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(12) **United States Patent**
Matsushima

(10) **Patent No.:** **US 8,901,546 B2**
(45) **Date of Patent:** ***Dec. 2, 2014**

(54) **ORGANIC LIGHT-EMITTING PANEL,
MANUFACTURING METHOD THEREOF,
AND ORGANIC DISPLAY DEVICE**

(58) **Field of Classification Search**
USPC 257/40, 43, 88-89; 313/504; 216/23
See application file for complete search history.

(71) Applicant: **Panasonic Corporation**, Osaka (JP)

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(72) Inventor: **Hideaki Matsushima**, Osaka (JP)

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(73) Assignee: **Panasonic Corporation**, Osaka (JP)

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 105 days.

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This patent is subject to a terminal disclaimer.

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(21) Appl. No.: **13/717,930**

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(65) **Prior Publication Data**

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(Continued)

Related U.S. Application Data

Primary Examiner — Fernando L Toledo

Assistant Examiner — Mohammed Shamsuzzaman

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(74) *Attorney, Agent, or Firm* — Greenblum & Bernstein, P.L.C.

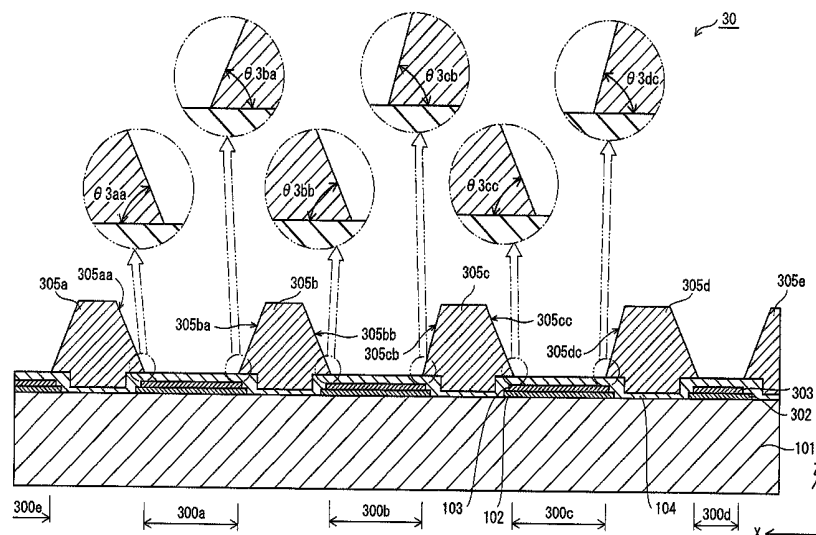
(51) **Int. Cl.**
H01L 29/08 (2006.01)
H01L 51/50 (2006.01)
H01L 27/32 (2006.01)
H01L 51/56 (2006.01)
H01L 33/08 (2010.01)
H01L 51/00 (2006.01)

ABSTRACT

A pixel in the panel includes sub-pixels **100a**, **100b**, and **100c**. The sub-pixel **100a** is defined by banks **105a** and **105b**. The sub-pixel **100b** is defined by banks **105b** and **105c**. The sub-pixel **100c** is defined by banks **105c** and **105d**. Organic light-emitting layers are formed in sub-pixels by, for each pixel, applying ink to the sub-pixels **100a**, **100b**, and **100c** in the stated order and drying the applied ink. With regard to a sidewall **105aa** of the bank **105a**, sidewalls **105ba** and **105bb** of the bank **105b**, and a sidewall **105cb** of the bank **105c**, inclination angles of the sidewalls satisfy relationships: inclination angle θ_{aa} and inclination angle θ_{ba} are equal, and inclination angle θ_{cb} is larger than inclination angle θ_{bb} .

(52) **U.S. Cl.**
CPC **H01L 51/50** (2013.01); **H01L 27/3246** (2013.01); **H01L 51/56** (2013.01); **H01L 33/08** (2013.01); **H01L 51/0005** (2013.01)
USPC **257/40**; 257/43; 257/88; 257/89; 313/504; 216/23

14 Claims, 24 Drawing Sheets



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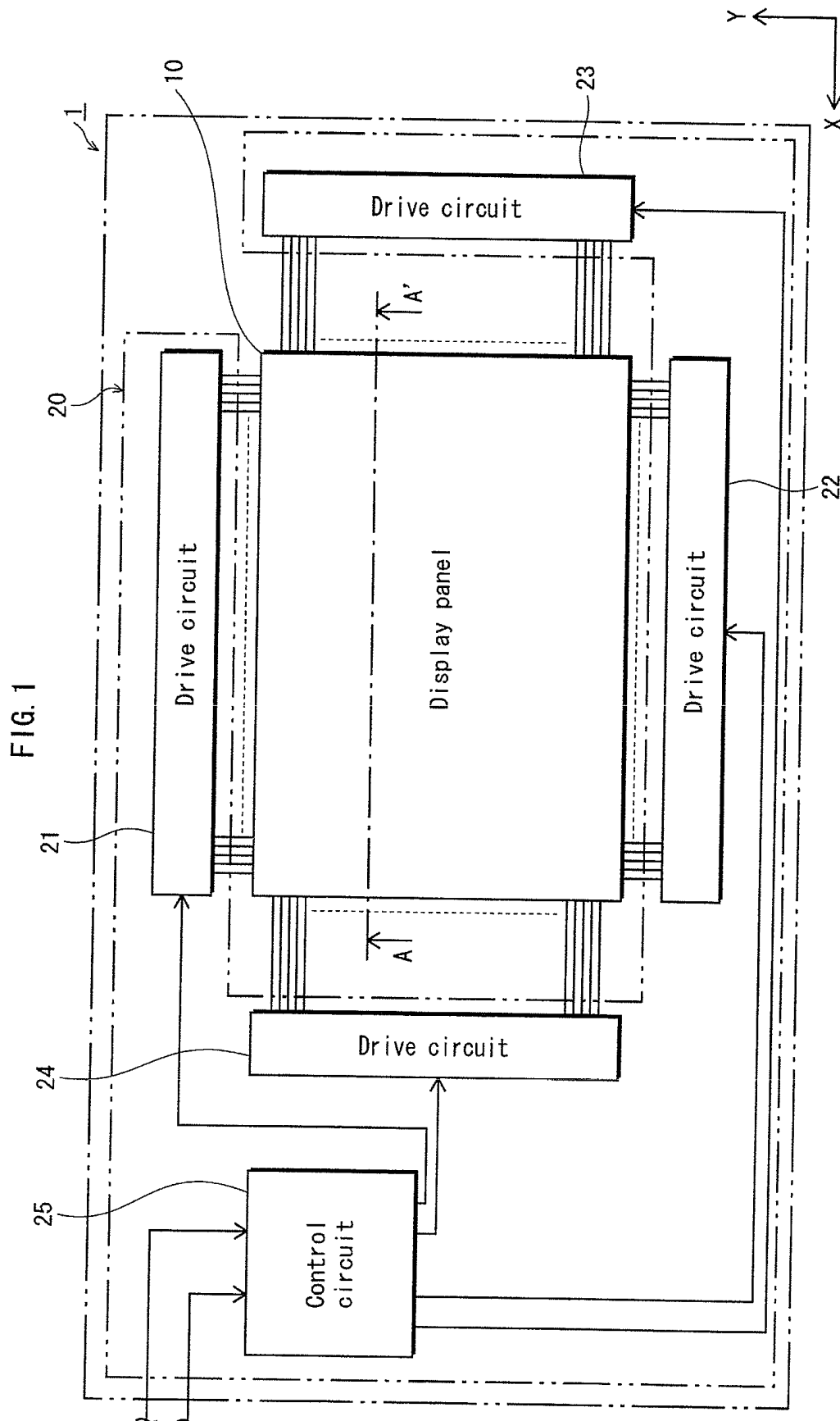


