forming regions **600**. For a resin material of the second protection sublayers **182**, for example, a fluorine-based resin, an acrylic resin, an epoxy resin, a silicone resin, or the like is used.

[0112] The third protection sublayer **183** is a thin film of silicon nitride similar to the first protection sublayer **181** and covers upper surfaces of the second protection sublayers **182**.

[0113] Due to the three-layered structure of the protection layer **18** as described above, the resin of the second protection sublayers **182** compensates for vulnerability of the first protection sublayer **181** and the third protection sublayer **183** that are each made of an inorganic layer, and even when a minute impurity exists on the common electrode **17**, such an impurity is sufficiently covered and occurrence of cracks and liquid proofing deterioration are prevented.

[0114] Note that, in the auxiliary electrode forming regions **600** and regions surrounding the organic EL display panel **10**, the first protection sublayer **181** and the third protection sublayer **183** are in direct and close contact with each other without the second protection sublayers **182** disposed therebetween.

(9) Auxiliary Electrodes

[0115] The auxiliary electrodes **19** are made of a metal having great electrical conductivity. For the metal material of the auxiliary electrodes **19**, a metal such as silver, aluminum, copper, or the like can be used.

(10) Others

[0116] Although not illustrated in FIG. **3**, an antiglare polarizing plate or an upper substrate may be joined onto the protection layer **18** through adhesive. Through joining such a layer, the components of the organic EL elements **2**, specifically organic layers, are further protected from moisture, air, and the like.

3. Organic EL Display Panel Manufacturing Method

[0117] The following describes a method of manufacturing the organic EL display panel **10**, with reference to the drawings.

[0118] FIG. **4** is a flowchart of processes of manufacturing the organic EL display panel **10** pertaining to at least one embodiment, and FIG. **5**A, FIG. **5**B, FIG. **5**C, FIG. **6**A, FIG. **6**B, and FIG. **6**C are schematic cross-sectional diagrams of processes of forming the auxiliary electrodes in manufacturing of the organic EL display panel **10** pertaining to at least one embodiment.

(1) Substrate Preparation Process

[0119] First, the substrate **11** is prepared through forming the TFT layer **112** on the base member **111** (step S1 in FIG. **4**). The TFT layer **112** can be formed through a publicly known TFT manufacturing method.

[0120] The interlayer insulating layer **12** is formed on the TFT layer **112**. Specifically, a photosensitive resin material having a certain level of fluidity is applied through, for example, die coating along an upper surface of the substrate **11** such that unevenness on the substrate **11** due to the TFT layer **112** is compensated for. Due to this, the upper surface of the interlayer insulating layer **12** has a shape planarized along an upper surface of the base member **111**.

[0121] Further, portions of the interlayer insulating layer **12** on, for example, the source electrodes of the TFT elements are dry-etched to form the contact holes (not illustrated). The contact holes are formed through patterning or the like such that surfaces of the source electrodes are exposed at bottom portions of the contact holes.

[0122] Next, the connection electrode layers are formed along inner walls of the contact holes. Upper portions of the connection electrode layers are partially over the interlayer insulating layer **12**. The connection electrode layers can be formed through, for example, sputtering. Specifically, the connection electrode layers are formed through forming a metal film and patterning the metal film by photolithography and wet-etching. (2) Pixel Electrodes Forming Process

[0123] Next, the pixel electrodes **13** are formed on the interlayer insulating layer **12** (step S3 in FIG. **4**). The pixel electrodes **13** are formed through: (i) forming a pixel electrode material layer on the interlayer insulating layer **12** through, for example, vacuum vapor deposition, sputtering, or the like; and (ii) subsequently patterning the pixel electrode material layer through etching to form the pixel electrodes **13**, which are divided to correspond one-to-one with the subpixels.

(3) Banks and Pixel Regulation Layers Forming Process

[0124] Next, the banks **14** and the pixel regulation layers **141** are formed (step S3 in FIG. **4**).

[0125] In the present embodiment, the banks **14** and the pixel regulation layers **141** are formed at the same time by using a halftone mask as described below.

[0126] First, a bank material layer is formed through applying a resin material by the film thickness of the banks **14** on the interlayer insulating layer **12** on which the pixel electrodes **13** are formed. Specifically, the resin material can be applied through a wet process such as die coating, slit coating, spin coating, or the like.

