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(54) **DISPLAY DEVICE**

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(57) **ABSTRACT**

A display device includes pixel electrodes including first and second pixel electrodes separated from each other; a bank covering ends of the pixel electrodes and a region between the pixel electrodes, and having openings exposing the pixel electrodes; a first organic layer covering the first pixel electrode, and including a first light emitting layer; a second organic layer covering the second pixel electrode, and including a second light emitting layer; and a counter electrode covering the first and second organic layers and the bank. The first light emitting layer emits light having a first wavelength, the second light emitting layer emits light having a second wavelength longer than the first wavelength, the second organic layer is thicker than the first organic layer, and an angle made by the bank and the second pixel electrode is larger than an angle made by the bank and the first pixel electrode.

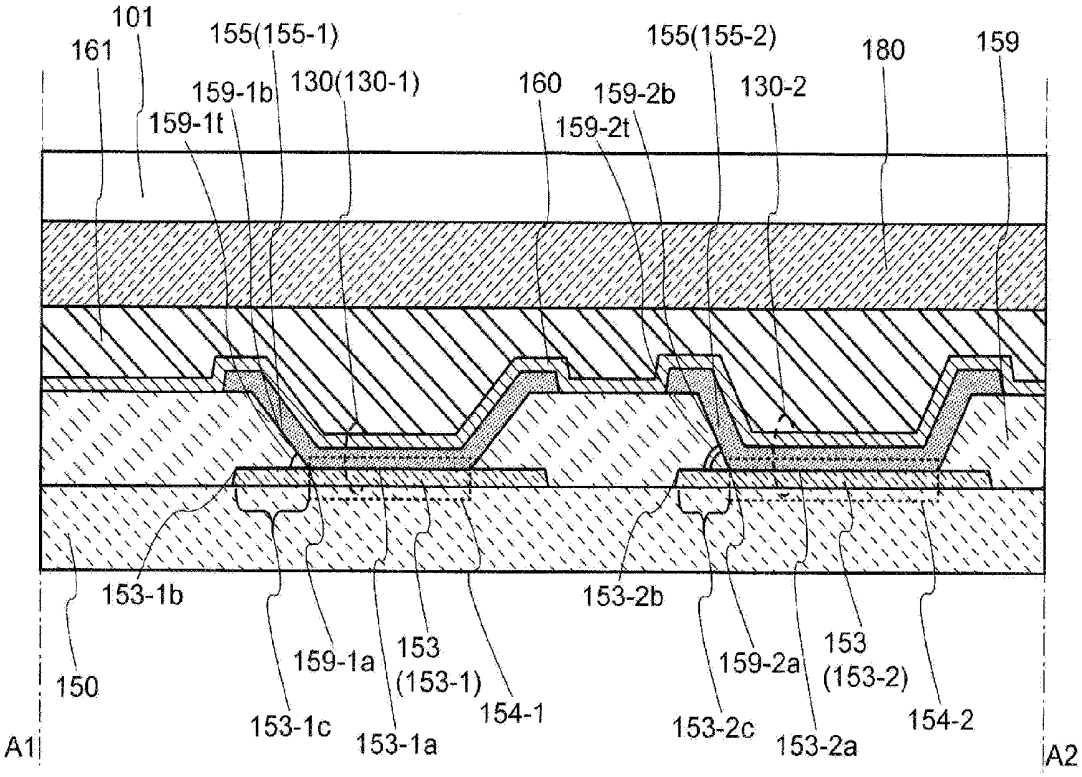
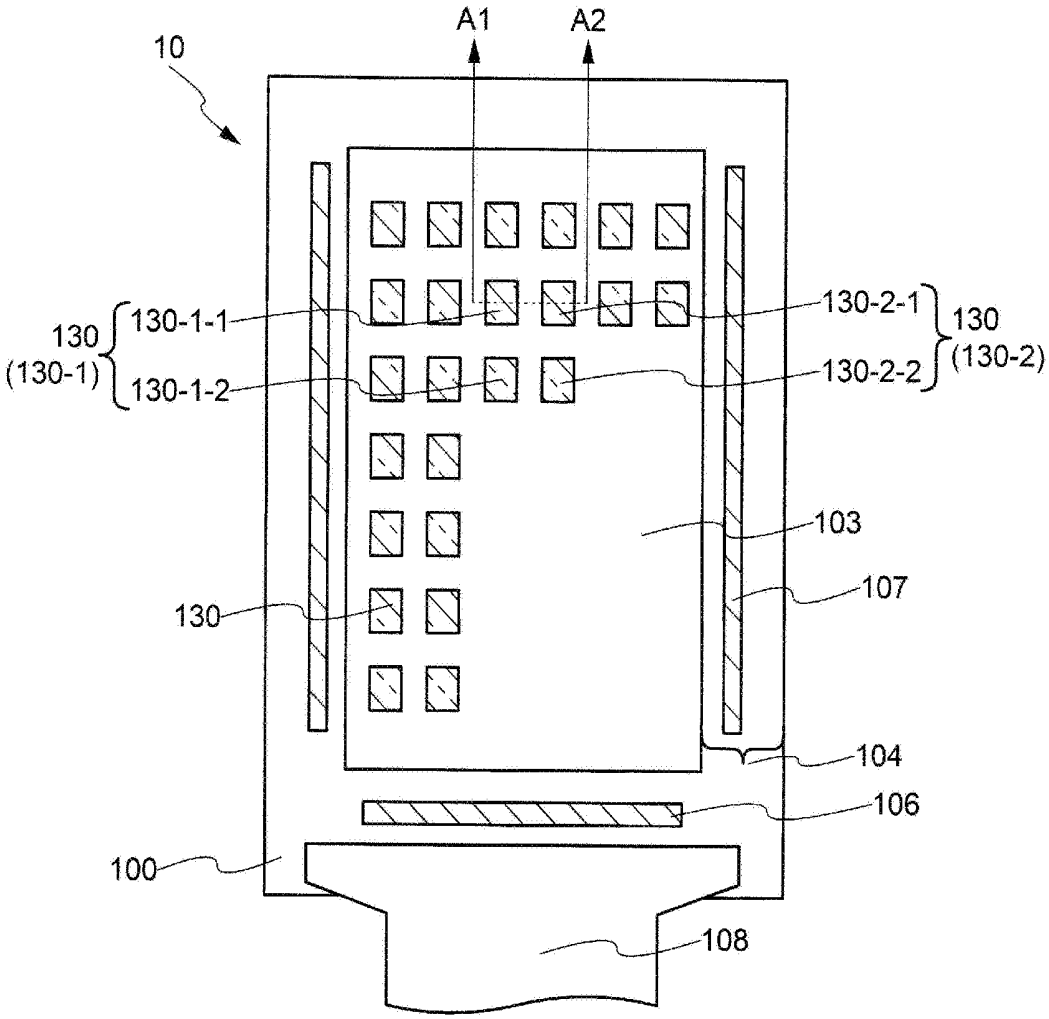


FIG. 1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(130-2)
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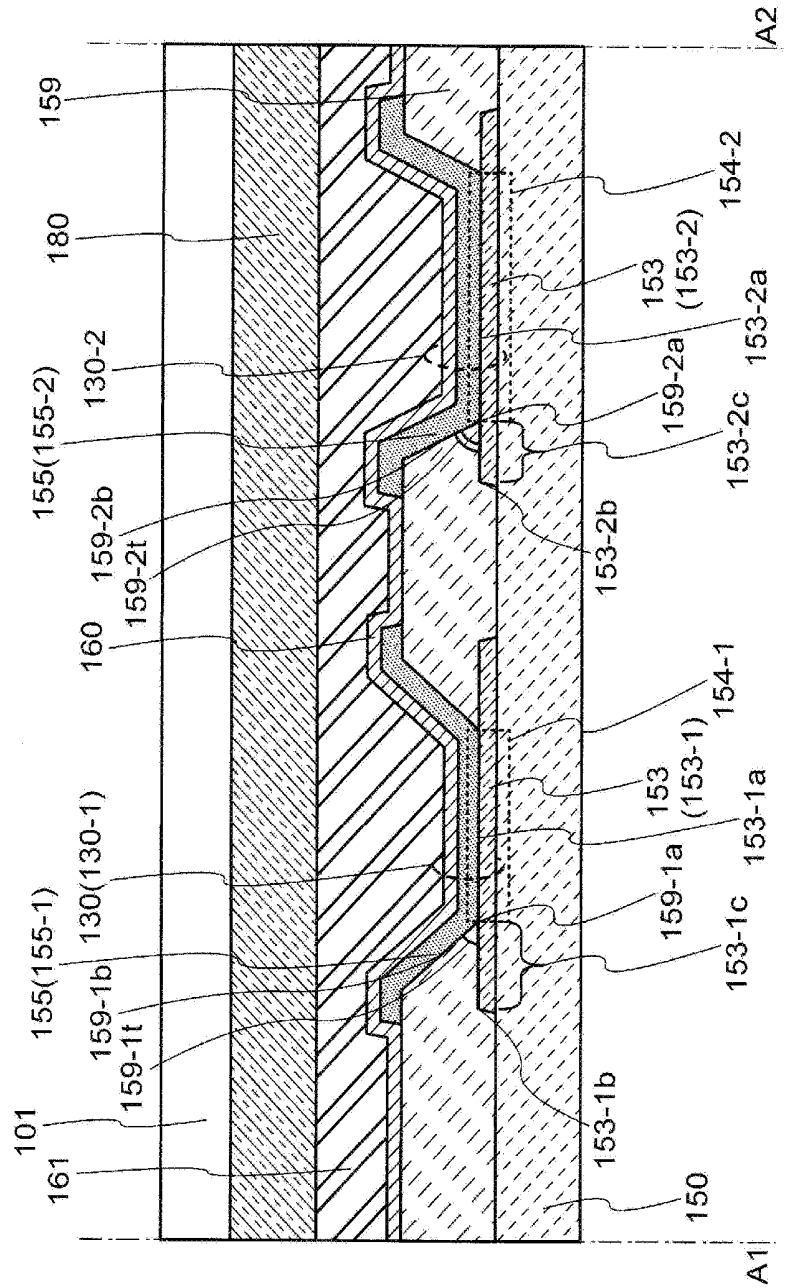
107
130
104
106
100
108

FIG. 2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159-2b
159-2t
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154-2
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153-2a
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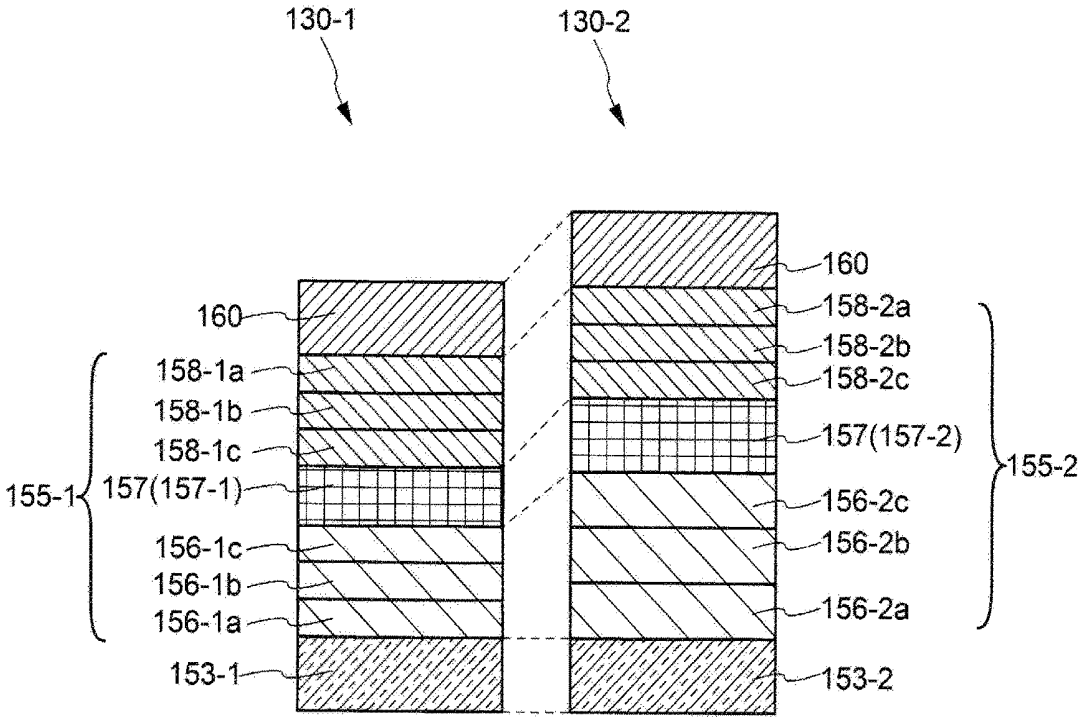
153-2c
153-2b
154-1
153
(153-1)
153-1a
159-1a
153-1c
130(130-1)
155(155-1)
159-1b
159-1t
153-1b
101
161
150
A1

FIG. 3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158-1b
158-1c
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156-1c
156-1b
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153-1
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156-2c
156-2b
156-2a
153-2