FIG. 2

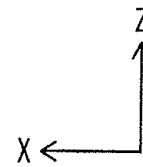
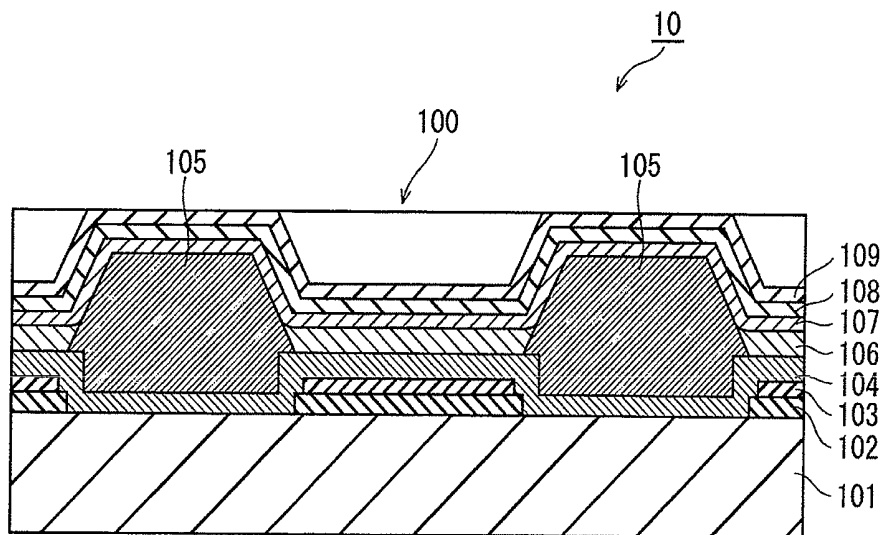