[0127] After application, for example, unnecessary solvents are removed through vacuum drying, low-temperature drying around 60° C. to 120° C. (prebaking) and the like, and the bank material layer is irradiated through a photomask (not illustrated).

[0128] For example, when the bank material layer has positive photosensitivity, portions in which the bank material layer **140** is to remain are shielded, and portions from which the bank material layer **140** is to be removed are irradiated.

[0129] In the present example, the pixel regulation layers **141** have a smaller film thickness than the banks **14**, and therefore portions of the bank material layer **140** in which the pixel regulation layers **141** are to be formed are subjected to half-exposure.

[0130] Accordingly, the photomask used in the exposure process has light-shielding portions that are placed at positions corresponding to the banks **14** and completely shield light, semi-transparent portions that are placed at positions corresponding to the pixel regulation layers **141**, and light-transmissive portions that are placed at positions corresponding to portions in which the pixel electrodes **13** are exposed.

[0131] The light-transmittance of the semi-transparent portions is determined such that the bank material layer on the pixel electrodes **13** is subjected to full-exposure and the bank material layer on the pixel regulation layers **141** is subjected to half-exposure such that the bank material layer remains by the height of the pixel regulation layers **141** when the bank material layer is irradiated for a defined time period.

[0132] Next, through performing developing to remove regions of the bank material layer **140** that have been irradiated, the banks **14** and the pixel regulation layers **141**, which have a smaller film thickness than the banks **14**, are formed. Specifically, the developing is performed through, for example, dipping an entirety of the substrate **11** into a development solution such as an organic solvent, an alkali liquid, or the like that dissolves portions of the bank material layer **140** that have been irradiated and subsequently washing the substrate **11** by using a rinse liquid such as pure water or the like.

[0133] Due to this, the banks **14** extending in the Y direction and the pixel regulation layers **141** extending in the X direction are formed on the interlayer insulating layer **12**.

(4) Light-Emitting Layers Forming Process

[0134] Next, the light-emitting layers **15** are formed above the pixel electrodes **13** described above (step S4 in FIG. **4**).

[0135] Specifically, into openings that are each sandwiched by a pair of the banks **14**, ink including a light-emitting material of a corresponding light-emission color is sequentially discharged from a nozzle of an application head of a printing device to apply the ink onto the pixel electrodes **13** in the openings. Here, the ink is applied continuously above the pixel regulation layers **141**. Due to this, the ink can flow along the Y direction. This structure helps to reduce application unevenness of the ink and unify the film thickness of the light-emitting layer **15** in the same subpixel array.

[0136] Then, the substrate **11** after ink application is conveyed into a vacuum drying chamber and is heated in a vacuum environment to volatilize the organic solvent in the ink. Due to this, the light-emitting layers **15** are formed.

(5) Electron Transport Layer Forming Process

[0137] Next, the electron transport layer **16** is formed on the light-emitting layers **15** and the banks **14** (step S5 in FIG. **4**) through, for example, vapor deposition such that the electron transport layer **16** spans over the subpixels.

(6) Common Electrode (Counter Electrode) Forming Process

[0138] Next, the common electrode **17** is formed on the electron transport layer **16** (step S7 in FIG. **4**). In the present embodiment, the common electrode **17** is formed through forming a film of silver, aluminum, or the like through sputtering or vacuum vapor deposition.

(7) Protection Layer Forming Process

[0139] Next, the protection layer **18** is formed on the common electrode **17** (step S**10** in FIG. **4**).

[0140] First, the first protection sublayer **181**, which is made of SiN, is formed through, for example, plasma-enhanced chemical vapor deposition (PECVD) (FIG. **5**A).

[0141] For example, silane (SiH_4) and ammonia (NH_3) are used as gas for forming the first protection sublayer **181**. Nitrogen (N_2) may additionally be used.

[0142] Next, the second protection sublayers **182** are formed through discharging a resin material from a nozzle of a head unit of a printing device onto the first protection sublayer **181** (FIG. **5**B). Here, the resin material is applied separately by the printing device such that the resin material would not flow into the auxiliary electrode forming regions **600** (auxiliary regions). Note that the second protection sublayers **182** are not formed in the regions surrounding the organic EL display panel **10**, either.