FIG. 4

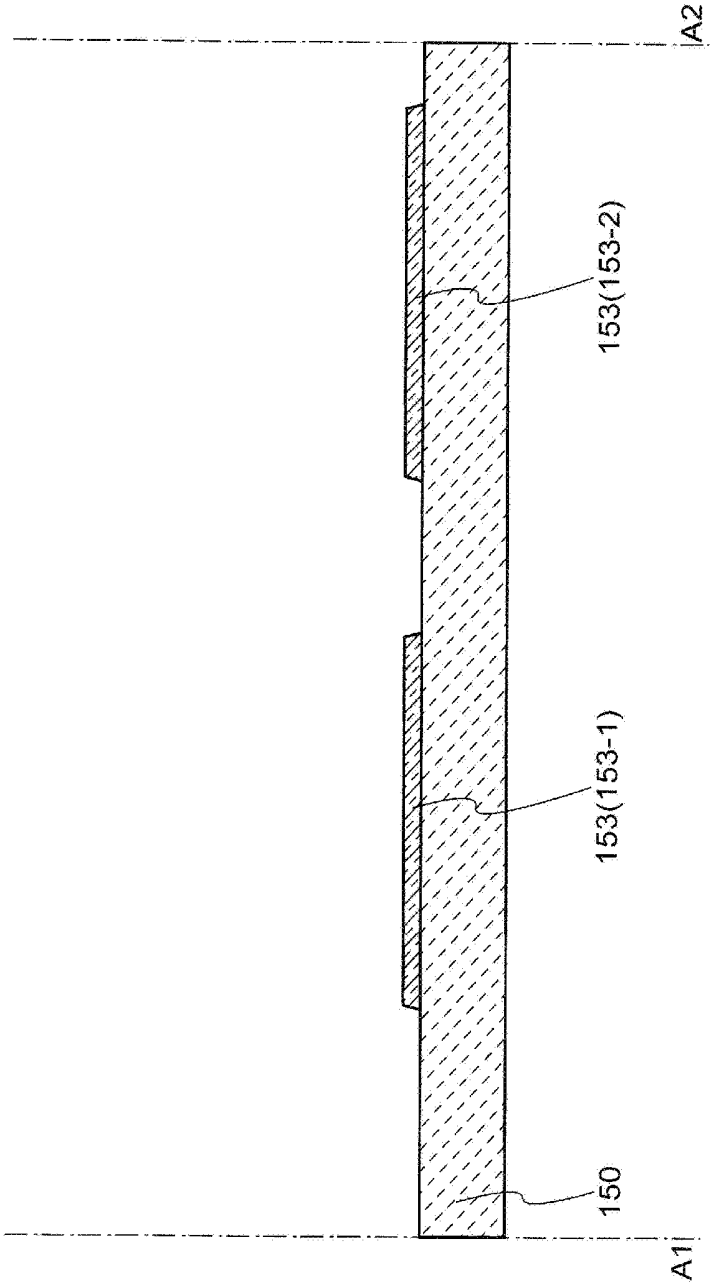


FIG. 5

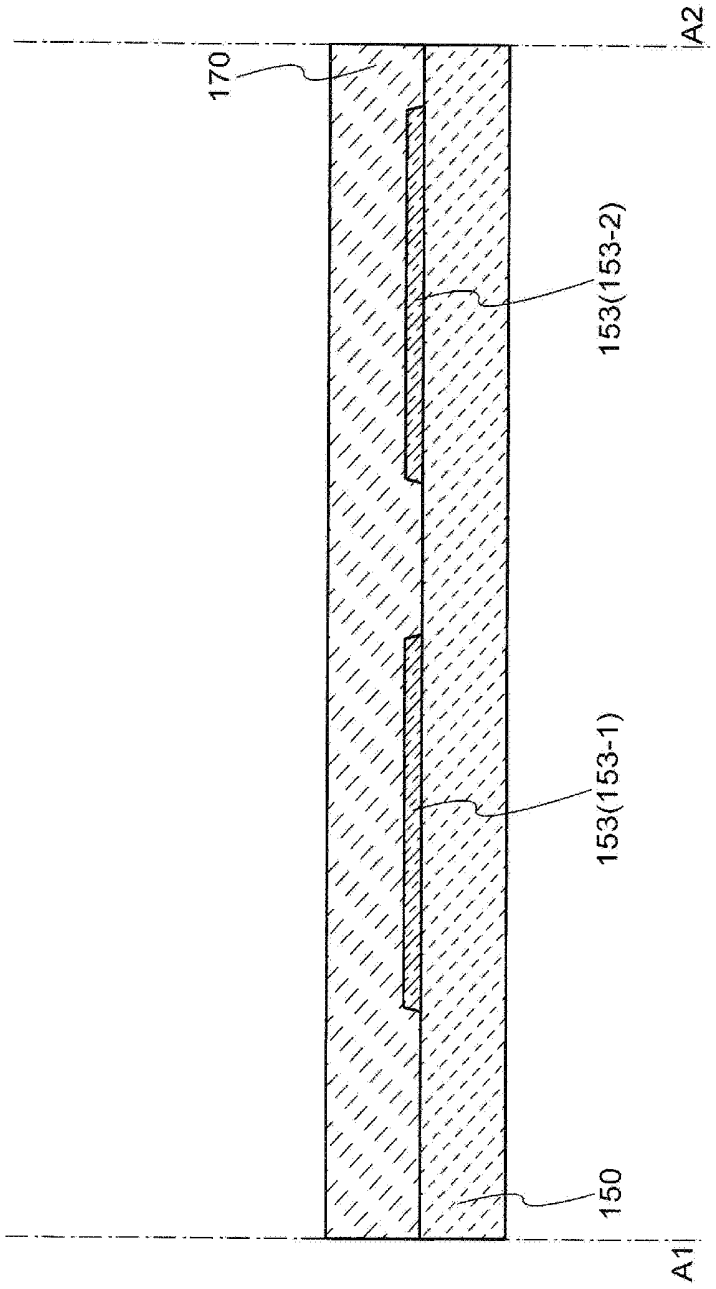


FIG. 6

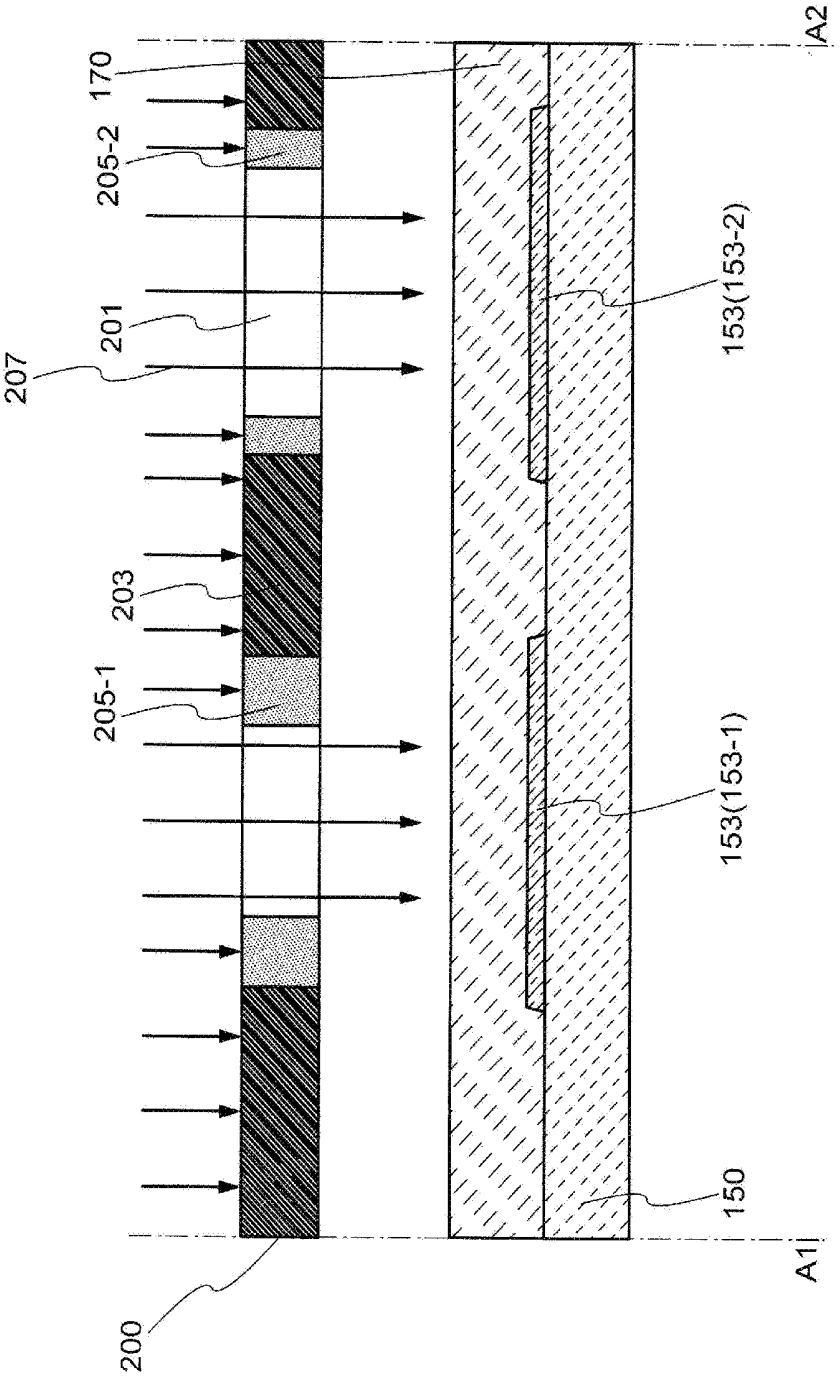
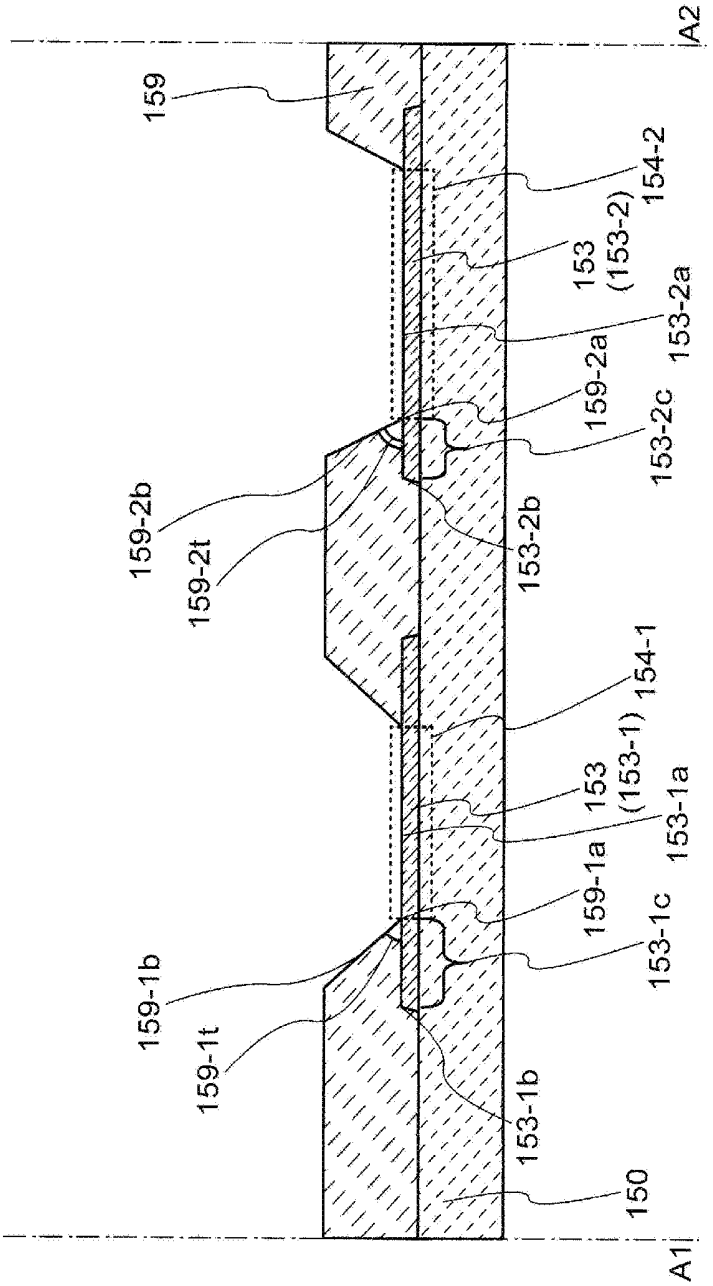


FIG. 7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153
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153-2a
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153-2c
159-2b
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153-2b
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153
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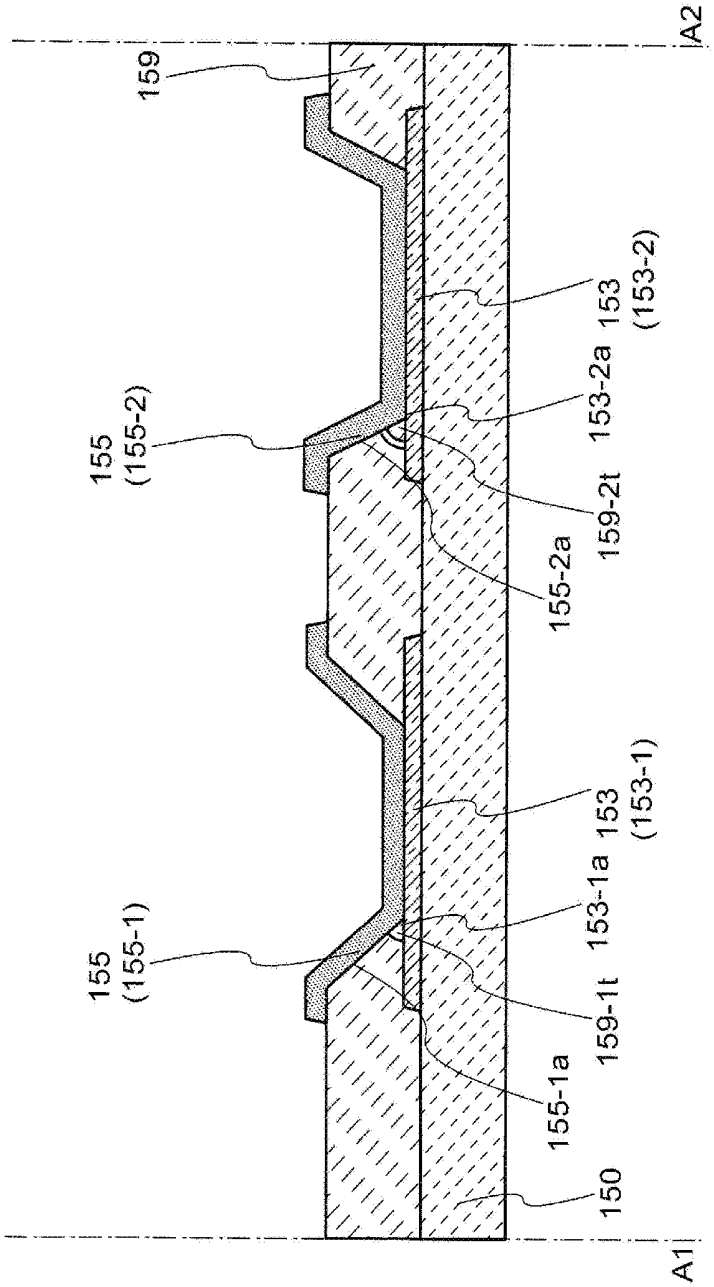
159-1b
159-1t
153-1b
150
A1