FIG. 3

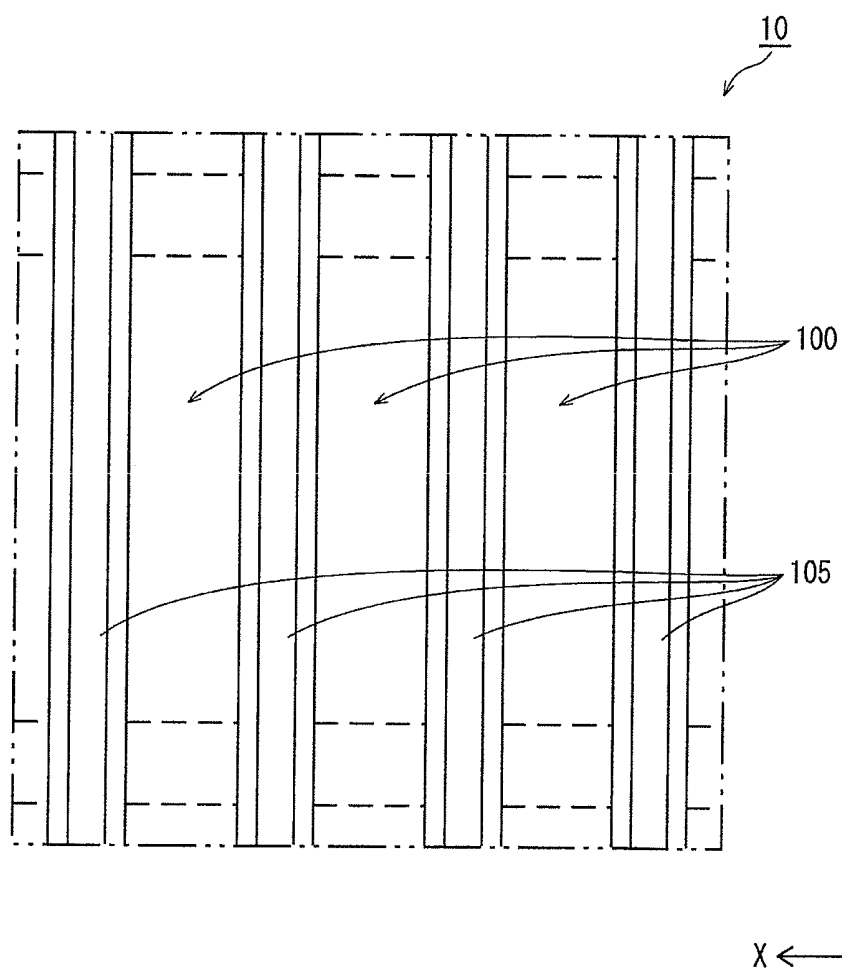


FIG. 4

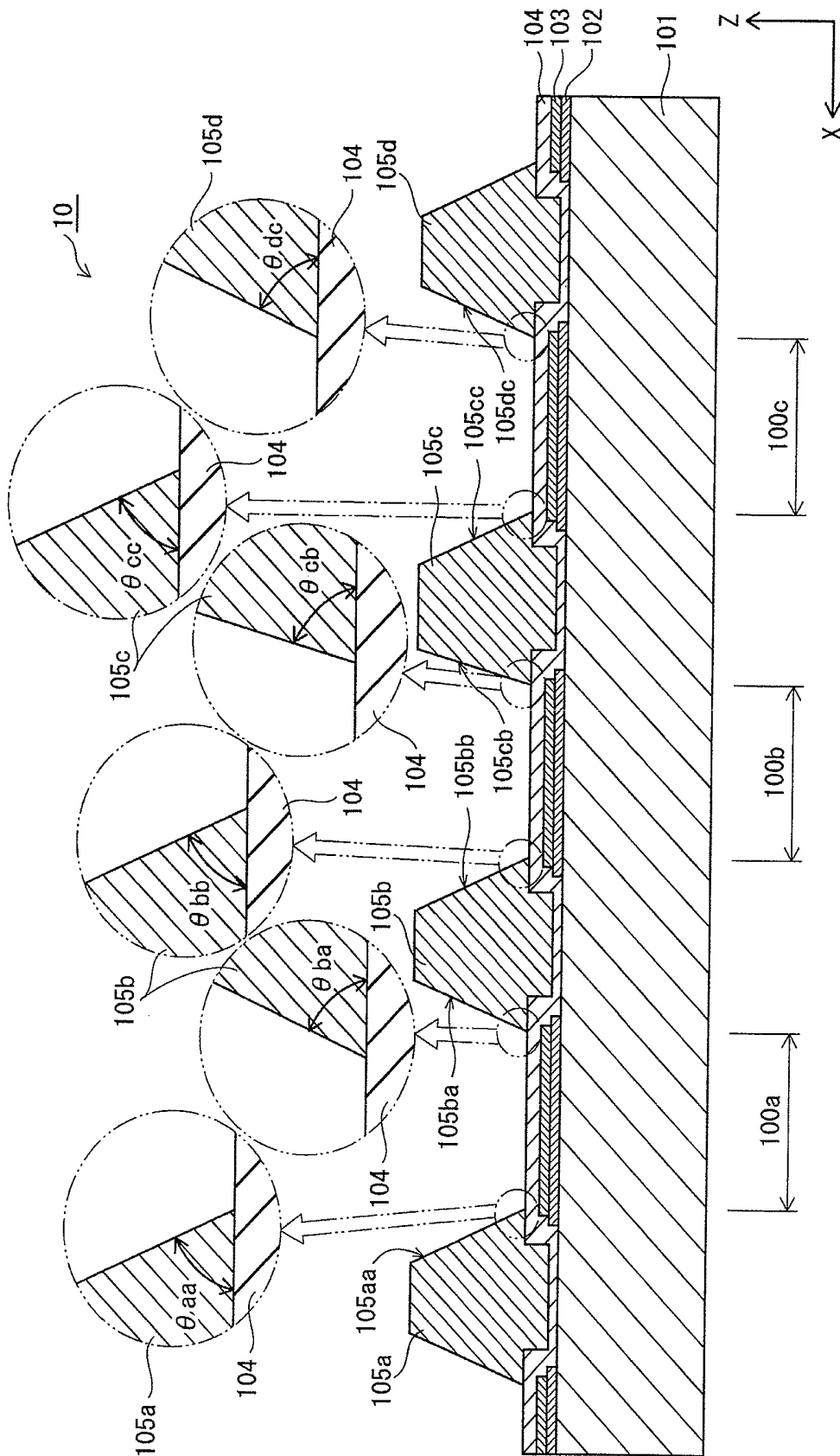


FIG. 5A

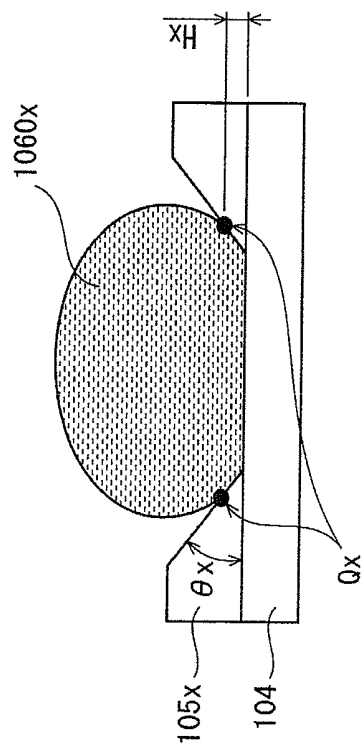


FIG. 5C

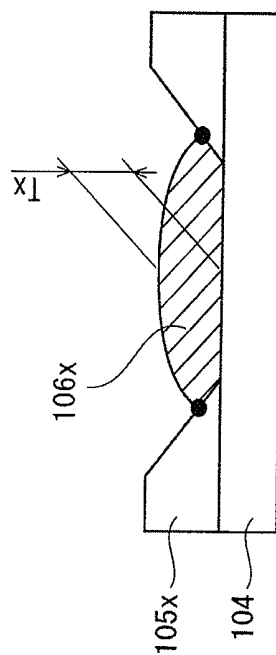


FIG. 5B

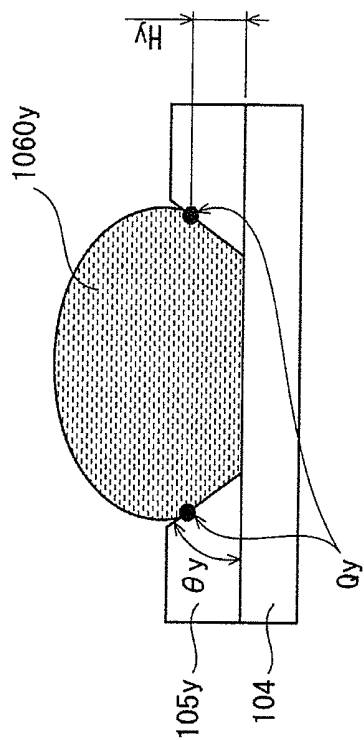


FIG. 5D

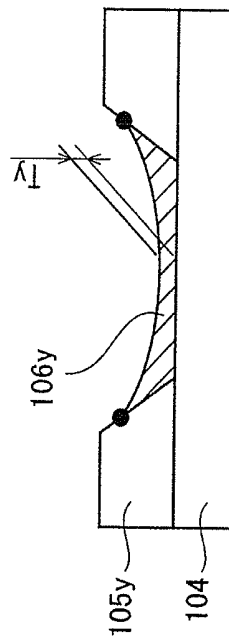


FIG. 6

Taper angle (θ)	Small ←————→ Large
Pinning location (H)	Low ←————→ High
Film thickness (T)	Thick ←————→ Thin

FIG. 7

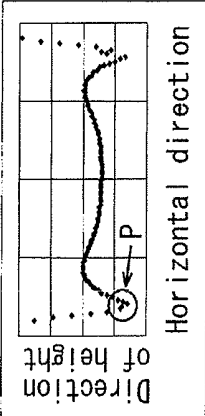
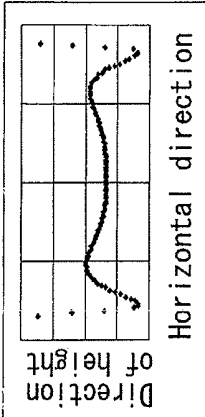
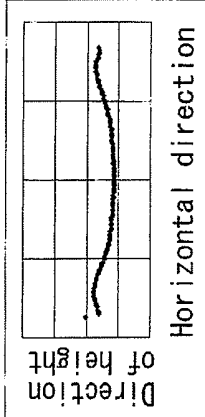
	Sample 1	Sample 2	Sample 3
Bank height [μm]	0.3	0.5	0.6
Contact angle [°]	—	55	44
Taper angle [°]	28	22	24
Film thickness distribution	 Direction of height Horizontal direction	 Direction of height Horizontal direction	 Direction of height Horizontal direction

FIG. 8

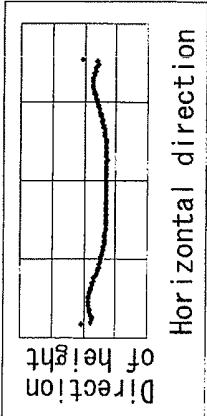
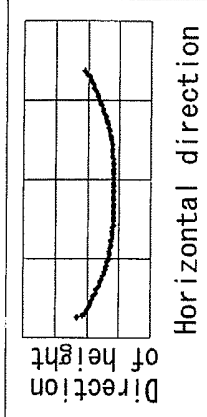
	Sample 4	Sample 5
Bank height [μm]	0.7	1.0
Contact angle [$^{\circ}$]	43	47
Taper angle [$^{\circ}$]	28	50
Film thickness distribution		