[0143] Here, portions of the banks **14** at the sides of the auxiliary electrode forming regions **600** in the X direction function as, so to speak, dams that prevent the resin material from flowing into the auxiliary electrode forming regions **600**.

[0144] Then, the resin material is cured. For example, the resin material is cured through heating when the resin material has a thermosetting property; alternatively, the resin material is cured through ultraviolet irradiation when the resin material has an ultraviolet-curing property. Note that the resin material can be applied through screen printing, dispensing, or the like.

[0145] Then, the third protection sublayer **183** is formed on the second protection sublayers **182** by using the same film-forming conditions as the first protection sublayer **181**. However, the second protection sublayers **182** are not present in the auxiliary electrode forming regions **600** and the regions surrounding the organic EL display panel **10** as described above, and therefore the third protection sublayer **183** is laminated directly on the first protection sublayer **181** (FIG. **5**C). Due to this, the resin of the second protection sublayers **182** would not be exposed to the outside. Accordingly, moisture or the like in the air would not penetrate into the second protection sublayers **182** easily, and a film thickness of the protection layer **18** in the auxiliary electrode forming regions **600** can be made much smaller than in the conventional technology.

[0146] The organic EL element **2** is not present in the auxiliary electrode forming regions **600**, and therefore deterioration of the organic EL elements **2** would not occur easily even when the protection layer **18** does not have a three-layered structure as in the light-emitting regions **500**.

(8) Contact Openings Forming Process

[0147] Next, contact openings **20** (in the present embodiment, the contact openings are formed to have a groove shape, and therefore such contact openings and standard contact holes as penetrating holes are collectively referred to as "contact openings") for forming the auxiliary electrodes **19** are formed within the auxiliary electrode forming regions **600** in the protection layer **18** (step S8).

[0148] As described above, the second protection sublayers **182** are not formed in the auxiliary electrode forming regions **600**, and the first protection sublayer **181** and the third protection sublayer **183** are directly laminated with each other. Thus, the film thicknesses in the auxiliary electrode forming regions **600** can be made much thinner (around 500 nm to 2000 nm) than in the structure in FIG. **18**. Accordingly, the contact openings **20** can be formed easily through etching.

[0149] For example, the contact openings **20** are formed through the following processes.

[0150] (A) First, a resist **21** made of a photosensitive resin is formed on the third protection sublayer **183**, and the resist **21** is patterned through photolithography such that portions corresponding to positions at which the contact openings **20** (see FIG. **6**B) are to be formed are opened (FIG. **6**A).

[0151] (B) Next, the contact openings **20** for forming the auxiliary electrodes **19** are formed in the first protection sublayer **181** and the third protection sublayer **183** through dry-etching such that a surface of the common electrode **17** is exposed (FIG. **6**B).

[0152] The resist **21** does not have a great resistance against etching. Accordingly, during the dry-etching, inner circumferential portions of the openings in the resist **21** are slightly corroded and the diameters of the openings gradually become large, and therefore inner side surfaces of the contact openings **20** after forming have a tapered shape that has a greater diameter toward their upper portions. Further, etching is performed within a short time period and therefore hardly any side etching occurs.

[0153] (C) The resist **21** is removed through a wet process and washed by using a rinse liquid.

[0154] In the present embodiment, the contact openings are each formed in a shape of a groove extending in a column direction (Y direction in FIG. **2**), but a plurality of contact holes may be arrayed at defined intervals in the column direction.

(9) Auxiliary Electrodes Forming Process

[0155] Next, the auxiliary electrodes **19** are formed (step S9 in FIG. **4**).

[0156] The auxiliary electrodes **19** are formed through forming a metal layer on the protection layer **18** in the state of FIG. **6**B and patterning the metal layer through photolithography.

[0157] For example, the auxiliary electrodes **19** are formed through the following processes.

[0158] (A) The metal layer is formed through sputtering or vacuum vapor deposition such that an upper surface of the protection layer **18** is covered by the metal layer.

[0159] (B) On the metal layer, a resist mask that is patterned to mask portions in which the auxiliary electrodes **19** are to be formed is formed through photolithography.

[0160] (C) Portions of the metal layer excluding portions of the metal layer that are masked are removed through wet-etching or dry-etching, the remaining resist mask is removed through a wet process (resist peeling), and washing is performed by using a rinse liquid.