FIG. 8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(153-2)
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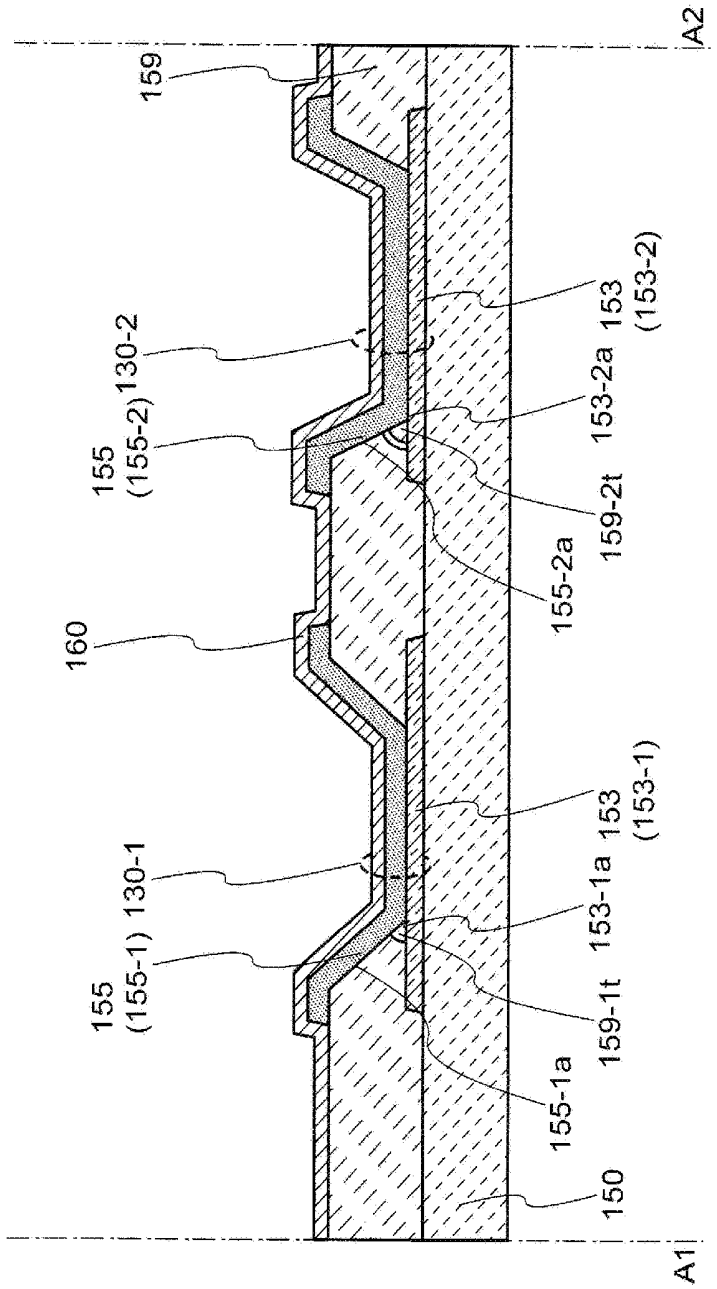
(153-1)
153-1a
159-1t
155-1a
150
A1

FIG. 9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159
130-2
155
(155-2)
153
(153-2)
153-2a
159-2t
155-2a
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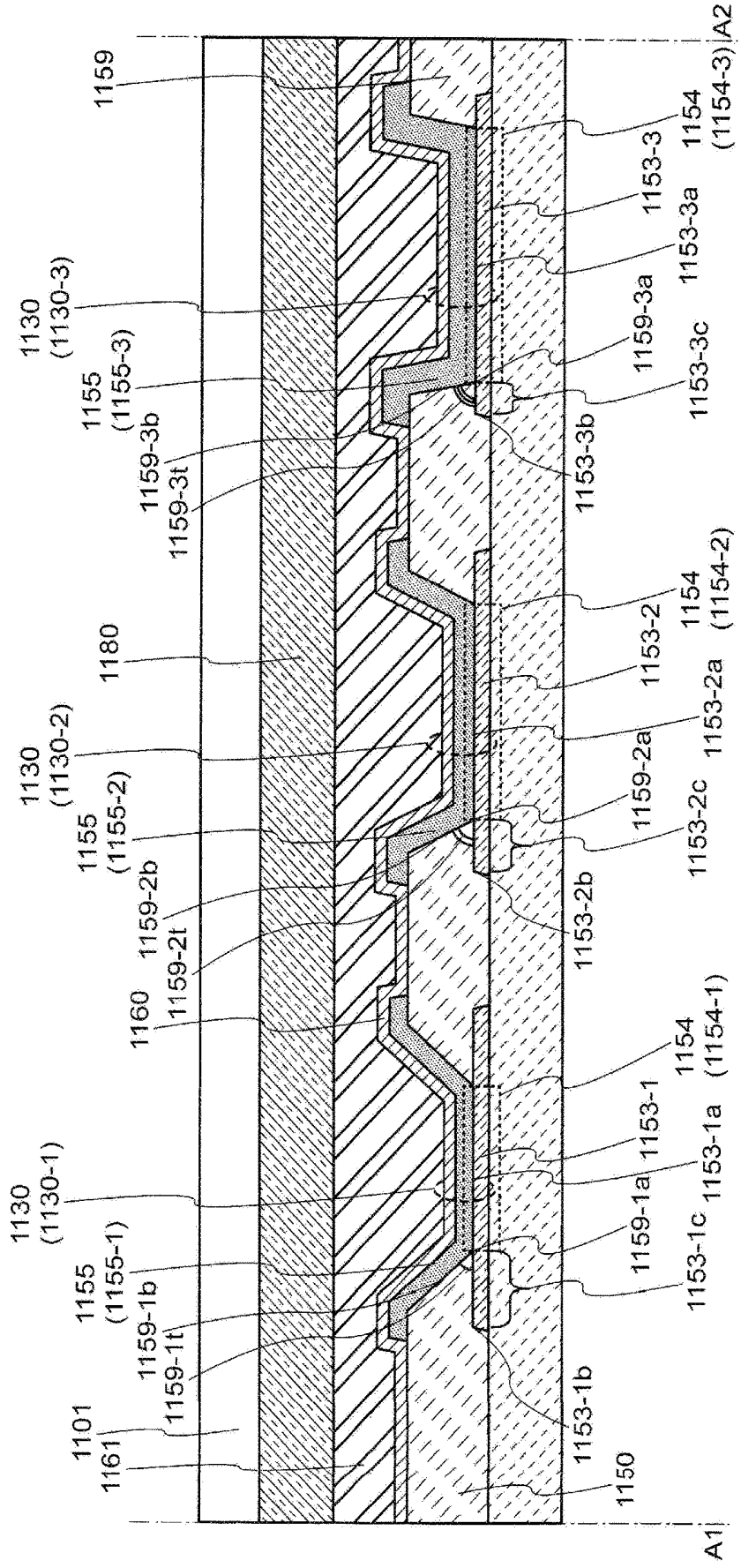
130-1
155
(155-1)
153
(153-1)
153-1a
159-1t
155-1a
150
A1

FIG. 10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1155
(1155-3)
1159-3b
1159-3t
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1159-2b
1159-2t
1160
1130
(1130-1)
1155
(1155-1)
1159-1b
1159-1t
1101
1161
1150
A1
A2
1154
(1154-3)
1153-3
1153-3a
1153-3c
1159-3a
1153-3b
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1159-2a
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1153-1c
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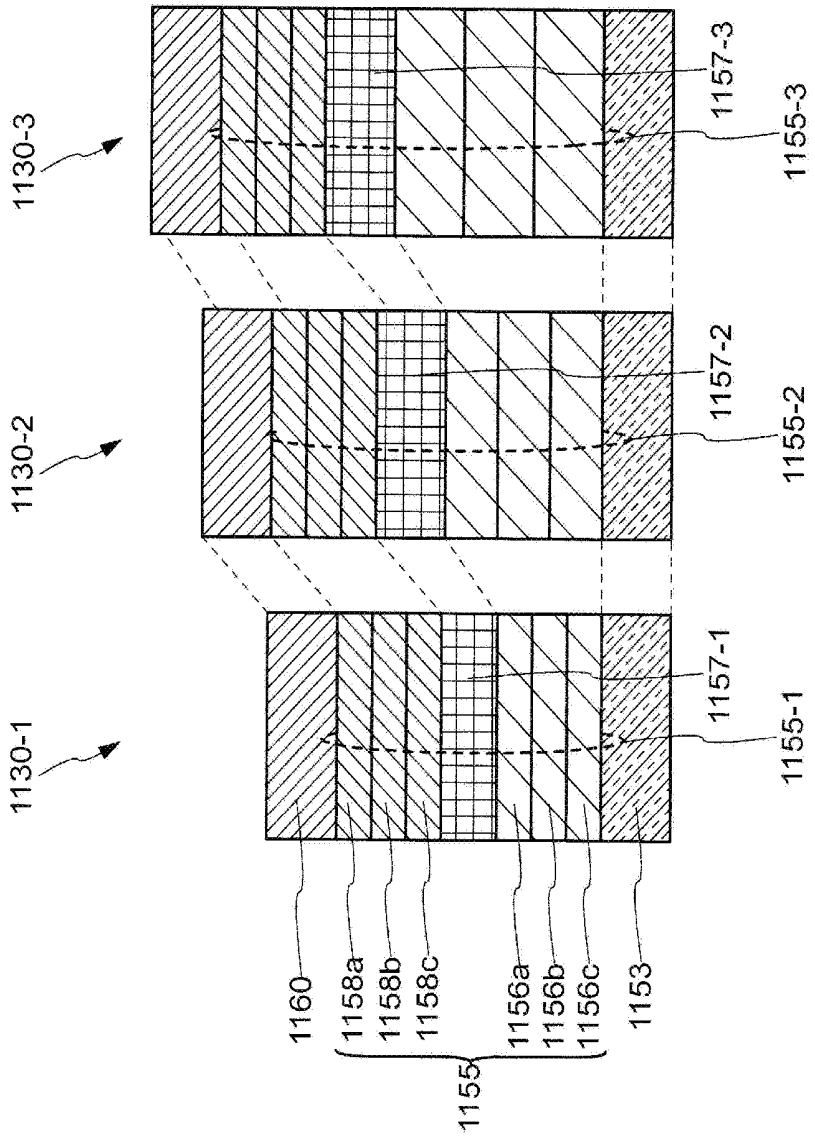
1153-1b

FIG. 11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1158c
1156a
1156b
1156c
1153
1155