FIG. 9A

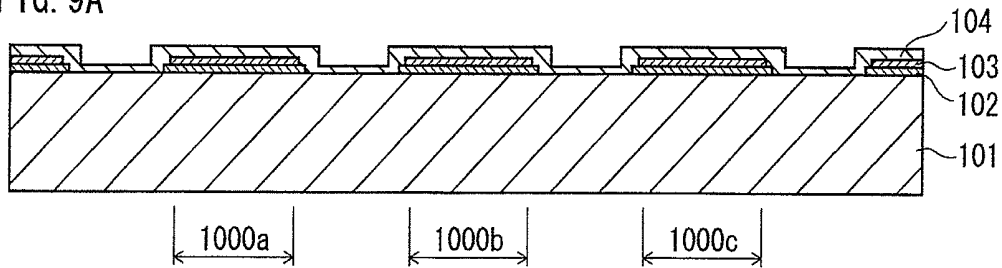


FIG. 9B

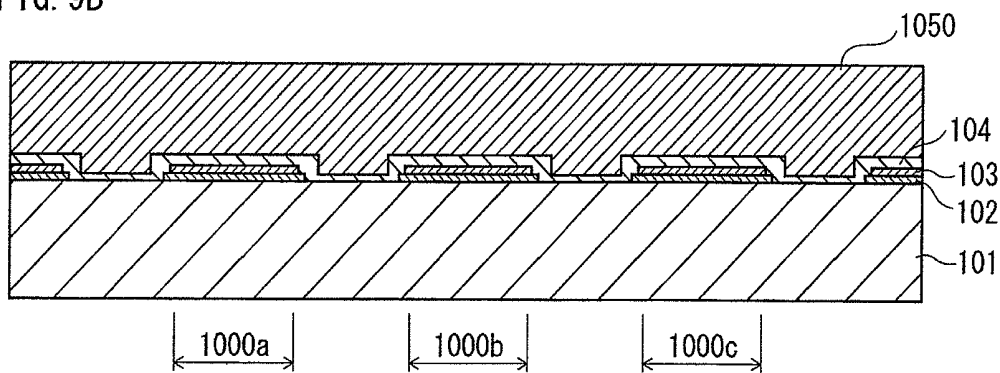


FIG. 9C

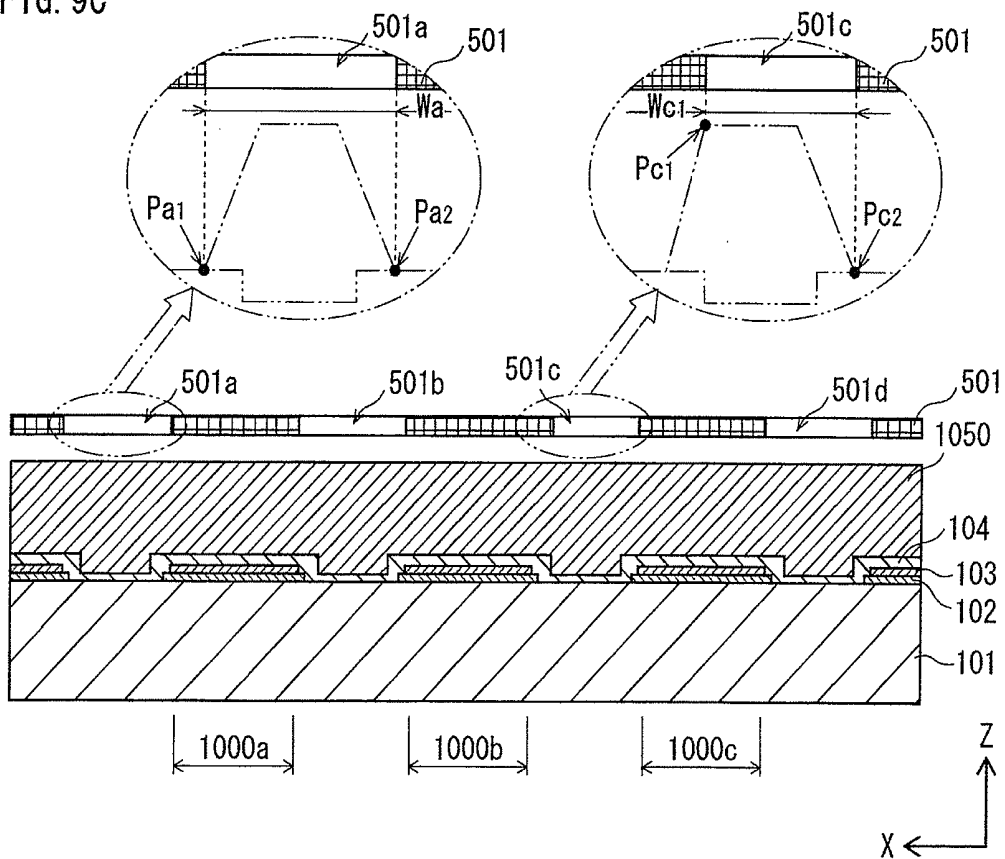


FIG. 10A

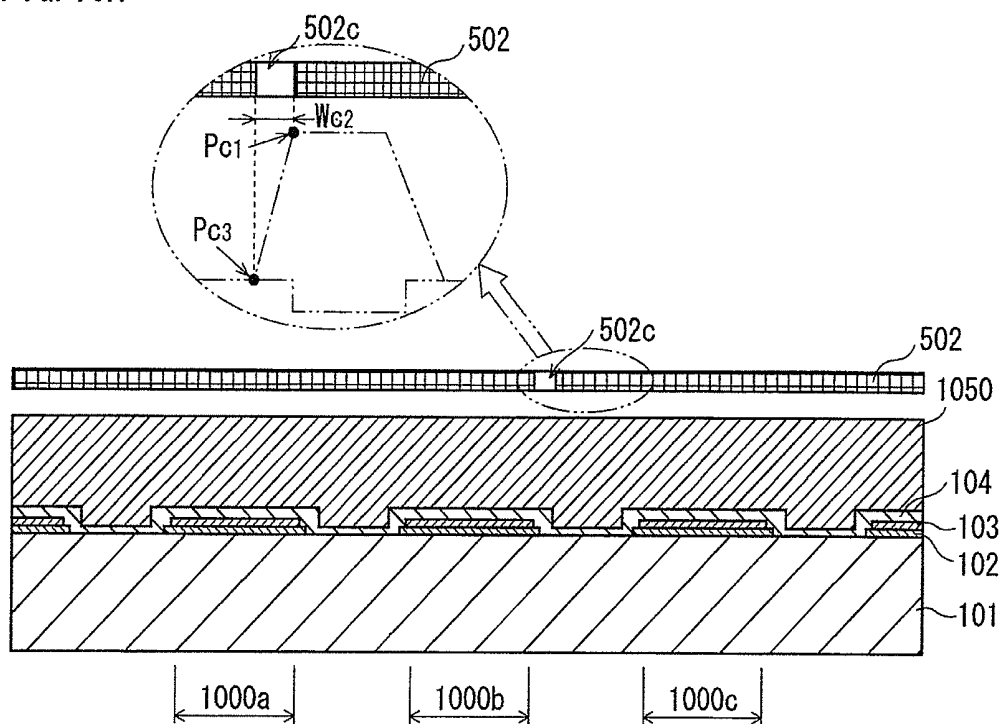


FIG. 10B

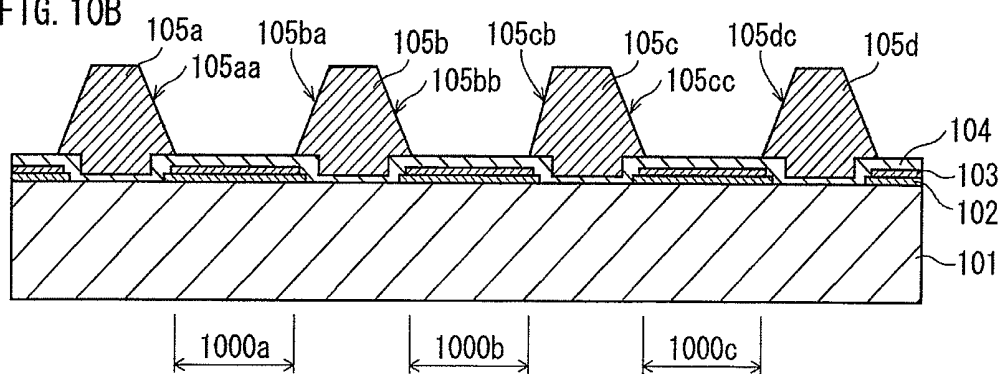


FIG. 10C

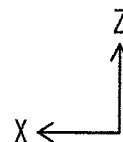
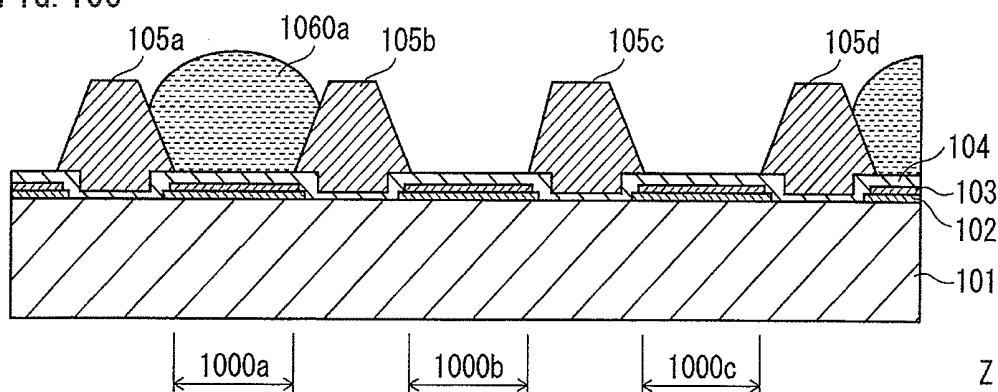