[0161] Due to this, the auxiliary electrodes **19** are formed (FIG. **6**C), and the organic EL display panel **10** is completed.

[0162] Note that the above-described manufacturing method is a mere example and can be appropriately changed.

[0163] As described above, the contact openings **20** each have a tapered shape and have good surface states. Accordingly, the contact openings **20** have good coverage when forming the metal layer, and the auxiliary electrodes **19** after completion have a small electrical resistance. This helps to suppress voltage decline of the common electrode **17** and to display high-quality images without luminance unevenness.

[0164] Note that the auxiliary electrodes **19** need not be formed in all the auxiliary electrode forming regions **600**; the effect of suppressing voltage decline of the common electrode **17** is obtained even when the auxiliary electrodes **19** are formed in some of the auxiliary electrode forming regions **600** at defined intervals. In such a case, the second protection sublayers **182** are not formed and the first protection sublayer **181** and the third protection sublayer **183** are directly laminated with each other in, among the plurality of auxiliary electrode forming regions **600** (non-light-emitting portions), ones of the auxiliary electrode forming regions **600** in each of which an auxiliary electrode **19** is disposed.

4. Effects

[0165] The embodiment described above has the following effects.

[0166] (1) In the light-emitting regions of the organic EL display panel **10**, the protection layer **18** has a three-layered structure in which the first protection sublayer **181** and the third protection sublayer **183**, which are made of an inorganic material that does not allow liquids such as moisture to penetrate easily, sandwich the second protection sublayers **182** made of a resin material. Due to this, the protection layer **18** has a sufficient thickness, and even when a minute impurity exists on the common electrode **17**, such an impurity is sufficiently covered. Further, the second protection sublayers **182** are made of a resin material, and therefore the second protection sublayers **182** absorb shocks from the outside and suppress occurrence of cracks in the protection layer **18**.

[0167] (2) Further, in the auxiliary electrode forming regions **600**, the first protection sublayer **181** and the third protection sublayer **183** are directly laminated with each other without the second protection sublayers **182** disposed therebetween, and therefore the protection layer **18** has a small film thickness in portions having such a structure. Due to this, the contact openings **20** can be formed easily and the task time can be shortened. Further, side etching would not occur on inner surfaces of the contact openings **20**, and therefore the auxiliary electrodes **19** that are subsequently formed have good film-forming states, and have electrical conductivity great enough to suppress voltage decline of the common electrode **17**.

[0168] (3) Because the task time is shortened, a typical photosensitive resin can be used for the etching mask, and this is beneficial from the perspective of costs. Further, the inner side surfaces of the contact openings **20** can be formed in a tapered shape that is wider in their upper portions, the film-forming properties and coverage of the auxiliary electrodes **19** are further improved, and therefore good electrical conductivity of the auxiliary electrodes **19** is ensured.

OTHER EMBODIMENTS

[0169] An organic EL display panel and a method of manufacturing the organic EL display panel have each been described as at least one embodiment of the present disclosure, but the present disclosure is not limited to the description above, except for essential characteristic elements thereof. The following describes modifications that exemplify other embodiments of the present disclosure.

1. Modification of Contact Openings Forming Process

[0170] In at least one embodiment, in the contact openings forming process in step **S8** in FIG. **4**, the resist **21** made of a photosensitive resin is formed on the third protection sublayer **183**, the resist **21** is patterned, and the resist **21** after patterning is dry-etched to form the contact openings **20**. However, a so-called hard mask **22** such as an ITO film or the like may be formed instead of the resist **21**. FIG. **7** is a schematic cross-sectional diagram of the contact openings forming process in such a modification.

[0171] First, the hard mask **22** is formed on the third protection sublayer **183**, which is the uppermost layer in the protection layer **18**, and the hard mask **22** is patterned through photolithography to form openings **221** at positions in which the contact openings are to be formed (FIG. **7**A).

[0172] Next, the first protection sublayer **181** and the third protection sublayer **183** are dry-etched through the hard mask **22** to form contact openings **20'** (FIG. **7**B).

[0173] The hard mask **22** has a great resistance against etching, and therefore tapers are not formed in the contact openings **20'** as in FIG. **6**B in which the resist **21** is used. However, a total film thickness of the first protection sublayer **181** and the third protection sublayer **183** is much smaller than in the conventional technology, and therefore etching can be performed within a short time period, and side etching does not occur on inner side surfaces of the contact openings **20'**.