FIG. 12

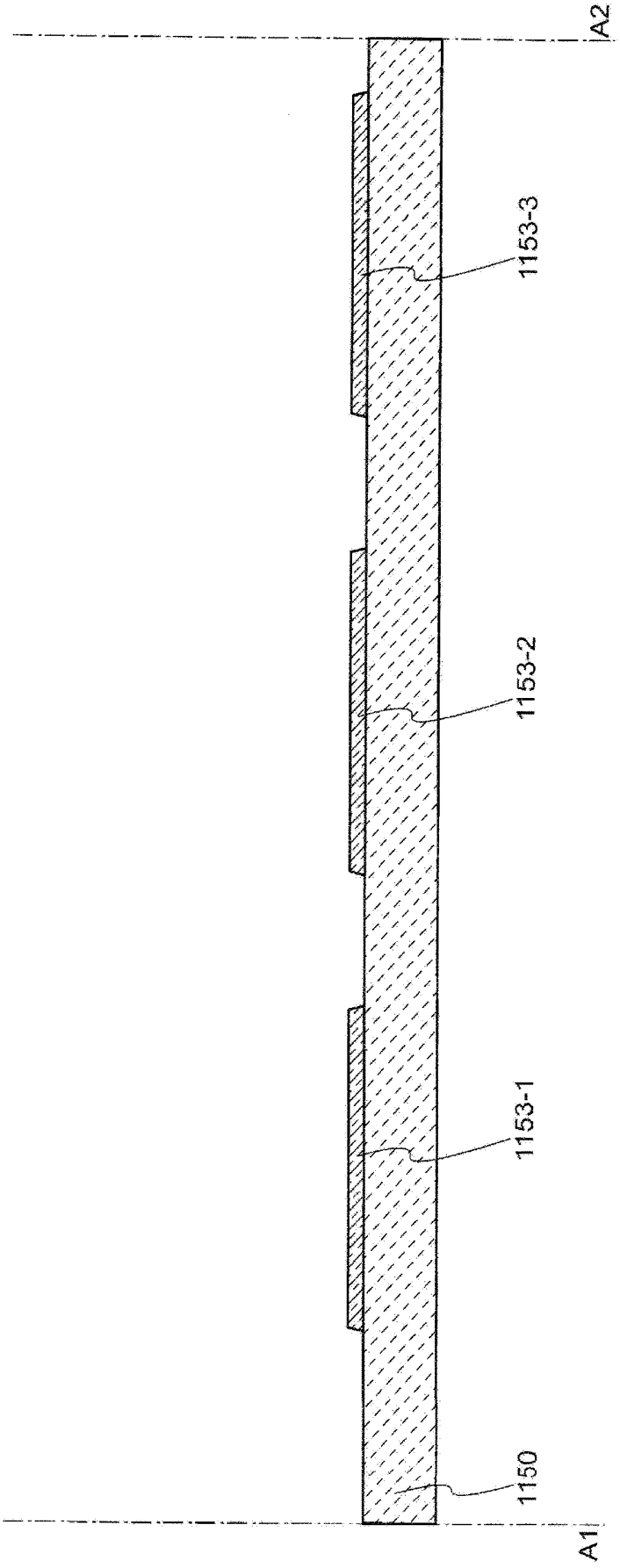


FIG. 13

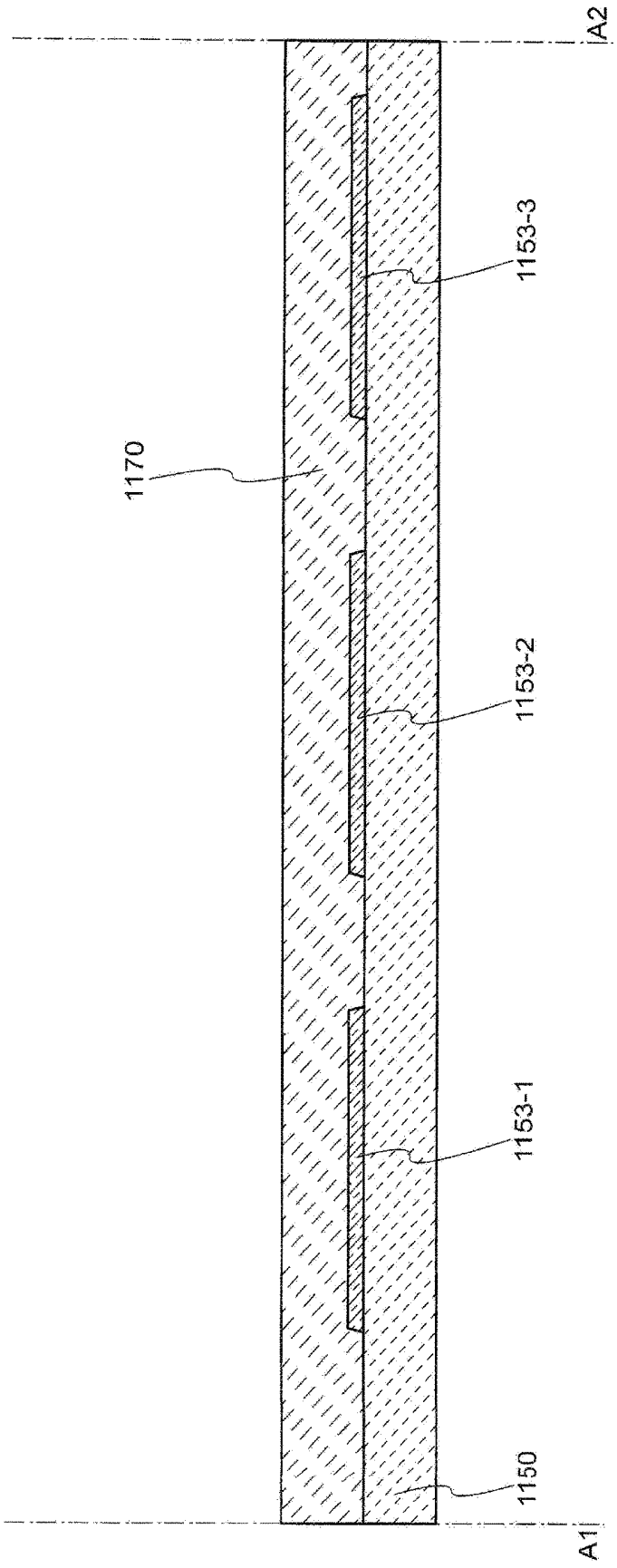
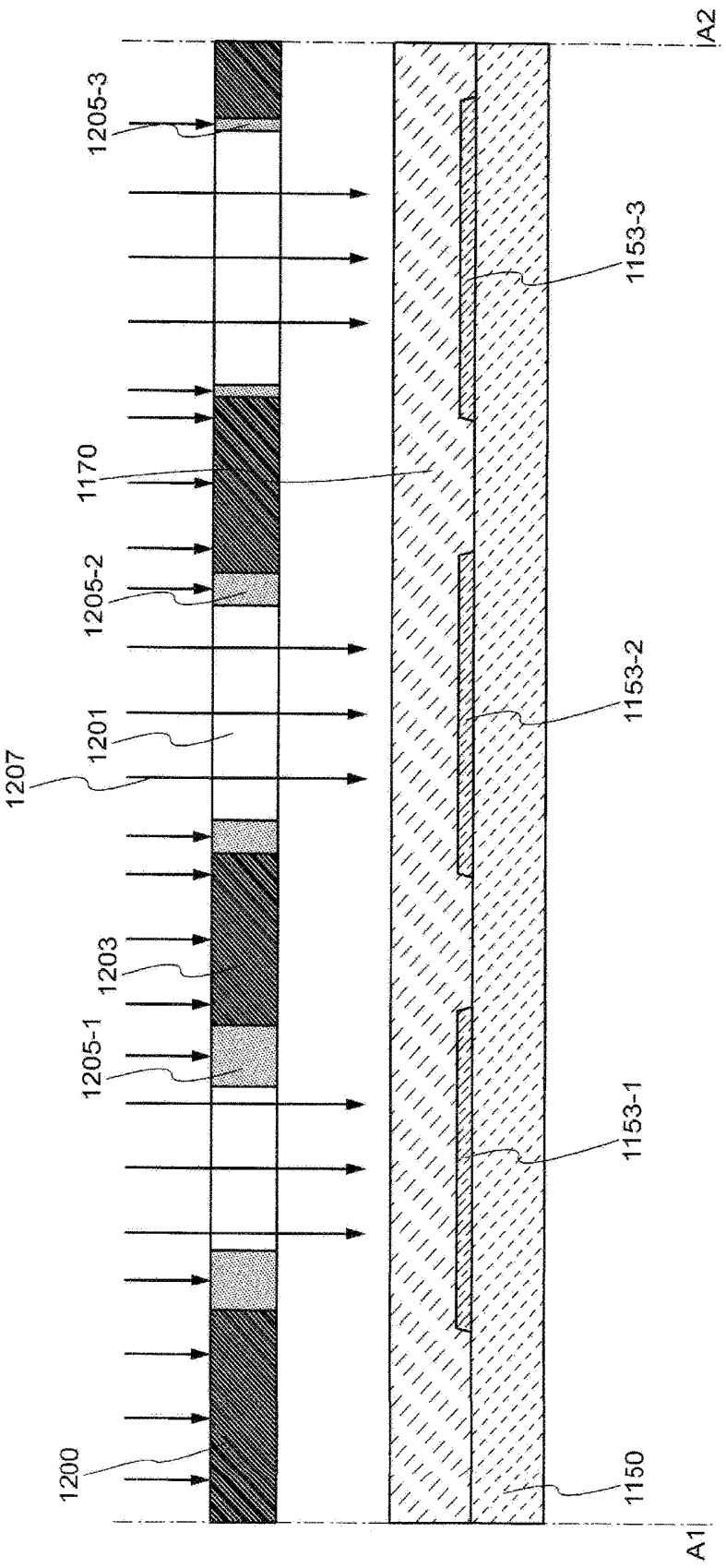


FIG. 14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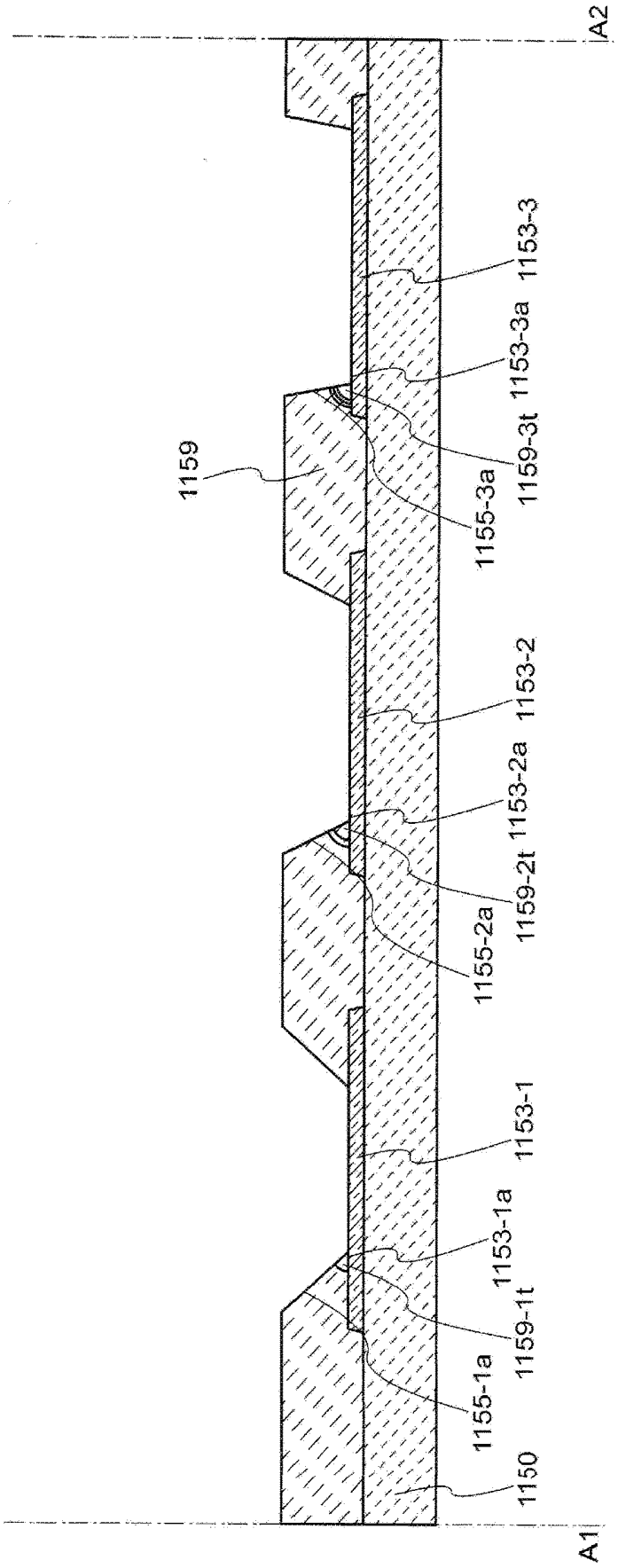
A1

FIG. 15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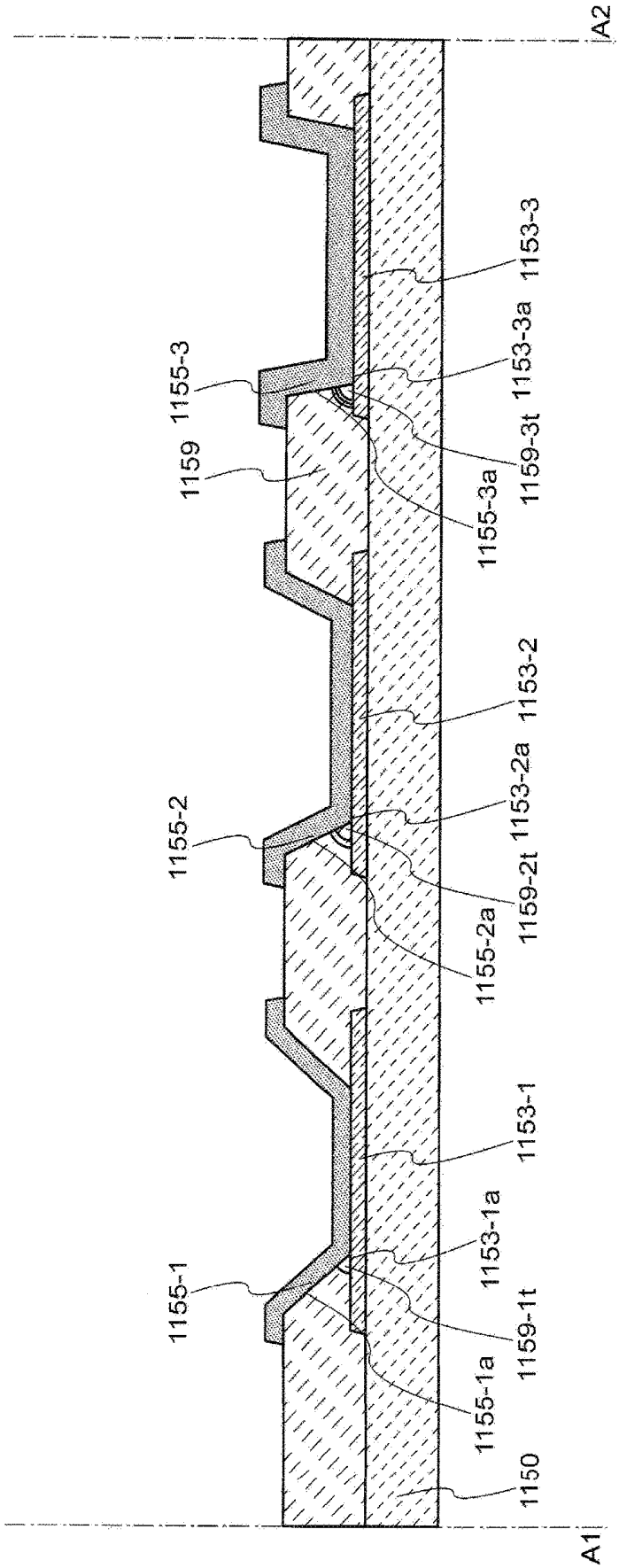
A1