FIG. 12A

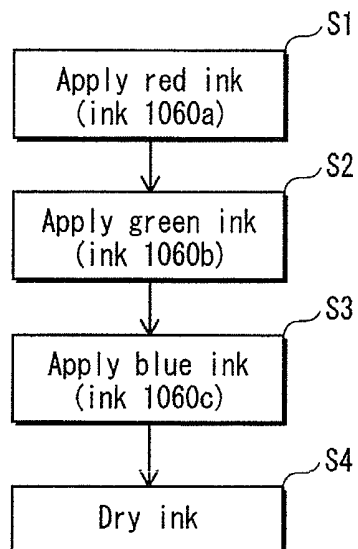


FIG. 12B

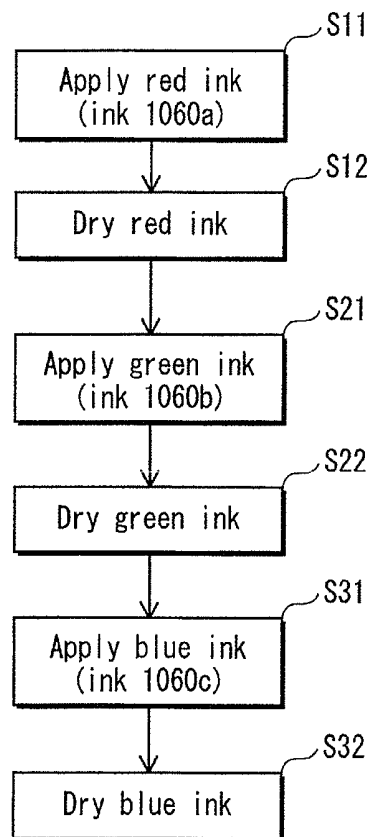


FIG. 13

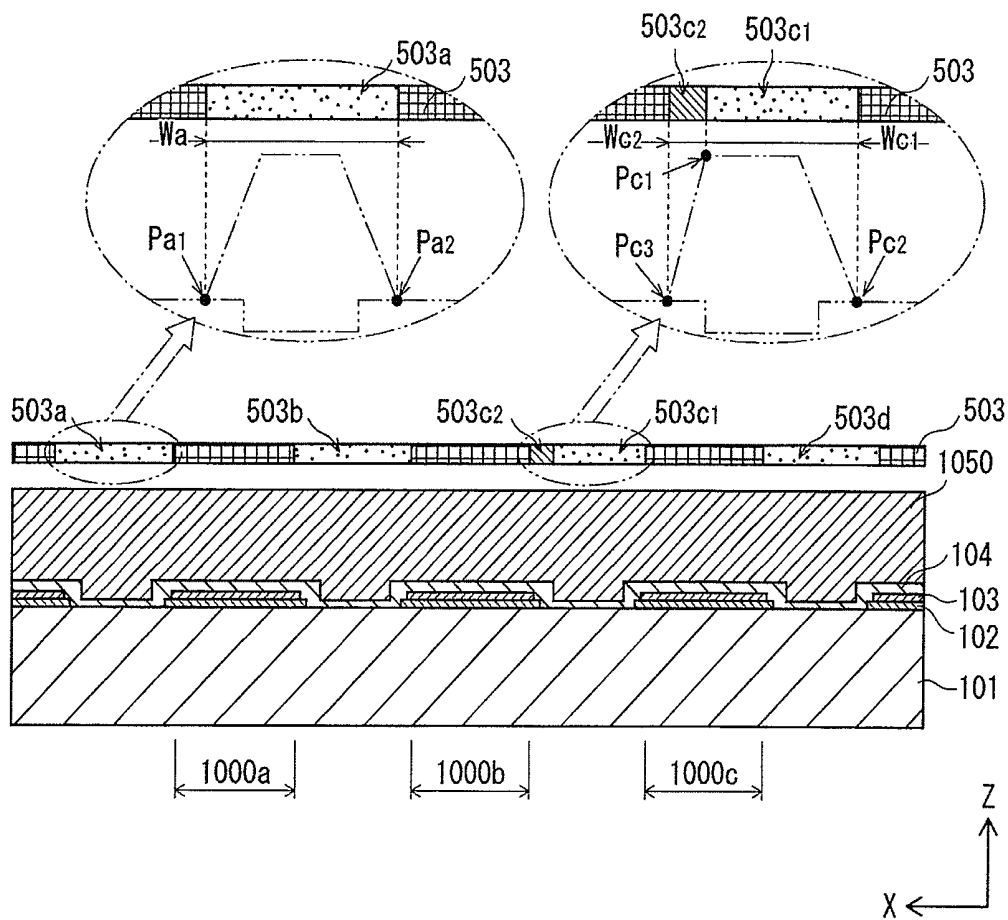


FIG. 14A

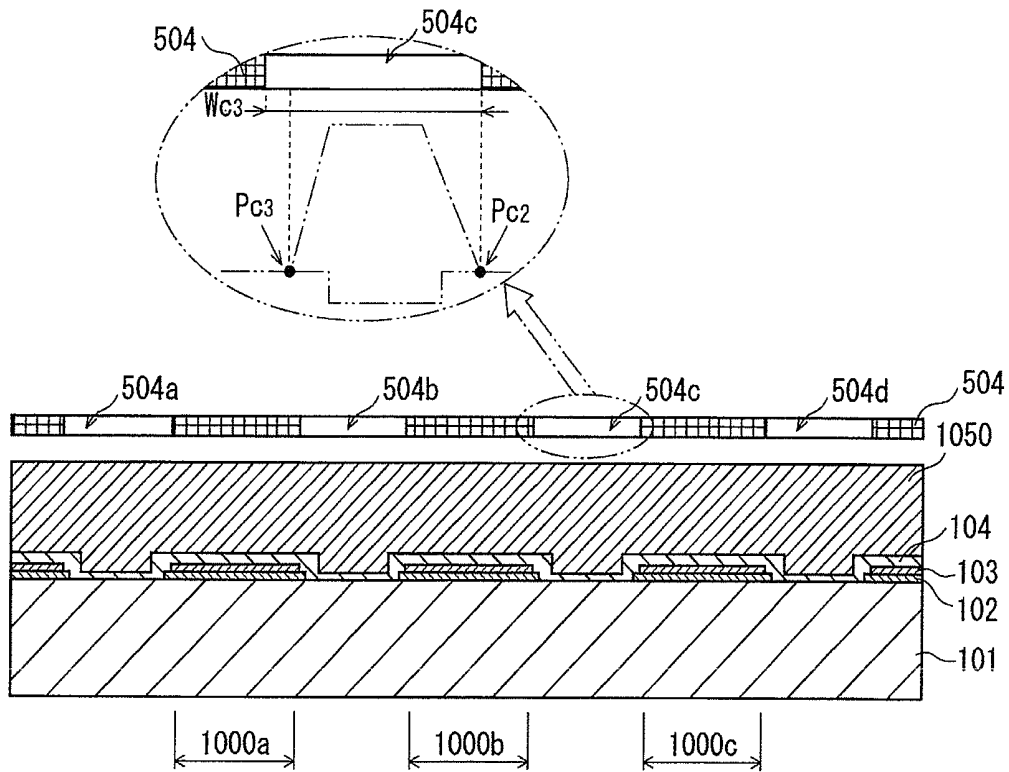


FIG. 14B

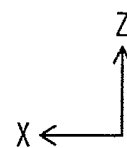