[0174] Then, a metal layer is formed through vapor deposition or sputtering and the metal layer is patterned to form auxiliary electrodes **19'** as in FIG. **7**C. Because side etching does not occur in the contact openings **20'**, the auxiliary electrodes **19'** have relatively uniform film thicknesses and have electrical conductivity great enough to suppress voltage decline.

[0175] According to this modification, the hard mask **22** is a transparent film of ITO or the like. Thus, the hard mask **22** does not have to be removed after forming the openings **20'**, and the number of processes can be reduced accordingly.

2. Modification of Partition Structure of Auxiliary Electrode Forming Regions **600**

[0176] In at least one embodiment, each of the auxiliary electrode forming regions **600** is formed through partitioning the sides of the auxiliary electrode forming region **600** by the banks **14** in the light-emitting regions **500**.

[0177] However, the second protection sublayers **182** of the protection layer **18** are formed through applying a resin having a relatively great fluidity by using a printing device, and therefore may flow into the auxiliary electrode forming regions **600** in some cases.

[0178] FIG. **9**A and FIG. **9**B are schematic cross-sectional diagrams illustrating such a case.

[0179] The resin material immediately after application has a great fluidity. Accordingly, when the application position is slightly aside from the target application position or the dropping amount is slightly greater than the desired dropping amount, the resin material goes over the banks **14** and flows into the auxiliary electrode forming regions **600** as in FIG. **9**A.

[0180] In such cases, the protection layer **18** has a great film thickness in portions where the contact openings **20** are to be formed, and after etching, the resin of the second protection sublayers **182** are exposed in the contact openings **20** as in FIG. **9**B. During the wet process for removing the resist **21** and the like that are subsequently performed, liquids penetrate from the portions of the contact openings **20** in which the resin of the second protection sublayers **182** is exposed, and the aim of the protection layer **18** cannot be fully achieved.

[0181] FIG. **8**A and FIG. **8**B are schematic cross-sectional diagrams of an organic EL display panel **10** pertaining to a first modification of the auxiliary electrode forming regions for overcoming such a problem.

[0182] As in FIG. **8**A, in the present modification, banks (dam banks) **42** provided specifically for preventing the organic material of the second protection sublayers **182** from flowing are disposed inside banks that each form a boundary between an auxiliary electrode forming region **600** and a light-emitting region **500** (hereinafter referred to as "boundary banks **41**"). Consequently, regions into which the organic material can flow (flow margin region) **601** are formed between the boundary banks **41** (first partition walls) and the dam banks **42** (second partition walls), and regions each partitioned by a pair of dam banks **42** serve as actual auxiliary electrode forming regions **602**.

[0183] Due to this, even when the resin material of the second protection sublayers **182** goes over the boundary banks **41** during forming, the resin material is dammed by the dam banks **42** and is prevented from flowing further inside (see FIG. **8**B).

[0184] FIG. **10** is a schematic cross-sectional diagram of a second modification of a partition structure of the auxiliary electrode forming regions.

[0185] In FIG. **10**, the dam banks **42** have a greater height than the boundary banks **41**. This structure helps to further ensure prevention of flowing of the resin material when forming the second protection sublayers **182**.

[0186] FIG. **11** is a schematic cross-sectional diagram of a third modification of the partition structure of the auxiliary electrode forming regions.

[0187] In the present modification, the boundary banks **41** are as high as the dam banks **42**. This structure helps to further ensure prevention of flowing of the resin material.

[0188] FIG. **12** is a schematic cross-sectional diagram of a fourth modification of the partition structure of the auxiliary electrode forming regions.

[0189] In the present modification, the boundary banks **41** have a greater width than the above embodiment to form a step portion such that the boundary banks **41** have greater heights toward the auxiliary electrode forming regions **600** than toward the light-emitting regions **500**; that is, the boundary banks **41** each have a shape such that the dam bank **42** in FIG. **10** is integrated with the boundary bank **41** in FIG. **10**.