FIG. 16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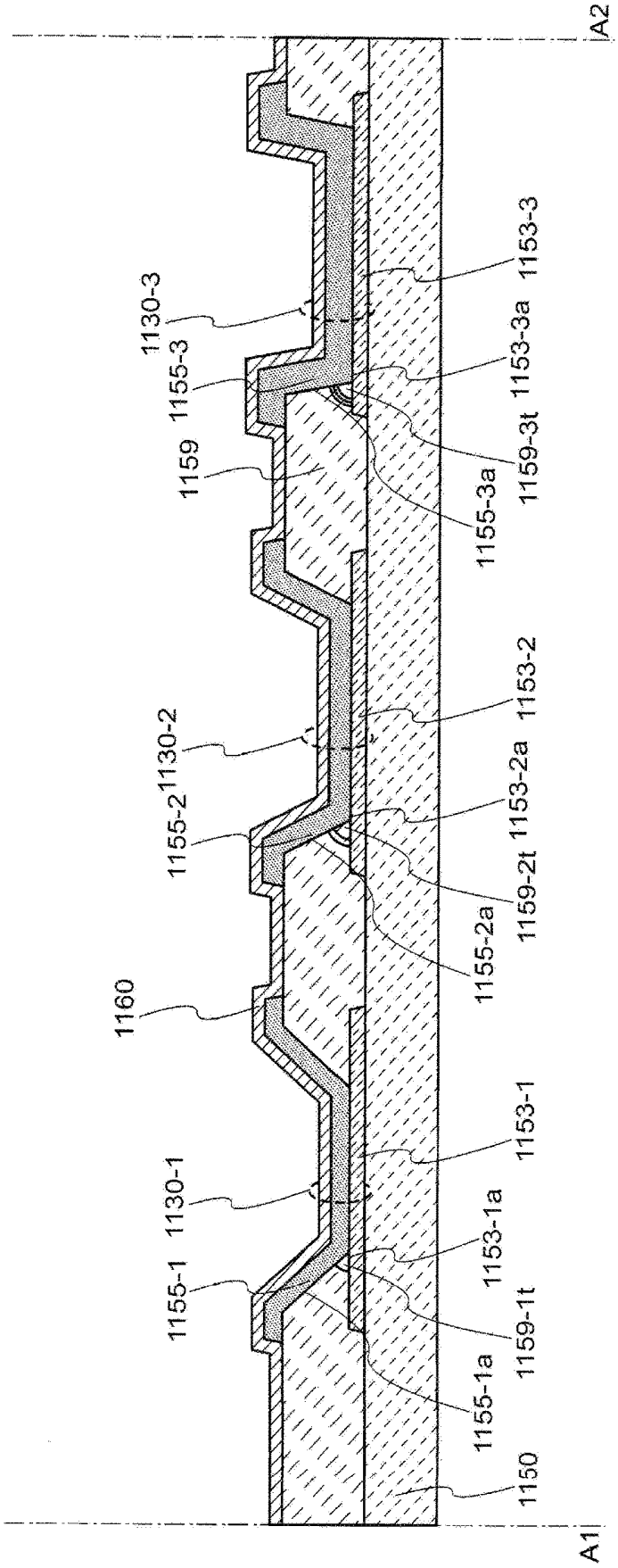
A1

FIG. 17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1159-2t
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1150
A1

FIG. 18

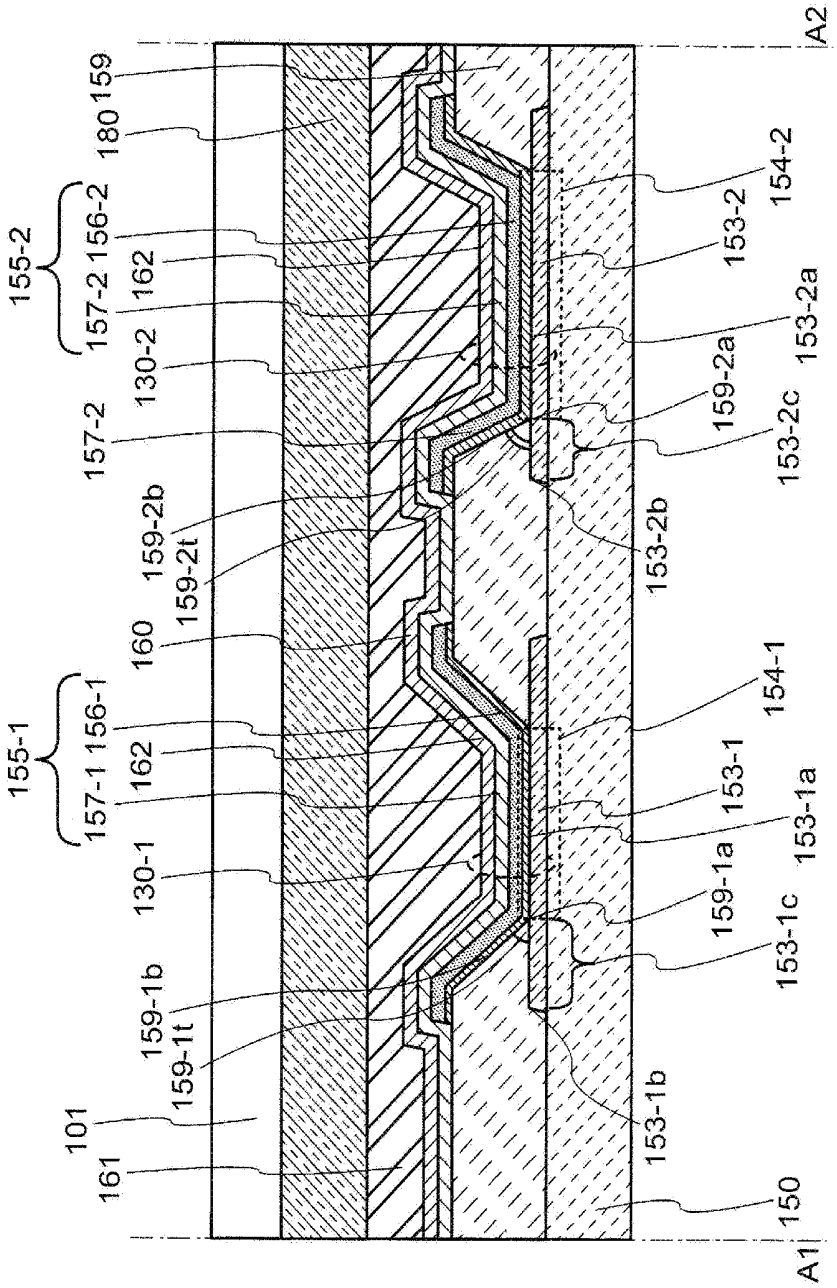
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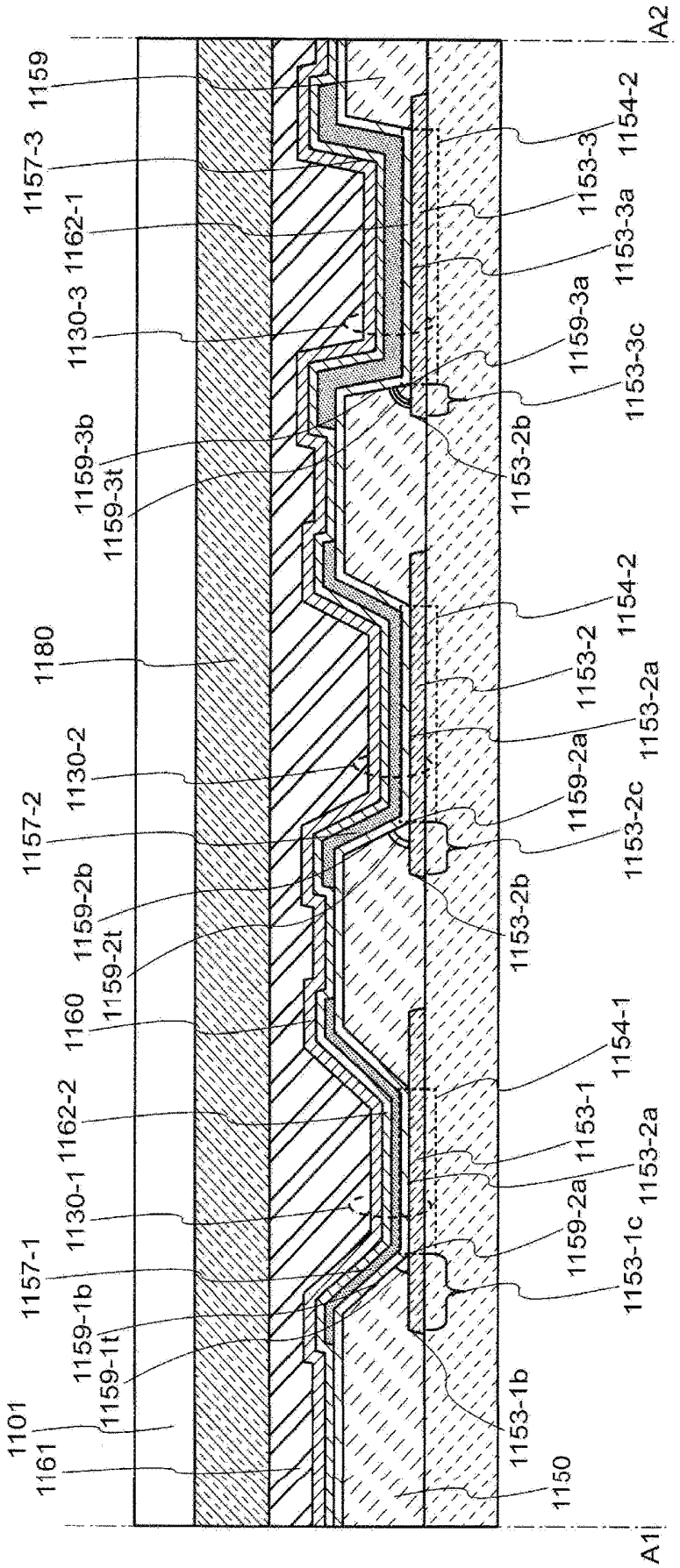
FIG. 19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1154-2
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1153-2c
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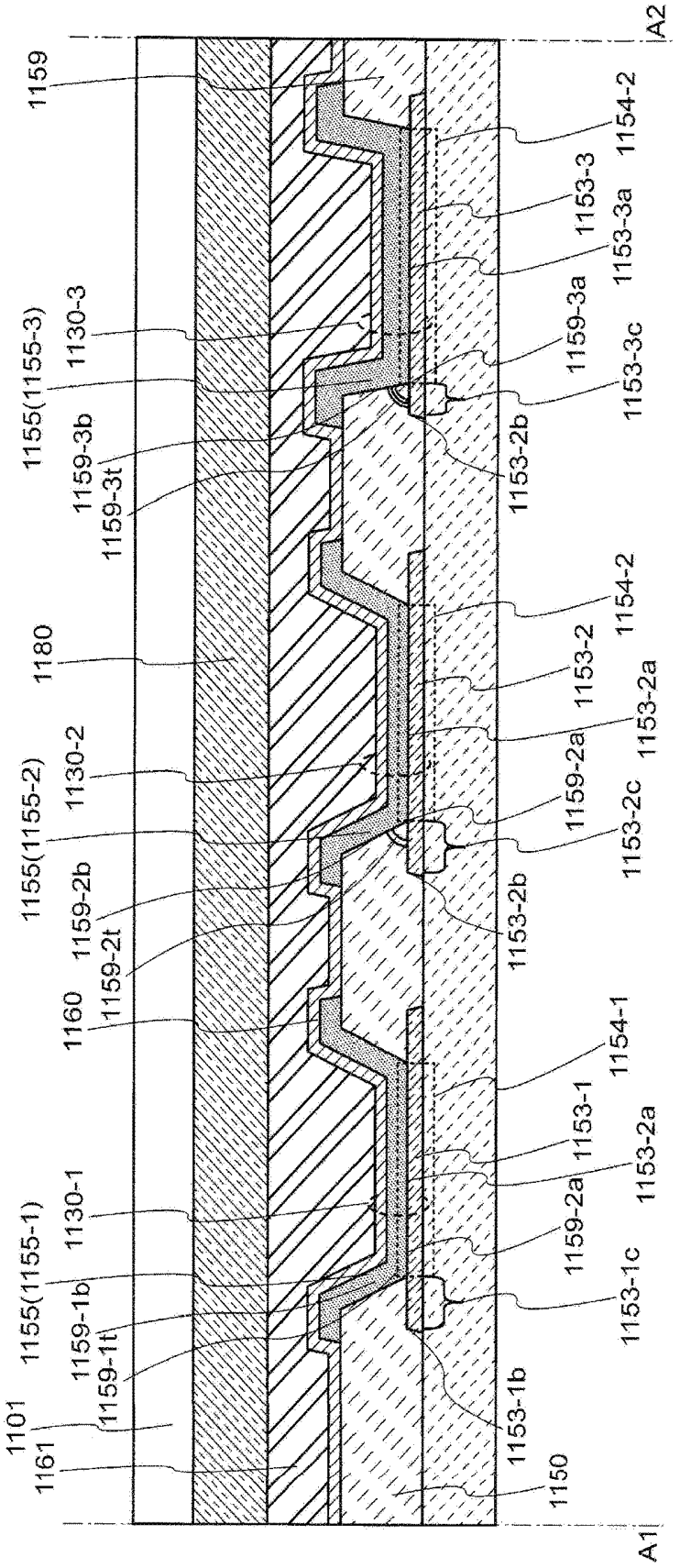
1153-1b
1150
A1

FIG. 20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1130-2
1159-2a
1153-2c
1159-2b
1159-2t
1153-2b
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1130-1
1159-2a
1153-1c
1159-1b
1159-1t
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1101
1161
1150
A1

DISPLAY DEVICE

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is based upon and claims the benefit of priority from the prior Japanese Patent Application No. 2017-006516, filed on Jan. 18, 2017, the entire contents of which are incorporated herein by reference.

FIELD

[0002] An embodiment according to the present invention relates to a display device easy to be manufactured and highly reliable.

BACKGROUND

[0003] As display devices which are usable for electric appliances and electronic devices, a liquid crystal display device using an electro-optical effect of a liquid crystal material and an organic EL (electroluminescence) display device including an organic electroluminescence (EL) element have been developed and put into actual products.

[0004] Especially in the case of being used as a display element, the organic EL element has a feature of providing a large viewing angle and high definition display. Japanese Laid-Open Patent Publication No. 2007-294421 discloses a display device including organic EL elements respectively providing a plurality of colors of light. The organic EL elements providing the plurality of colors of light each include a light emitting layer located between an anode electrode and a cathode electrode. Such light emitting layers are respectively provided for different colors of light (e.g., red (R), green (G) and blue (B)) and have different thicknesses. The organic EL elements are insulated from each other by a bank (may also be referred to as a "partitioning wall"). The organic EL elements each have an optical path length thereof adjusted accordance with the color of the light to be emitted, and thus have a light output efficiency thereof improved.