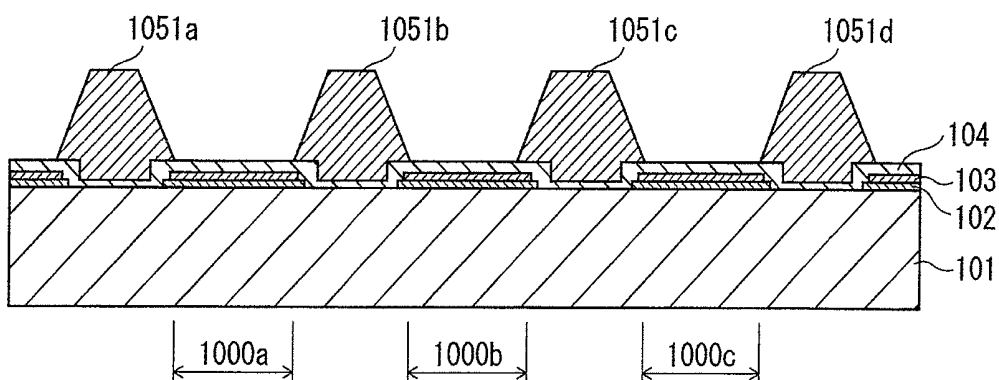


FIG. 15A

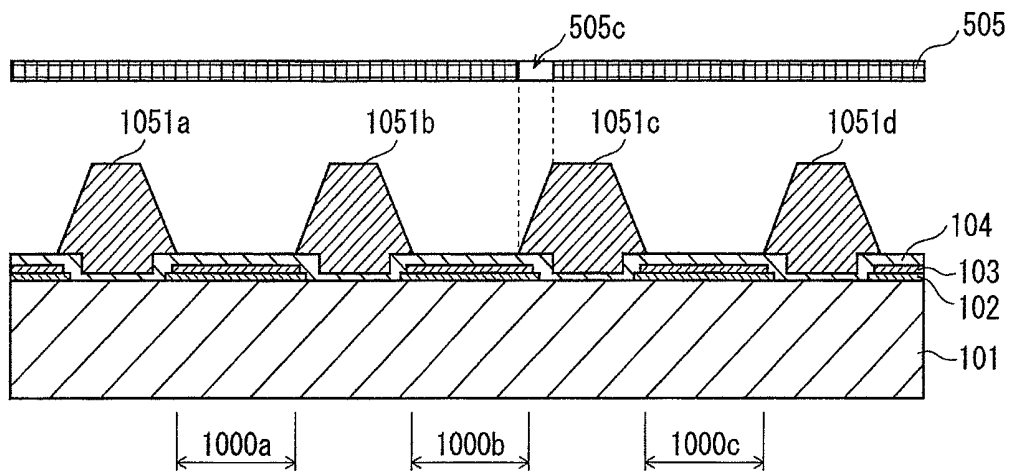
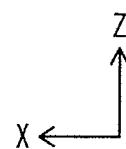
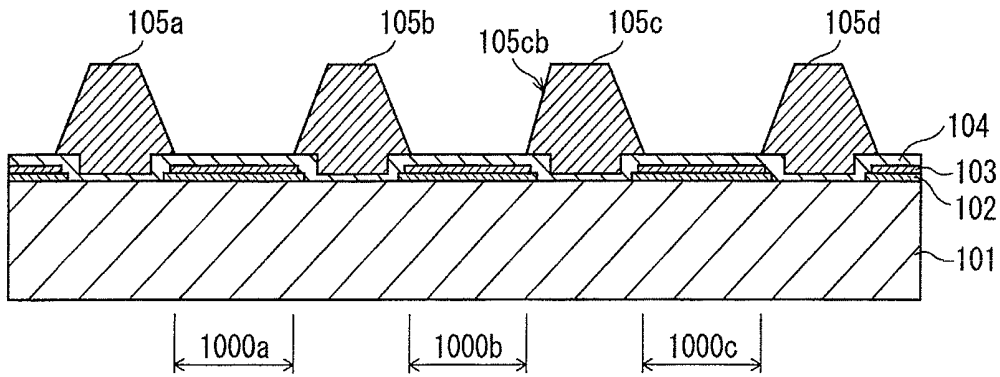


FIG. 15B



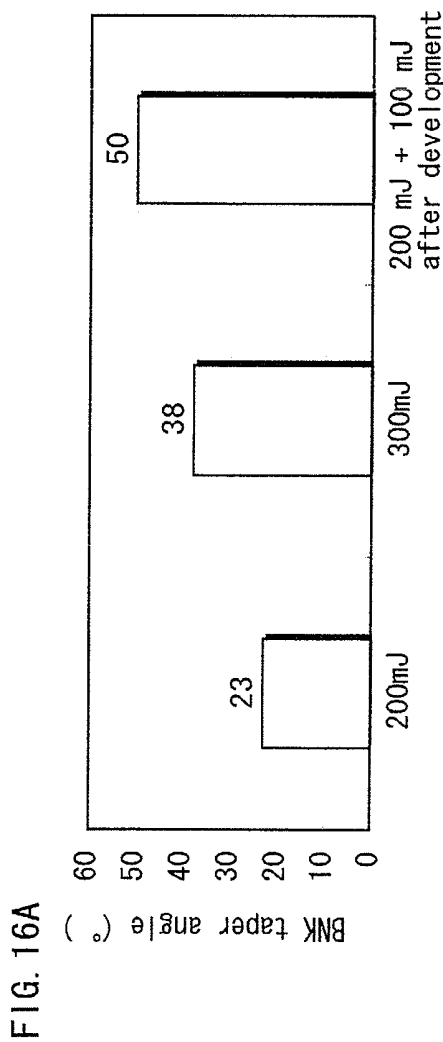
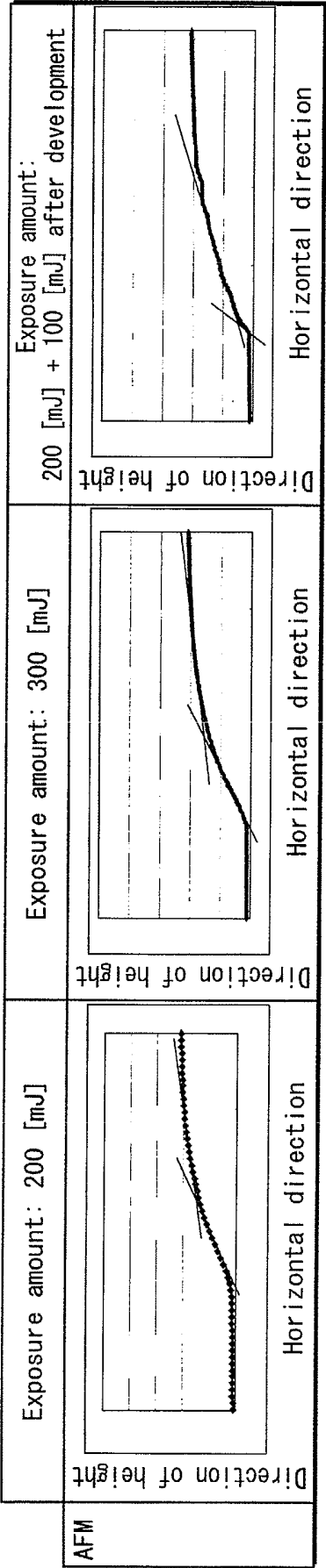