[0190] FIG. **13** is a diagram of a fifth modification in which the widths of the boundary banks **41** are the same as the above embodiment and a distance between each pair of adjacent ones of the boundary banks **41** in the auxiliary electrode forming regions **600** is greater than a distance between each pair of adjacent ones of the banks **14** in the light-emitting portions **500**. FIG. **14** is a diagram of a sixth modification in which the boundary banks **41** have a greater width than other banks **14**.

[0191] These structures help to suppress the organic resin flowing to positions at which the contact openings **20** for the auxiliary electrodes **19** are actually formed (centers of each pair of the boundary banks **41**) more easily.

3. Modification of Shapes of Second Protection Sublayers **182**

[0192] In at least one embodiment, the second protection sublayers **182** cover an entirety of the light-emitting regions **500** excluding the auxiliary electrode forming regions **600** and the and regions surrounding the organic EL display panel **10**, respectively. However, from the perspective of protection of, specifically, the organic layers in the organic EL elements, the second protection sublayers **182** may be disposed only at positions that are above the light-emitting layers **15** and that span over the banks **14** as in FIG. **15**.

4. Modification in Which Protection Layer **18** does not Include First Protection Sublayer **181**

[0193] Further, the protection layer **18** need not necessarily include the first protection sublayer **181**. A structure including the second protection sublayers **182** (first protection layer) and the third protection sublayer **183** (second protection layer) as in FIG. **16** can play the role of preventing absorption of liquids to the inside and oxidization and alternation of the components of the organic EL elements due to contact with external air to some extent. Further, in such a case, only the third protection sublayer **183** is disposed above the common electrode **17** in the auxiliary electrode forming regions, and therefore the contact openings **20** can be formed more easily and the task time can be further shortened.

5. Modification in Which Second Auxiliary Electrodes are Disposed below Electron Transport Layer **16**

[0194] FIG. **17** is a schematic cross-sectional diagram of a structure in which second auxiliary electrodes **191** are disposed below the electron transport layer **16** independently from the auxiliary electrodes (first auxiliary electrodes) **19**.

[0195] The second auxiliary electrodes **191** may be formed simultaneously with the pixel electrodes **13** when patterning the pixel electrode material layer formed on the interlayer insulating layer **12** during the pixel electrodes forming process.

[0196] The electron transport layer **16** typically does not have great electrical conductivity, and therefore the second auxiliary electrodes help prevention of voltage decline in the common electrode **17** to some extent, although not as greatly as the auxiliary electrodes **19** that are in direct contact with the common electrode **17**.

6. Other Modifications

[0197] (1) In at least one embodiment, the light-emitting layers **15**(R) including a light-emitting material emitting light of the color corresponding to the subpixels of R, the light-emitting layers **15**(G) including a light-emitting material emitting light of the color corresponding to the subpixels of G, and the light-emitting layers **15**(B) including a light-emitting material emitting light of the color corresponding to the subpixels of B are formed to form the organic EL display panel **10** displaying full-color images. However, a structure in which the light-emitting layers all emit white light and a publicly known color filter substrate including filters of R, G, and B is joined above the protection layer **18** through transparent adhesive or the like is possible.

[0198] (2) In at least one embodiment, the light-emitting layers are formed through a wet process, but the present disclosure should not be construed as being limited to this. For example, a dry process can be used such as vacuum vapor deposition, electron beam deposition, sputtering, reactive sputtering, ion plating, a vapor phase growth process, or the like.

[0199] (3) In at least one embodiment, the film-forming conditions and composition of the first protection sublayer **181** and the film-forming conditions and composition of the third protection sublayer **183** are the same. However, they need not necessarily be exactly the same, and may be appropriately changed by a skilled artisan.

[0200] Further, inorganic materials typically have a lower moisture absorbing property than resins, and therefore another appropriate inorganic material (such as silicon oxynitride (SiON), silicon carbide (SiC), or the like) may be used for a material of the first protection sublayer **181** and the third protection sublayer **183** instead of or in addition to silicon nitride (SiN) described above.

[0201] (4) In at least one embodiment, the organic EL elements each include a pixel electrode, a light-emitting layer, an electron transport layer, and a common electrode. However, the organic EL elements may each include, between the pixel electrode and the light-emitting layer, a hole injection layer and/or a hole transport layer. Further, the organic EL elements may include, between the electron transport layer and the common electrode, an electron injection layer.