SUMMARY

[0005] An embodiment of the present invention provides a display device including a plurality of pixel electrodes including a first pixel electrode and a second pixel electrode separated from each other; a bank covering ends of the plurality of pixel electrodes and a region between the plurality of pixel electrodes, the bank having openings exposing top surfaces of the plurality of pixel electrodes; a first organic layer covering the top surface of the first pixel electrode, the first organic layer including a first light emitting layer; a second organic layer covering the top surface of the second pixel electrode, the second organic layer including a second light emitting layer; and a counter electrode covering the first organic layer, the second organic layer and the bank. The first light emitting layer emits light having a first wavelength, the second light emitting layer emits light having a second wavelength longer than the first wavelength, the second organic layer is thicker than the first organic layer, and an angle made by a second side surface of the bank and the top surface of the second pixel electrode is larger than an angle made by a first side surface of the bank and the top surface of the first pixel electrode.

[0006] An embodiment of the present invention provides a display device including a plurality of pixel electrodes including a first pixel electrode, a second pixel electrode and a third pixel electrode separated from each other; a bank covering ends of the plurality of pixel electrodes and a region between the plurality of pixel electrodes, the bank having openings exposing top surfaces of the plurality of pixel electrodes; a first organic layer covering the top surface of the first pixel electrode, the first organic layer including a first light emitting layer; a second organic layer covering the top surface of the second pixel electrode, the second organic layer including a second light emitting layer; a third organic layer covering the top surface of the third pixel electrode, the third organic layer including a third light emitting layer; and a counter electrode covering the first organic layer, the second organic layer, the third organic layer and the bank. The first light emitting layer emits light having a first wavelength, the second light emitting layer emits light having a second wavelength longer than the first wavelength, the third light emitting layer emits light having a third wavelength longer than the second wavelength, the second organic layer is thicker than the first organic layer, the third organic layer is thicker than the second organic layer, an angle made by the bank and the top surface of the second pixel electrode is larger than an angle made by the bank and the top surface of the first pixel electrode, and an angle made by the bank and the top surface of the third pixel electrode is larger than an angle made by the bank and the top surface of the second pixel electrode.

BRIEF EXPLANATION OF THE DRAWINGS

[0007] FIG. **1** is a plan view of a display device in an embodiment according to the present invention;

[0008] FIG. **2** is a cross-sectional view of the display device in an embodiment according to the present invention;

[0009] FIG. **3** is an enlarged view of display elements in an embodiment according to the present invention;

[0010] FIG. **4** is a cross-sectional view showing a manufacturing method for the display device in an embodiment according to the present invention;

[0011] FIG. **5** is a cross-sectional view showing the manufacturing method for the display device in an embodiment according to the present invention;

[0012] FIG. **6** is a cross-sectional view showing the manufacturing method for the display device in an embodiment according to the present invention;

[0013] FIG. **7** is a cross-sectional view showing the manufacturing method for the display device in an embodiment according to the present invention;

[0014] FIG. **8** is a cross-sectional view showing the manufacturing method for the display device in an embodiment according to the present invention;

[0015] FIG. **9** is a cross-sectional view showing the manufacturing method for the display device in an embodiment according to the present invention;

[0016] FIG. **10** is a cross-sectional view of a display device in an embodiment according to the present invention;

[0017] FIG. **11** is an enlarged view of display elements in an embodiment according to the present invention;

[0018] FIG. **12** is a cross-sectional view showing a manufacturing method for the display device in an embodiment according to the present invention;

[0019] FIG. **13** is a cross-sectional view showing the manufacturing method for the display device in an embodiment according to the present invention;

[0020] FIG. **14** is a cross-sectional view showing the manufacturing method for the display device in an embodiment according to the present invention;

[0021] FIG. **15** is a cross-sectional view showing the manufacturing method for the display device in an embodiment according to the present invention;

[0022] FIG. **16** is a cross-sectional view showing the manufacturing method for the display device in an embodiment according to the present invention;

[0023] FIG. **17** is a cross-sectional view showing the manufacturing method for the display device in an embodiment according to the present invention;

[0024] FIG. **18** is a cross-sectional view showing a display device in a modification of one of the above-described embodiments according to the present invention;

[0025] FIG. **19** is a cross-sectional view showing a display device in a modification of one of the above-described embodiments according to the present invention; and

[0026] FIG. **20** is a cross-sectional view showing a display device in a modification of one of the above-described embodiments according to the present invention.

DESCRIPTION OF EMBODIMENTS

[0027] Hereinafter, embodiments according to the present invention will be described with reference to the drawings. This disclosure merely provides an example, and modifications or alterations thereof readily conceivable by a person of ordinary skill in the art without departing from the gist of the present invention are duly encompassed in the scope of the present invention. In the drawings, components may be shown schematically regarding the width, thickness, shape and the like, instead of being shown in accordance with the actual sizes, for the sake of clearer illustration. The drawings are merely examples and do not limit the interpretations of the present invention in any way.

[0028] In the specification and the drawings, components that have substantially the same functions as those described before with reference to a previous drawing(s) bear the identical reference signs thereto or similar reference signs thereto (for example, numerical figure "1" is put before the reference signs in the previous drawing(s) (e.g., "1130" as opposed to "130"), and detailed descriptions thereof may be omitted. The words "first", "second" and the like provided for components are used merely to distinguish the components from each other, and do not have any further meaning unless otherwise specified.

[0029] In the specification and the claims, an expression that a component or a region is "on" another component or region encompasses a case where such a component or region is in direct contact with the another component or region and also a case where such a component is above or below the another component or region, namely, a case where still another component or region is provided between such a component or region and the another component or region, unless otherwise specified. In the following description, unless otherwise specified, the side on which a display element is provided with respect to a substrate as seen in a cross-sectional view will be referred to as "above", and the opposite side will be referred to as "below".

[0030] In this specification, the expressions that "a includes A, B or C", "a includes any of A, B and C", and "a includes one selected from the group consisting of A, B and C" do not exclude a case where a includes a plurality of combinations of A to C unless otherwise specified. The above expressions do not exclude a case where a include an element other than A, B and C.

[0031] In order to enlarge a light emitting area size of each of pixels, the bank needs to have a side surface steeply inclining. In the case where the bank has such a shape, a cathode electrode provided on an organic EL layer may be broken by the shape of the bank adjacent thereto. Therefore, conventionally, the side surface of the bank is mildly inclining, so that the breakage of the cathode electrode is avoided. However, such a mildly inclining side surface of the bank increases the total width of the bank, which decreases the light emitting area size and thus may decrease the life of the organic EL element.

[0032] A display device in an embodiment of the present invention disclosed hereinafter prevents the line breakage of a display element and has a high reliability.

Embodiment 1

[0033] A display device **10** in this embodiment will be described with reference to the drawings.

(1-1. Structure of the Display Device)

[0034] FIG. **1** is a plan view of the display device **10** in an embodiment according to the present invention. As shown in FIG. **1**, the display device **10** includes a substrate **100**, a display portion **103** including a plurality of display elements **130**, and a peripheral portion **104** enclosing the display portion **103**. The peripheral portion **104** includes a driving circuit **106** having a function of a source driver, a driving circuit **107** having a function of a gate driver, and a flexible printed circuit **108**. In the display device **10**, the display portion **103**, the driving circuit **106**, the driving circuit **107** and the flexible printed circuit **108** are electrically connected with each other. The driving circuit **106** and the driving circuit **107** are each formed of an integrated circuit such as an ASIC (Application Specific Integrated Circuit) or the like. Alternatively, the driving circuit **106** and the driving circuit **107** may each be an element directly formed on the substrate **100**. The display device **10** operates as follows. An external video signal is input to the display device **10** via the flexible printed circuit **108**. As a result, the driving circuit **106** and the driving circuit **107** drive the display elements **130**, and thus a still image or a moving image are displayed on the display portion **103**. The display elements **130** are organic EL elements. In a longer axis direction of the display portion **103**, the display elements **130** displaying the same color are arrayed.

[0035] In a region shown in the cross-sectional view of FIG. **2** along line A**1**-A**2** in FIG. **1**, there are two display elements **130** (a first display element **130-1** and a second display element **130-2**). For example, the first display element **130-1** is an organic EL element that emits blue or green light. A first display element **130-1-1** and a first display element **130-1-2** adjacent to the first display element **130-1-1** in the longer axis direction of the display portion **103** are organic EL elements that emit light of the same color, more specifically, blue or green light. Similarly, the second display element **130-2** is an organic EL element that emits red light. A second display element **130-2-1** and a second display element **130-2-2** adjacent to the second display element **130-2-1** in the longer axis direction of the display portion **103** are organic EL elements that emit red light.

(1-2. Structure of the Display Elements)

[0036] FIG. **2** is a cross-sectional view of the display portion **103**, more specifically, the display elements **130-1** and **130-2**, taken along line A1-A2 in FIG. **1**. As shown in FIG. **2**, the display elements **130** include pixel electrodes **153**, organic layers **155** and a counter electrode **160**. One pixel electrode **153** and one organic layer **155** are provided for each of the first display element **130-1** and the second display element **130-2**. The first display element **130-1** includes a first pixel electrode **153-1** and a first organic layer **155-1**, and the second display element **130-2** includes a second pixel electrode **153-2** and a second organic layer **155-2**. In the case where the first pixel electrode **153-1** and the second pixel electrode **153-2** do not need to be distinguished from each other, the first pixel electrode **153-1** and the second pixel electrode **153-2** may be collectively referred to as the pixel electrodes **153**. In the case where the first organic layer **155-1** and the second organic layer **155-2** do not need to be distinguished from each other, the first organic layer **155-1** and the second organic layer **155-2** may be collectively referred to as the organic layers **155**. In the case where the first display element **130-1** and the second display element **130-2** do not need to be distinguished from each other, the first display element **130-1** and the second display element **130-2** may be collectively referred to as the display elements **130**. The display elements **130** each have a so-called top emission type structure, in which light emitted from the organic layer **155** is output toward the counter electrode **160**. The display device **10** includes a thin film transistor (TFT) layer **150** including a semiconductor layer, a line layer and an insulating layer, a bank **159**, a sealing layer **161**, a filler **180**, and a substrate **101**, in addition to the display elements **130**.

[0037] The pixel electrodes **153** are provided on the TFT layer **150**. The pixel electrodes **153** each have a function of an electrode that drives a pixel, and preferably have a light reflecting property. For example, the pixel electrodes **153** may be formed of a light reflective metal material such as aluminum (Al), silver (Ag) or the like. Alternatively, the pixel electrodes **153** may each have a stack structure of a transparent conductive layer containing ITO (Indium Tin Oxide) or IZO (Indium Zinc Oxide) both having a superb hole injection property and a light reflective metal layer. The first pixel electrode **153-1** of the first display element **130-1** and the second pixel electrode **153-2** of the second display element **130-2** are separated from each other. Although not shown in FIG. **2**, the pixel electrodes **153** are each connected with a drain electrode of the TFT layer **150** when necessary.

[0038] The bank **159** covers ends of the first pixel electrode **153-1**, ends of the second pixel electrode **153-2**, and a region between the first pixel electrode **153-1** and the second pixel electrode **153-2**. The bank **159** has openings **154** (a first opening **154-1** and a second opening **154-2**) to expose a top surface **153-1***a* of the first pixel electrode **153-1** and a top surface **153-2***a* of the second pixel electrode **153-2**. The bank **159** is formed of an organic resin material. For example, the bank **159** may be formed of an acrylic resin, a polyimide resin, or the like. The bank **159** has a thickness that is appropriately set in the range of 1 μm or greater and 10 μm or less.

[0039] The organic layers **155** cover the top surfaces of the bank **159** and the pixel electrodes **153**. In the first display element **130-1**, the first organic layer **155-1** covers the top surface **153-1***a* of the first pixel electrode **153-1** (corresponding to the first opening **154-1**). In the second display element **130-2**, the second organic layer **155-2** covers the top surface **153-2***a* of the second pixel electrode **153-2**. The organic layers **155** are selectively formed in regions separated from each other by the bank **159** and are respectively provided for the display elements **130**. The organic layers **155** each include a light emitting layer **157** (see FIG. **3**) containing an organic electroluminescence material or the like. The first organic layer **155-1** includes a first light emitting layer **157-1**. The first light emitting layer **157-1** emits light having a first wavelength. The second organic layer **155-2** includes a second light emitting layer **157-2**. The second light emitting layer **157-2** emits light having a second wavelength.

[0040] The counter electrode **160** covers the first organic layer **155-1**, the second organic layer **155-2**, and the bank **159**. The counter electrode **160** has a function of a cathode electrode of each of the display elements **130**. The counter electrode **160** has a function of reflecting a part of the light emitted by the organic layers **155** and transmitting a part of the light emitted by the organic layers **155**. The counter electrode **160** is formed of a thin film of an alloy of silver (Ag) and magnesium (Mg). The counter electrode **160** is connected with a power source line having a constant potential.

[0041] Now, the first display element **130-1** and the second display element **130-2** will be compared against each other. FIG. **3** is an enlarged view of the first display element **130-1** and the second display element **130-2**.

[0042] The second wavelength of the light emitted from the second light emitting layer **157-2** is longer than the first wavelength of the light emitted from the first light emitting layer **157-1**. The second organic layer **155-2** is thicker than the first organic layer **155-1**.

[0043] As shown in FIG. **3**, the first organic layer **155-1** may include at least one of a first hole injection layer **156-1***a*, a first hole transfer layer **156-1***b*, and a first hole blocking layer **156-1***c*, in addition to the first light emitting layer **157-1**. The first organic layer **155-1** may include at least one of a first electron injection layer **158-1***a*, a first electron transfer layer **158-1***b*, and a first electron blocking layer **158-1***c*. Similarly, the second organic layer **155-2** may include at least one of a second hole injection layer **156-2***a*, a second hole transfer layer **156-2***b*, and a second hole blocking layer **156-2***c*, in addition to the second light emitting layer **157-2**. The second organic layer **155-2** may include at least one of a second electron injection layer **158-2***a*, a second electron transfer layer **158-2***b*, and a second electron blocking layer **158-2***c*.

[0044] The thickness of at least one of the second hole injection layer **156-2***a*, the second hole transfer layer **156-2***b* and the second hole blocking layer **156-2***c* included in the second organic layer **155-2** is larger than the thickness of at least one of the first hole injection layer **156-1***a*, the first hole transfer layer **156-1***b* and the first hole blocking layer **156-1***c* included in the first organic layer **155-1**. Namely, the thickness of the second organic layer **155-2** is larger than the thickness of the first organic layer **155-1**. The thickness of at least one of the second electron injection layer **158-2***a*, the second electron transfer layer **158-2***b* and the second electron blocking layer **158-2***c* may be larger than the thickness of at least one of the first electron injection layer **158-1***a*, the first electron transfer layer **158-1***b* and the first electron blocking layer **158-1***c*.