FIG. 16B



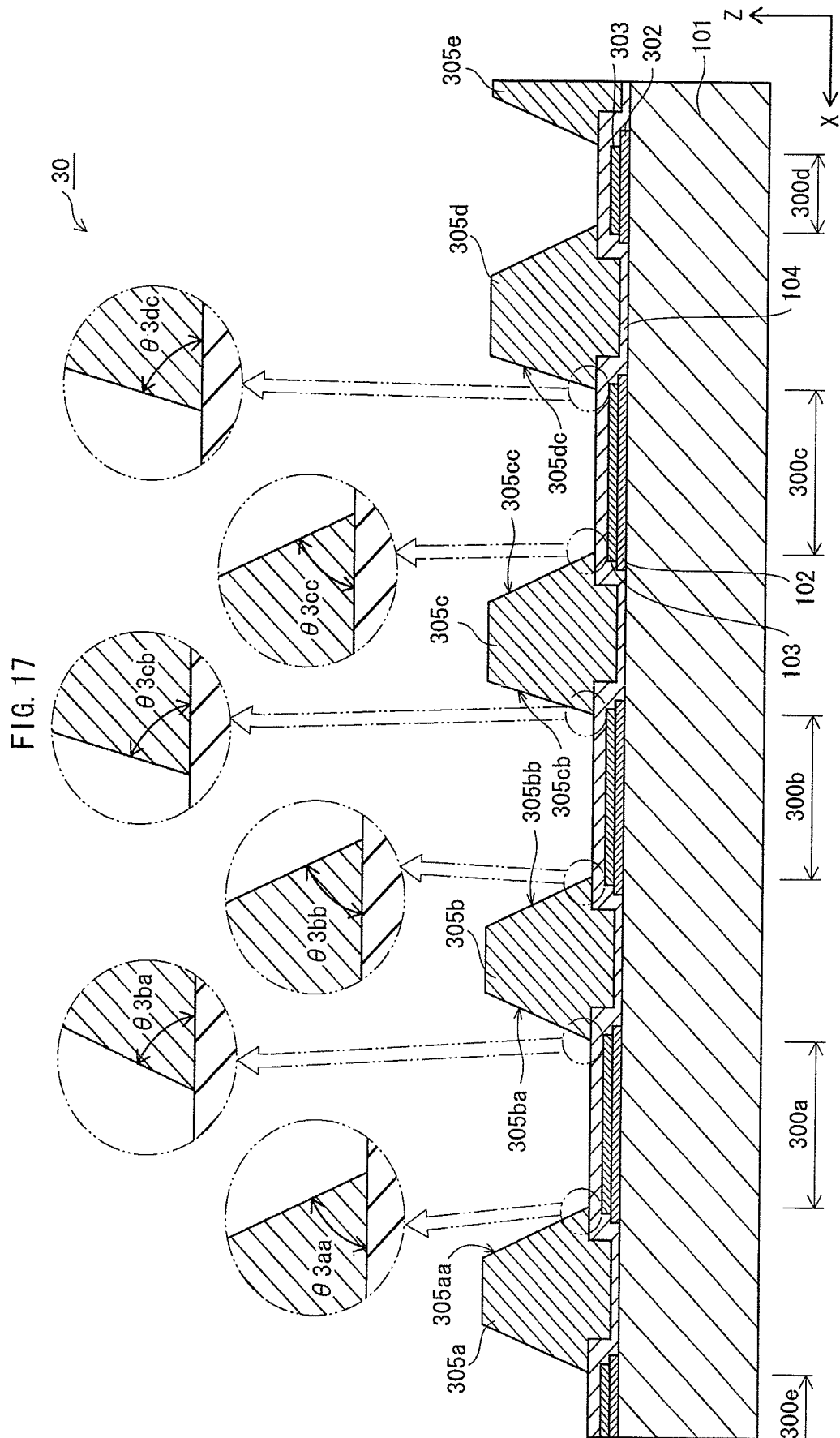


FIG. 18A

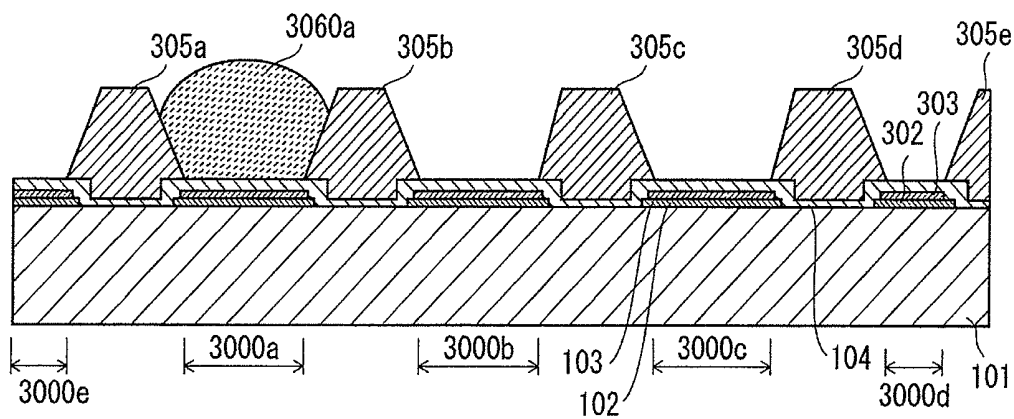


FIG. 18B

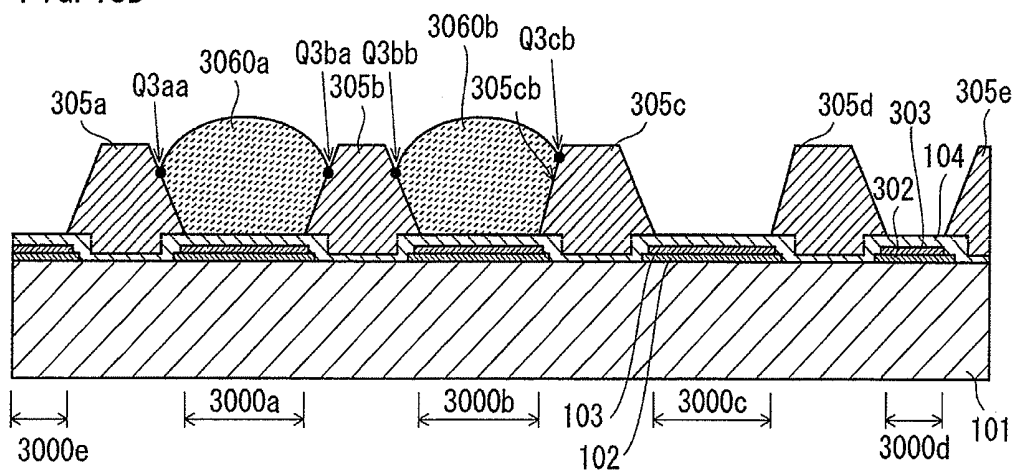


FIG. 18C

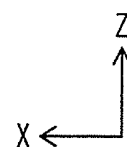
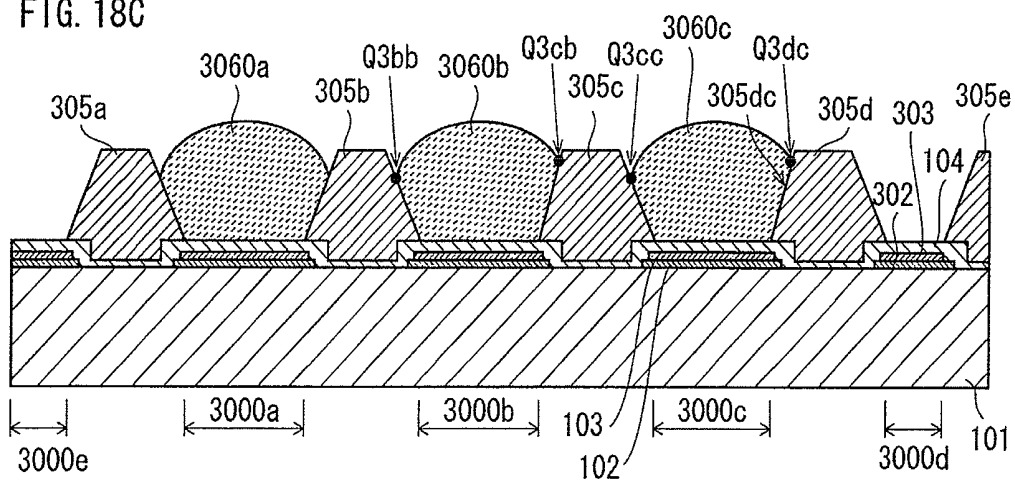