[0202] (5) In at least one embodiment, the banks **14** and the pixel regulation layers **141** having heights differing from each other are formed simultaneously in a single process with use of a halftone mask, but the banks **14** and the pixel regulation layers **141** may be formed in different processes.

[0203] For example, firstly, the pixel regulation layers **141** for partitioning the pixel electrode arrays in the Y direction are formed.

[0204] Specifically, the pixel regulation layers **141** are formed through, for example, applying a resin material by die coating or the like on the upper surface of the substrate **11** on which the pixel electrodes have been formed. Next, through patterning the resin material by using photolithography and then baking, the pixel regulation layers **141** are formed between the pixel electrodes **13** that are adjacent in the Y direction.

[0205] Next, a bank resin that is a material of the banks **14** is uniformly applied through, for example, die coating to form a bank material layer, and the bank material layer is patterned through photolithography and then is baked to form the banks **14**.

[0206] (6) In at least one embodiment, description is provided of an organic EL display panel employing the line bank structure, but an organic EL display panel employing a so-called pixel bank structure in which each of the subpixels has four sides surrounded by banks in the light-emitting regions **500** is possible.

[0207] (7) In the organic EL display panel **10** pertaining to at least one embodiment, the subpixels **100**R emitting light of the color R, the subpixels **100**G emitting light of the color

G, and the subpixels **100**B emitting light of the color B are arrayed, but the colors of light emitted from the subpixels should not be construed as being limited to this. For example, the subpixels may emit four colors of light of R, G, B, and yellow (Y). Further, in each of the pixels P, the number of subpixels per each color should not be construed as being limited to one, and the pixels P may each include a plurality of subpixels of the same color. Further, the order of the subpixels in the pixels P should not be construed as being limited to the order of R, G, and B in FIG. **2**, and the order may be rearranged.

[0208] (8) In the organic EL display panel **10** pertaining to at least one embodiment, the pixel electrodes **13** are the anodes and the common electrode **17** is the cathode. However, the present disclosure should not be construed as being limited to this, and an inverted structure in which the pixel electrodes **13** are cathodes and the common electrode **17** is an anode is possible. The order in which the hole injection layer, the hole transport layer, the electron transport layer, the electron injection layer, and the like are laminated is appropriately adjusted in accordance with the positions of the cathode and the anode.

[0209] Note that the hole injection layer, the hole transport layer, the electron transport layer, the electron injection layer, and the like may be regarded as an "electric charge movement facilitating layer" that is a generic concept including these layers, taking into account functions of these layers.

[0210] (9) In at least one embodiment, the contact openings **20** are each formed in a shape of a groove in a direction parallel with the banks **14** (column direction). However, instead of such a structure, a plurality of contact holes (penetrating holes) may be provided linearly at appropriate pitches.

[0211] (10) Further, the organic EL display panel **10** pertaining to at least one embodiment is an active matrix type of panel. However, the organic EL display panel **10** should not be construed as being limited to this, and may be a passive matrix type of panel.

[0212] Although an organic EL display panel and a manufacturing method thereof pertaining to the present disclosure have been fully described by way of one or more embodiments and modifications with reference to the accompanying drawings, the present disclosure should not be construed as being limited to the above embodiments and modifications. Therefore, various changes and modifications that are apparent to a skilled artisan should be construed as being included therein unless such changes and modifications and one or more embodiments that are achieved through combining elements and functions of embodiments and modifications depart from the scope of the present disclosure.

1. An organic electroluminescence (EL) display panel, comprising:

a substrate;

a plurality of first electrodes that are spaced away from each other and are arrayed in rows and columns above the substrate;

a plurality of light-emitting layers that include organic light-emitting material and are disposed above the first electrodes;

a second electrode that is disposed above the light-emitting layers;

a first protection layer that includes resin and is disposed above the second electrode and is not disposed within an auxiliary region which, in plan view, extends in a column direction between ones of the first electrodes that are adjacent in a row direction across the substrate;

a second protection layer that includes inorganic material and is disposed above the first protection layer and the second electrode; and

an auxiliary electrode layer that extends in the column direction within the auxiliary region and is electrically connected to the second electrode through a contact opening in the first protection layer within the auxiliary region.