[0045] As described above, the organic layers **155** for different wavelengths of light have different thicknesses, so that the light interference effect of the pixel electrodes **153**, the organic layers **155** and the counter electrode **160** is optimized. This will be described more specifically. Each of wavelengths of light has an optimal optical path length. While a part of the light is reflected between the pixel electrodes **153** and the counter electrode **160**, the rest of the light is transmitted through the counter electrode **160** to be output, so that an effect of reinforcing light of a specific wavelength is provided. Such a phenomenon is referred to as a "microcavity effect".

[0046] As shown in FIG. **2**, in the first display element **130-1**, the bank **159** has a first side surface **159-1***b* (first side surface). As seen in the cross-sectional view, an angle made by the first side surface **159-1***b* and the top surface **153-1***a* of the first pixel electrode **153-1** is labeled as a first tapering angle **159-1***t*. Similarly, in the second display element **130-2**, the bank **159** has a second side surface **159-2***b* (second side surface). As seen in the cross-sectional view, an angle made by the second side surface **159-2***b* and the top surface **153-2***a* of the second pixel electrode **153-2** is labeled as a second tapering angle **159-2***t*. In this case, the second tapering angle **159-2***t* is larger than the first tapering angle **159-1***t*.

[0047] The bank **159** may have a curved side surface instead of a straight side surface. The bank **159** may have a side surface having a smaller tapering angle in a bottom portion thereof. Thus, the tapering angle of the side surface of the bank **159** may be an angle made by a tangential line to a middle portion of the side surface between a top surface and a bottom surface of the bank **159** and the top surface of the pixel electrode **153**.

[0048] The bank **159** has the first opening **154-1***a*t the top surface **153-1***a* of the first pixel electrode **153-1**. A distance between a first opening end **159-1***a* and a first pixel electrode end **153-1***b* is labeled as a first distance **153-1***c*. Similarly, the bank **159** has the second opening **154-2** at the top surface **153-2***a* of the second pixel electrode **153-2**. A distance between a second opening end **159-2***a* and a second pixel electrode end **153-2***b* is labeled as a second distance **153-2***c*. The first distance **153-1***c* is longer than the second distance **153-2***c*.

[0049] As shown in FIG. **1**, a plurality of the first display elements **130-1** are provided in the longer axis direction of the display portion **103**. The first display element **130-1-1** and the first display element **130-1-2** have substantially the same structure as each other in the shape of the bank **159**, the thickness of the organic layer **155** and the like. Namely, among two adjacent first display elements **130-1** provided in two regions adjacent to each other, one first display element **130-1** (i.e., the first display element **130-1-1**) includes one of a plurality of the first pixel electrodes **153-1**. Similarly, the other of the two adjacent first display elements **130-1** (i.e., the first display element **130-1-2**) includes the other of the plurality of first pixel electrodes **153-1**. In this region, an angle made by a side surface (first side surface) of the bank **159** and the top surface of the one of the plurality of first pixel electrodes **153-1**, and an angle made by a side surface (second side surface) of the bank **159** and the top surface of the other of the plurality of first pixel electrodes **153-1**, are equal to each other. This is applicable to the second display elements **130-2**.

[0050] With the above-described structure, the display elements **130** emitting different colors of light each have an optimal shape of the bank **159** and an optimal thickness of the organic layer **155**. Namely, in the first display element **130-1**, in which the organic layer **155** is thin, the tapering angle of the bank **159** is small. By contrast, in the second display element **130-2**, in which the organic layer **155** is thick, the tapering angle of the bank **159** is large. The thickness of the organic layer **155** and the tapering angle of the bank **159** have the following relationship. In the display element **130** emitting light of a long wavelength, the thickness of the organic layer **155** is large and the tapering angle of the bank **159** is large. In the display element **130** emitting light of a short wavelength, the thickness of the organic layer **155** is small and the tapering angle of the bank **159** is small. As a result of such an arrangement, the coverage of the counter electrode **160** on the side surface of the bank **159** is increased, and therefore, the breakage of the counter electrode **160** provided on the organic layer **155** is prevented in the entire region of the display portion **103**. In the second display element **130-2**, the tapering angle of the bank **159** is maximized. Therefore, the top surface of the bank **159** between two adjacent display elements **130** is made large. As a result, even in the case where different organic materials are vapor-deposited, the organic materials are merely vapor-deposited on the top surface of the bank **159**. Therefore, an organic material unnecessary for the second display device **130-2** is prevented from being incorporated. Since the tapering angle of the bank **159** is maximized in the second display device **130-2**, the light emitting area size is enlarged. This suppresses the second organic layer **155-2** from being deteriorated by application of an electric current, which extends the life of the second display element **130-2**. The tapering angle of the bank **159** with which the light emitting area size is guaranteed to be a certain level with no breakage may be appropriately set in the range of 30 degrees or greater and less than 70 degrees.

(**1-3**. Method for Manufacturing the Display Device)

[0051] Now, a method for manufacturing the display device **10** will be described with reference to FIG. **4** to FIG. **9**. First, as shown in FIG. **4**, the pixel electrodes **153** (the first pixel electrode **153-1** and the second pixel electrode **153-2**) are formed on a flattened surface of the TFT layer **150**. The pixel electrodes **153** are formed by sputtering, vacuum vapor deposition, plating or the like. The pixel electrodes **153** may be formed to have a predetermined shape when necessary by photolithography, nanoimprinting, ink-jetting, etching or the like. Although not shown, the pixel electrodes **130** are each connected with a line extending from the TFT layer **150**.

[0052] Next, as shown in FIG. **5**, an organic film **170**, which is to become the bank **159**, is formed. The organic film **170** is formed by spin-coating, ink-jetting, lamination, dip-coating or the like. The organic film **170** is formed of an organic resin material. For example, the organic film **170** is formed of an acrylic resin, a polyimide resin or the like. The organic film **170** may contain a photosensitive material.

[0053] The organic film **170** is processed by photolithography. For being processed, the organic film **170** may be exposed to light by use of a half-one mask **200** as shown in FIG. **6**. The half-tone mask **200** includes a transmissive portion **201**, a light-blocking portion **203** and a semi-transmissive portion **205**. The half-tone mask **200** includes first semi-transmissive portions **205-1** in portions facing the ends of the first pixel electrode **153-1**. Similarly, the half-tone mask **200** includes second semi-transmissive portions

205-2 in portions facing the ends of the second pixel electrode 153-2. The second semi-transmissive portion 205-2 has a width smaller than that of the first semi-transmissive portion 205-1.

[0054] After being exposed to light by use of the half-tone mask 200, the organic film 170 is developed to form the bank 159 as shown in FIG. 7. The bank 159 has the first tapering angle 159-1*t* on the first pixel electrode 153-1. The bank 159 has the second tapering angle 159-2*t* on the second pixel electrode 153-2.

[0055] Next, as shown in FIG. 8, the organic layers 155 (the first organic layer 155-1 and the second organic layer 155-2) are formed. The organic layers 155 are formed by vacuum vapor deposition, coating or ink-jetting. The first organic layer 155-1 and the second organic layer 155-2 are formed separately. In the case where, for example, the organic layers 155 are formed by vacuum vapor deposition, a shadow mask is used.

[0056] Next, as shown in FIG. 9, the counter electrode 160 is formed on the bank 159 and the organic layers 155. The counter electrode 160 is formed by sputtering or physical vapor deposition. The counter electrode 160 is formed of a semi-transmissive metal material. For example, the counter electrode 160 is formed of an alloy of silver and magnesium. As a result, the display elements 130 (the first display element 130-1 and the second display element 130-2) are formed. The sealing layer 161, the filler 180 and the substrate 101 are further formed, and the display device 10 is manufactured.

Embodiment 2

(2-1. Structure of the Display Elements)

[0057] A case where there are three different display elements will be described below. The structures and methods described in embodiment 1 are also applicable to this embodiment. In order to be distinguished from those in embodiment 1, the display elements will be labeled as "1130" in this embodiment.

[0058] FIG. 10 is a cross-sectional view of display portions 1103 in this embodiment. FIG. 10 corresponds to the cross-sectional view taken along line A1-A2 in FIG. 1. In a region corresponding to the region shown in the cross-sectional view of FIG. 2 along line A1-A2 in FIG. 1, there are three display elements 1130 (a first display element 1130-1, a second display element 1130-2, and a third display element 1130-3) taken along line A1-A2. The first display element 1130-1 is a light emitting element that emits blue light. The second display element 1130-2 is a light emitting element that emits green light. The third display element 1130-3 is a light emitting element that emits red light. The display elements 1130 include pixel electrodes 1153, organic layers 1155, and a counter electrode 1160.

[0059] The pixel electrodes 1153 are each formed on a TFT layer 1150 including thin film transistors. A first pixel electrode 1153-1 of the first display element 1130-1, a second pixel electrode 1153-2 of the second display element 1130-2, and a third pixel electrode 1153-3 of the third display element 1130-3 are separated from each other. The pixel electrodes 1153 are each connected with a power source line having a constant potential.

[0060] A bank 1159 is provided on the TFT layer 1150 and the pixel electrodes 1153. The bank 1159 covers ends of the first pixel electrode 1153-1, ends of the second pixel electrode 1153-2, ends of the third pixel electrode 1153-3, and regions between the first pixel electrode 1153-1, the second pixel electrode 1153-2 and the third pixel electrode 1153-3. The bank 159 has openings 1154 (a first opening 1154-1, a second opening 1154-2, and a third opening 1154-3) to expose a top surface 1153-1*a* of the first pixel electrode 1153-1, a top surface 1153-2*a* of the second pixel electrode 1153-2, and a top surface 1153-3*a* of the third pixel electrode 1153-3.

[0061] The organic layers 1155 cover the stop surfaces of the bank 1159 and the pixel electrodes 1153. In the first display element 1130-1, the first organic layer 1155-1 covers the top surface 1153-1*a* of the first pixel electrode 1153-1 (corresponding to the first opening 1154-1). In the second display element 1130-2, the second organic layer 1155-2 covers the top surface 1153-2*a* of the second pixel electrode 1153-2. In the third display element 1130-3, the third organic layer 1155-3 covers the top surface 1153-3*a* of the third pixel electrode 1153-3. The organic layers 1155 are respectively provided for the display elements 1130 and are separated from each other by the bank 1159. The first organic layer 1155-1 includes a first light emitting layer 1157-1*a*s shown in FIG. 11. The first light emitting layer 1157-1 emits light having a first wavelength. The second organic layer 1155-2 includes a second light emitting layer 1157-2 as shown in FIG. 11. The second light emitting layer 1157-2 emits light having a second wavelength. The third organic layer 1155-3 includes a third light emitting layer 1157-3 as shown in FIG. 11. The third light emitting layer 1157-3 emits light having a third wavelength.

[0062] The counter electrode 1160 covers the first organic layer 1155-1, the second organic layer 1155-2, the third organic layer 1155-3, and the bank 1159.

[0063] Now, the first display element 1130-1, the second display element 1130-2 and the third display element 1130-3 will be compared against each other. FIG. 11 is an enlarged view of the first display element 1130-1, the second display element 1130-2 and the third display element 1130-3.

[0064] The second wavelength of the light emitted from the second light emitting layer 1157-2 is longer than the first wavelength of the light emitted from the first light emitting layer 1157-1. The third wavelength of the light emitted from the third light emitting layer 1157-3 is longer than the second wavelength of the light emitted from the second light emitting layer 1157-2. The second organic layer 1155-2 is thicker than the first organic layer 1155-1. The third organic layer 1155-3 is thicker than the second organic layer 1155-2.

[0065] As shown in FIG. 11, the organic layers 1155 may each include at least one of a hole injection layer 1156*a*, a hole transfer layer 1156*b*, and a hole blocking layer 1156*c*, in addition to the light emitting layer 1157. The organic layers 1155 may each include at least one of an electron injection layer 1158*a*, an electron transfer layer 1158*b*, and an electron blocking layer 1158*c*.

[0066] As shown in FIG. 10, in the first display element 1130-1, the bank 1159 has a first side surface 1159-1*b*. An angle made by the first side surface 1159-1*b* and the top surface 1153-1*a* of the first pixel electrode 1153-1 is labeled as a first tapering angle 1159-1*t*. Similarly, in the second display element 1130-2, the bank 1159 has a second side surface 1159-2*b*. An angle made by the second side surface 1159-2*b* and the top surface 1153-2*a* of the second pixel electrode 1153-2 is labeled as a second tapering angle 1159-2*t*. Similarly, in the third display element 1130-3, the

bank **1159** has a third side surface **1159-3***b*. An angle made by the third side surface **1159-3***b* and the top surface **1153-3***a* of the third pixel electrode **1153-3** is labeled as a third tapering angle **1159-3***t*. In this case, the second tapering angle **1159-2***t* is larger than the first tapering angle **1159-1***t*. The third tapering angle **1159-3***t* is larger than the second tapering angle **1159-2***t*.

[0067] The bank **1159** may have a curved side surface instead of a straight side surface. The bank **1159** may have a side surface having a smaller tapering angle in a bottom portion thereof. Thus, the tapering angle of the side surface of the bank **1159** may be an angle made by a tangential line to a middle portion of the side surface between a top surface and a bottom surface of the bank **1159** and the top surface of the pixel electrode **1153**.

[0068] The bank **1159** has the first opening **1154-1***a*t the top surface **1153-1***a* of the first pixel electrode **1153-1**. A distance between a first opening end **1159-1***a* of the first opening **1154-1** and a first pixel electrode end **1153-1***b* of the first pixel electrode **1153-1** is labeled as a first distance **1153-1***c*. Similarly, the bank **1159** has the second opening **1154-2** at the top surface **1153-2***a* of the second pixel electrode **1153-2**. A distance between a second opening end **1159-2***a* of the second opening **1154-2** and a second pixel electrode end **1153-2***b* of the second pixel electrode **1153-2** is labeled as a second distance **1153-2***c*. Similarly, the bank **1159** has the third opening **1154-3** at the top surface **1153-3***a* of the third pixel electrode **1153-3**. A distance between a third opening end **1159-3***a* of the third opening **1154-3** and a third pixel electrode end **1153-3***b* of the third pixel electrode **1153-3** is labeled as a third distance **1153-3***c*. The first distance **1153-1***c* is longer than the second distance **1153-2***c*. The second distance **1153-2***c* is longer than the third distance **1153-3***c*.