2. The organic EL display panel of claim **1**, further comprising:

partition walls, wherein

in plan view of the substrate, the partition walls extend in the column direction and are disposed between the auxiliary region and regions where the light-emitting layers are disposed.

3. The organic EL display panel of claim **2**, further comprising:

second partition walls, wherein

the partition walls are first partition walls, and

in plan view of the substrate, the second partition walls extend in the column direction and are disposed between the first partition walls and the auxiliary electrode layer.

4. The organic EL display panel of claim **3**, wherein

the second partition walls have a greater height than the first partition walls.

5. The organic EL display panel of claim **3**, further comprising:

banks extending in the column direction and partitioning the organic light-emitting layers arrayed in the column direction, wherein

the first partition walls and the second partition walls have greater heights than the banks.

6. The organic EL display panel of claim **4**, further comprising:

banks extending in the column direction and partitioning the organic light-emitting layers arrayed in the column direction, wherein

the first partition walls and the second partition walls have greater heights than the banks.

7. The organic EL display panel of claim **2**, further comprising:

banks extending in the column direction and partitioning the organic light-emitting layers arrayed in the column direction, wherein

the partition walls are ones of the banks that are closest to the auxiliary region.

8. The organic EL display panel of claim **7**, wherein

a width of the partition walls in the row direction is greater than a width of the banks, excluding the partition walls, in the row direction.

9. The organic EL display panel of claim **7**, wherein

a distance between the partition walls in the auxiliary region in the row direction is greater than a distance between each pair of adjacent ones of the banks, excluding the partition walls, in the row direction.

10. The organic EL display panel of claim **8**, wherein

a distance between the partition walls in the auxiliary region in the row direction is greater than a distance between each pair of adjacent ones of the banks, excluding the partition walls, in the row direction.

11. The organic EL display panel of claim **1**, further comprising:

an electric charge movement facilitating layer below the second electrode and above the light-emitting layers and the auxiliary region; and

a second auxiliary electrode layer extending in the column direction and electrically contacting a surface of the electric charge movement facilitating layer opposite the second electrode within the auxiliary region, wherein

the auxiliary electrode layer is referred to as a first auxiliary electrode layer.

12. The organic EL display panel of claim **11**, wherein

the second auxiliary electrode layer includes the same material as the first electrodes and is in the same layer as the first electrodes.

13. The organic EL display panel of claim **1**, further comprising:

a third protection layer that includes inorganic material and is disposed between the second electrode and the first protection layer.

14. The organic EL display panel of claim **1**, wherein

the second protection layer is disposed between the auxiliary electrode layer and the first protection layer.

15. A method of manufacturing an organic EL display panel, comprising:

preparing a substrate;

forming a plurality of first electrodes that are spaced away from each other and are arrayed in rows and columns above the substrate;

forming a plurality of light-emitting layers that include organic light-emitting material above the first electrodes;

forming a second electrode above the light-emitting layers;

forming a first protection layer through applying resin material above the second electrode excluding an auxiliary region which, in plan view, extends in a column direction between ones of the first electrodes that are adjacent in a row direction across the substrate;

forming a second protection layer through applying inorganic material above the first protection layer and the second electrode;

forming a contact opening in the second protection layer within the auxiliary region; and

forming an auxiliary electrode layer within the auxiliary region in the column direction, the auxiliary electrode layer electrically connecting to the second electrode through the contact opening.

* * * * *

专利名称(译)	有机el显示面板及其制造方法		
公开(公告)号	US20190363279A1	公开(公告)日	2019-11-28
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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	YAMAGUCHI JUN HARADA KENJI YADA SHUHEI		
发明人	YAMAGUCHI, JUN HARADA, KENJI YADA, SHUHEI		
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摘要(译)

有机电致发光（EL）显示面板包括基板；第一电极彼此间隔开并且在基板上方以行和列排列。发光层包括有机发光材料并设置在第一电极上方；设置在发光层上方的第二电极；第一保护层，其包括树脂并且设置在第二电极上方但不在辅助区域内，该辅助保护层在平面图中在行方向上相邻的多个第一电极之间在列方向上沿列方向延伸，所述多个第一电极跨基板。第二保护层，其包括无机材料并且设置在第一保护层和第二电极上方；辅助电极层在辅助区域内沿列方向延伸，并通过辅助区域内的第一保护层中的接触开口与第二电极电连接。