[0069] With the above-described structure, the display elements **1130** emitting different colors of light each have an optimal shape of the bank **1159** and an optimal thickness of the organic layer **1155**. Namely, in the first display element **1130-1**, in which the organic layer **1155** is thinnest, the tapering angle of the bank **1159** is smallest. By contrast, in the third display element **1130-3**, in which the organic layer **1155** is thickest, the tapering angle of the bank **1159** is largest. In the second display element **1130-2**, the tapering angle of the bank **1159** and the thickness of the organic layer **1155** are between those of the first display element **1130-1** and those of the third display element **1130-3**. As a result of such an arrangement, the coverage of the counter electrode **1160** on the side surface of the bank **1159** is increased, and therefore, the breakage of the counter electrode **1160** is prevented in each of the display elements **1130**. In the third display element **1130-3**, the light emitting area size is enlarged, and therefore, the third organic layer **1155-3** is suppressed from being deteriorated. In the third display element **1130-3**, the tapering angle of the bank **1159** is maximized. Therefore, the top surface of the bank **1159** between two adjacent display elements **1130** is made large. As a result, even in the case where different organic materials are vapor-deposited, the organic materials are merely vapor-deposited on the top surface of the bank **1159**. Therefore, an organic material unnecessary for the second display element **1130-2** is prevented from being incorporated.

[0070] Although not shown, a plurality of the first display elements **1130-1** are provided in the longer axis direction of the display portion **1103**. Two first display elements **1130** provided in such adjacent regions have the following relationship. One of the first display elements **1130-1** includes one of a plurality of the first pixel electrodes **1153-1**. Similarly, the other of the first display elements **1130-1** includes the other of the plurality of first pixel electrodes **1153-1**. In this region, an angle made by a side surface of the bank **1159** and the top surface of the one of the plurality of first pixel electrodes **1153-1**, and an angle made by a side surface of the bank **1159** and the top surface of the other of the plurality of first pixel electrodes **1153-1**, are equal to each other. This is applicable to the second display elements **1130-2** and the third display elements **1130-3**.

(2-2. Method for Manufacturing the Display Device)

[0071] Now, a method for manufacturing the display device, especially, the display elements **1130**, will be described with reference to FIG. **12** to FIG. **17**.

[0072] First, as shown in FIG. **12**, the pixel electrodes **1153** (the first pixel electrode **1153-1**, the second pixel electrode **1153-2** and the third pixel electrode **1153-3**) are formed on a flattened surface of the TFT layer **1150**.

[0073] Next, as shown in FIG. **13**, an organic film **1170**, which is to become the bank **1159**, is formed.

[0074] The organic film **1170** is processed by photolithography. As shown in FIG. **14**, a half-one mask **1200** is used in photolithography. The half-tone mask **1200** includes semi-transmissive portions **1205-1** in portions facing the ends of the first pixel electrode **1153-1**. Similarly, the half-tone mask **1200** includes semi-transmissive portions **1205-2** in portions facing the ends of the second pixel electrode **1153-2**. Similarly, the half-tone mask **1200** includes semi-transmissive portions **1205-3** in portions facing the ends of the third pixel electrode **1153-3**. The first semi-transmissive portion **1205-1** has a width larger than that of the first semi-transmissive portion **1205-2**. The second semi-transmissive portion **1205-2** has a width larger than that of the third semi-transmissive portion **1205-3**.

[0075] After being exposed to light by use of the half-tone mask **1200**, the organic film **1170** is developed to form the bank **1159** as shown in FIG. **15**. The bank **1159** has the first tapering angle **1159-1***t* on the first pixel electrode **1153-1**. The bank **1159** has the second tapering angle **1159-2***t* on the second pixel electrode **1153-2**. The bank **1159** has the third tapering angle **1159-3***t* on the third pixel electrode **1153-3**.

[0076] Next, as shown in FIG. **16**, the organic layers **1155** (the first organic layer **1155-1**, the second organic layer **1155-2** and the third organic layer **1155-3**) are formed. The first organic layer **1155-1**, the second organic layer **1155-2** and the third organic layer **1155-3** are formed separately.

[0077] Next, as shown in FIG. **17**, the counter electrode **160** is formed on the bank **1159**, the first organic layer **1155-1**, the second organic layer **1155-2** and the third organic layer **1155-3**. As a result, the display elements **130** are formed.

<Modifications>

[0078] In embodiment 1 of the present invention, the first organic layer **155-1** and the second organic layer **155-2** are formed separately. In the case where the first organic layer **155-1** and the second organic layer **155-2** are formed of the same material, a common layer **162** may be formed continuously on the first organic layer **155-1** and the second organic layer **155-2** as shown in FIG. **18**. The common layer

162 may include at least one of a hole injection layer, a hole transfer layer, a hole blocking layer, an electron injection layer, an electron transfer layer and an electron blocking layer. For example, as shown in FIG. **18**, a first layer **156-1** including at least one of the first hole injection layer **156-1***a*, the first hole transfer layer **156-1***b* and the first hole blocking layer **156-1***c* (see FIG. **3**) and the first light emitting layer **157-1** are provided separately from a second layer **156-2** including at least one of the second hole injection layer **156-2***a*, the second hole transfer layer **156-2***b* and the second hole blocking layer **156-2***c* (see FIG. **3**) and the second light emitting layer **157-2**. The common layer **162** including at least one of the electron injection layer, the electron transfer layer and the electron blocking layer is provided continuously on the first light emitting layer **157-1** and the second light emitting layer **157-2**.

[0079] Similarly, as shown in FIG. **19**, a first common layer **1162-1** and a second common layer **1162-2** may be formed continuously on the first light emitting layer **1157-1**, the second light emitting layer **1157-2** and the third light emitting layer **1157-3**. As shown in FIG. **19**, the first light emitting layer **1157-1**, the second light emitting layer **1157-2** and the third light emitting layer **1157-3** are formed separately. The first common layer **1162-1** including at least one of the hole injection layer **1156***a*, the hole transfer layer **1156***b* and the hole blocking layer **1156***c* (see FIG. **11**), and the second common layer **1162-2** including at least one of the electron injection layer **1158***a*, the electron transfer layer **1158***b* and the electron blocking layer **1158***c* (see FIG. **11**) are provided continuously on the first light emitting layer **1157-1** and the second light emitting layer **1157-2**. Such a structure simplifies the manufacturing method and thus decreases the manufacturing cost. The simplification of the manufacturing method improves the throughput and increases the yield of the products.

[0080] In embodiment 2 of the present invention, three display elements respectively include organic layers of different thicknesses. As shown in FIG. **20**, the first organic layer **1155-1** and the second organic layer **1155-2** may have the same thickness as each other. In this case, the third organic layer **1155-3** is thicker than each of the first organic layer **1155-1** and the second organic layer **1155-2**. In the case where the organic layers **1155** in the three display elements **1130** do not need to have different thicknesses from each other, two of the display elements **1130** may be manufactured at the same time with such a structure. This simplifies the manufacturing method and thus decreases the manufacturing cost. The simplification of the manufacturing method improves the throughput and increases the yield of the products.

[0081] A person of ordinary skill in the art would readily conceive various alterations or modifications of the present invention, and such alterations and modifications are construed as being encompassed in the scope of the present invention. For example, the display devices in the above-described embodiments may have an element added thereto, or deleted therefrom, or may be changed in design optionally by a person of ordinary skill in the art. The methods in the above-described embodiments may have a step added thereto, or deleted therefrom, or may be changed in the condition optionally by a person of ordinary skill in the art. Such devices and methods are encompassed in the scope of the present invention as long as including the gist of the present invention.

What is claimed is:

1. A display device, comprising:
- a plurality of pixel electrodes including a first pixel electrode and a second pixel electrode separated from each other;
- a bank covering ends of the plurality of pixel electrodes and a region between the plurality of pixel electrodes, the bank having openings exposing top surfaces of the plurality of pixel electrodes;
- a first organic layer covering the top surface of the first pixel electrode, the first organic layer including a first light emitting layer;
- a second organic layer covering the top surface of the second pixel electrode, the second organic layer including a second light emitting layer; and
- a counter electrode covering the first organic layer, the second organic layer and the bank, wherein
- the first light emitting layer emits light having a first wavelength,
- the second light emitting layer emits light having a second wavelength longer than the first wavelength,
- the second organic layer is thicker than the first organic layer, and
- an angle made by a second side surface of the bank and the top surface of the second pixel electrode is larger than an angle made by a first side surface of the bank and the top surface of the first pixel electrode.

2. The display device according to claim **1**, wherein a first distance between an end of a first opening, among the openings, of the bank on the top surface of the first pixel electrode and an end of the first pixel electrode is longer than a second distance between an end of a second opening, among the openings, of the bank on the top surface of the second pixel electrode and an end of the second pixel electrode.

3. The display device according to claim **1**, further comprising a common layer continuously provided on the first organic layer and the second organic layer.

4. The display device according to claim **1**, wherein
- the plurality of pixel electrodes include a plurality of the first pixel electrodes, and
- in a region where one of the first pixel electrodes and the other of the first pixel electrodes are adjacent to each other, an angle made by a first side surface of the bank and the top surface of the one of the first pixel electrodes is equal to an angle made by a first side surface of the bank and the top surface of the other of the first pixel electrodes.

5. The display device according to claim **4**, wherein
- the plurality of pixel electrodes include a plurality of the second pixel electrodes, and
- in a region where one of the second pixel electrodes and the other of the second pixel electrodes are adjacent to each other, an angle made by a second side surface of the bank and the top surface of the one of the second pixel electrodes is equal to an angle made by a second side surface of the bank and the top surface of the other of the second pixel electrodes.

6. A display device, comprising:
- a plurality of pixel electrodes including a first pixel electrode, a second pixel electrode and a third pixel electrode separated from each other;
- a bank covering ends of the plurality of pixel electrodes and a region between the plurality of pixel electrodes,

the bank having openings exposing top surfaces of the plurality of pixel electrodes;

a first organic layer covering the top surface of the first pixel electrode, the first organic layer including a first light emitting layer;

a second organic layer covering the top surface of the second pixel electrode, the second organic layer including a second light emitting layer;

a third organic layer covering the top surface of the third pixel electrode, the third organic layer including a third light emitting layer; and

a counter electrode covering the first organic layer, the second organic layer, the third organic layer and the bank, wherein

the first light emitting layer emits light having a first wavelength,

the second light emitting layer emits light having a second wavelength longer than the first wavelength,

the third light emitting layer emits light having a third wavelength longer than the second wavelength,

the second organic layer is thicker than the first organic layer,

the third organic layer is thicker than the second organic layer,

an angle made by the bank and the top surface of the second pixel electrode is larger than an angle made by the bank and the top surface of the first pixel electrode, and

an angle made by the bank and the top surface of the third pixel electrode is larger than an angle made by the bank and the top surface of the second pixel electrode.

7. The display device according to claim **6**, wherein

a first distance between an end of the opening of the bank at the top surface of the first pixel electrode and an end of the first pixel electrode is longer than a second distance between an end of the opening of the bank at the top surface of the second pixel electrode and an end of the second pixel electrode, and

the second distance is longer than a third distance between an end of the opening of the bank at the top surface of the third pixel electrode and an end of the third pixel electrode.

8. The display device according to claim **7**, further comprising a common layer continuously provided on the first organic layer, the second organic layer and the third organic layer.

9. The display device according to claim **6**, wherein

the plurality of pixel electrodes include a plurality of the first pixel electrodes, and

in a region where one of the first pixel electrodes and the other of the first pixel electrodes are adjacent to each other, an angle made by a side surface of the bank and the top surface of the one of the first pixel electrodes is equal to an angle made by a side surface of the bank and the top surface of the other of the first pixel electrodes.

10. The display device according to claim **9**, wherein

the plurality of pixel electrodes include a plurality of the second pixel electrodes, and

in a region where one of the second pixel electrodes and the other of the second pixel electrodes are adjacent to each other, an angle made by a side surface of the bank and the top surface of one of the second pixel electrodes is equal to an angle made by a side surface of the bank and the top surface of the other of the second pixel electrodes.

11. The display device according to claim **10**, wherein

the plurality of pixel electrodes include a plurality of the third pixel electrodes, and

in a region where one of the third pixel electrodes and the other of the third pixel electrodes are adjacent to each other, an angle made by a side surface of the bank and the top surface of one of the third pixel electrodes is equal to an angle made by a side surface of the bank and the top surface of the other of the third pixel electrodes.

12. The display device according to claim **3**, wherein the common layer includes at least one of a hole injection layer, a hole transfer layer, a hole blocking layer, an electron injection layer, an electron transfer layer, and an electron blocking layer.

13. The display device according to claim **8**, wherein the common layer includes at least one of a hole injection layer, a hole transfer layer, a hole blocking layer, an electron injection layer, an electron transfer layer, and an electron blocking layer.

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[标]申请(专利权)人(译)	株式会社日本显示器		
申请(专利权)人(译)	日本展示INC.		
当前申请(专利权)人(译)	日本展示INC.		
[标]发明人	HIRAGA KENTA		
发明人	HIRAGA, KENTA		
IPC分类号	H01L27/32 H01L51/52 G09G3/3208		
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摘要(译)

一种显示装置，包括：像素电极，该像素电极包括彼此分离的第一像素电极和第二像素电极。堤，其覆盖像素电极的端部和像素电极之间的区域，并且具有暴露像素电极的开口。第一有机层，其覆盖第一像素电极并包括第一发光层；第二有机层，覆盖第二像素电极，并包括第二发光层；以及覆盖第一有机层和第二有机层以及堤的对电极。第一发光层发射具有第一波长的光，第二发光层发射具有比第一波长长的第二波长的光，第二有机层比第一有机层厚，并且由堤和透镜形成角度。第二像素电极大于堤和第一像素电极所成的角度。