FIG. 19A

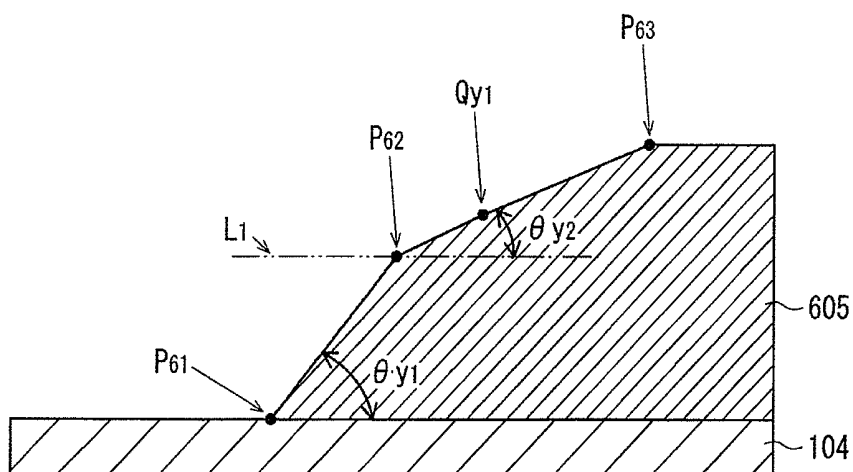


FIG. 19B

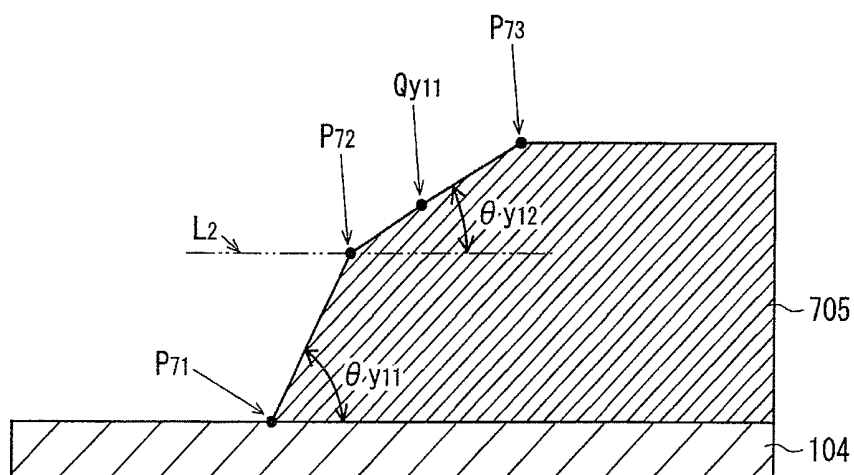


FIG. 20

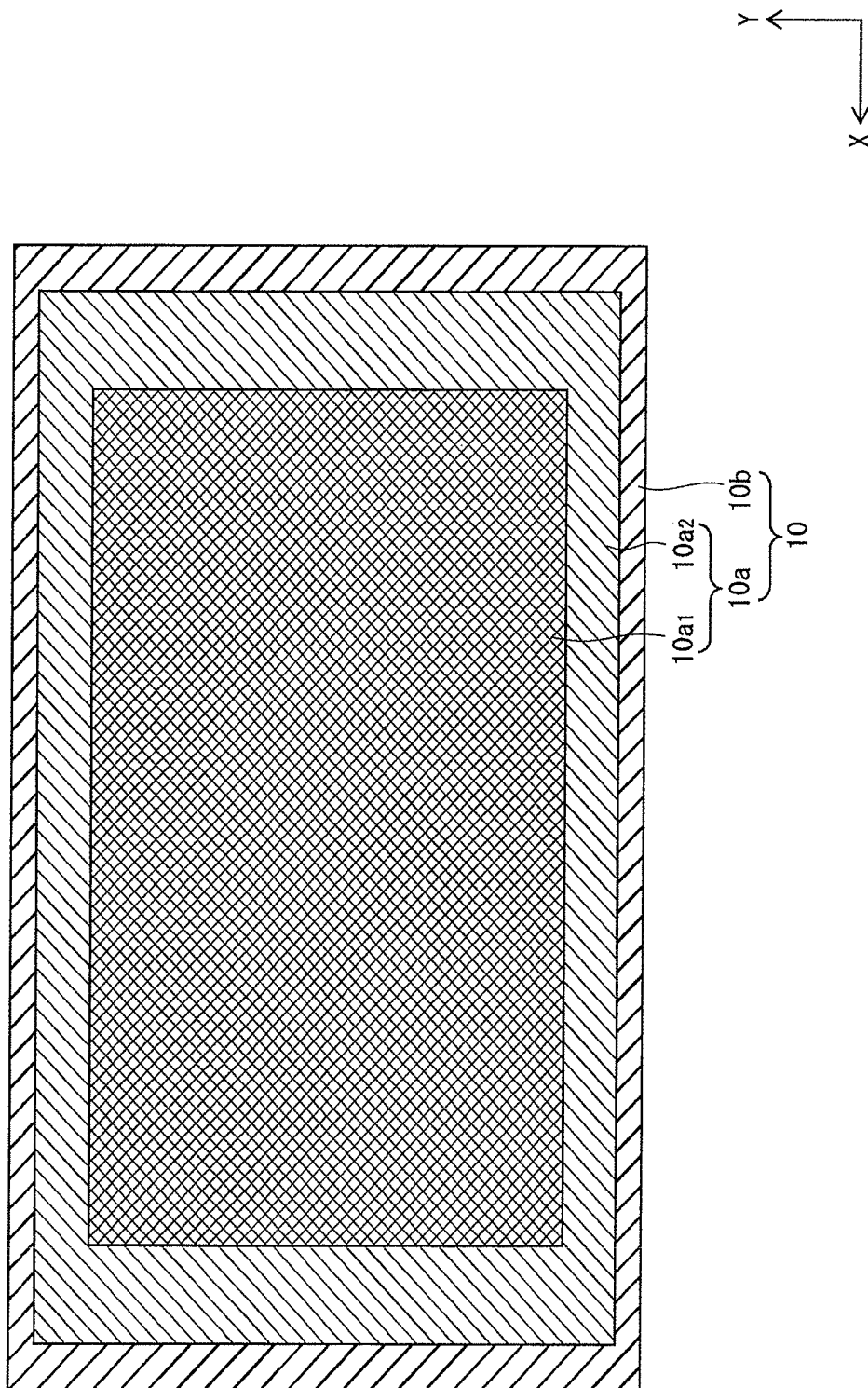


FIG. 21

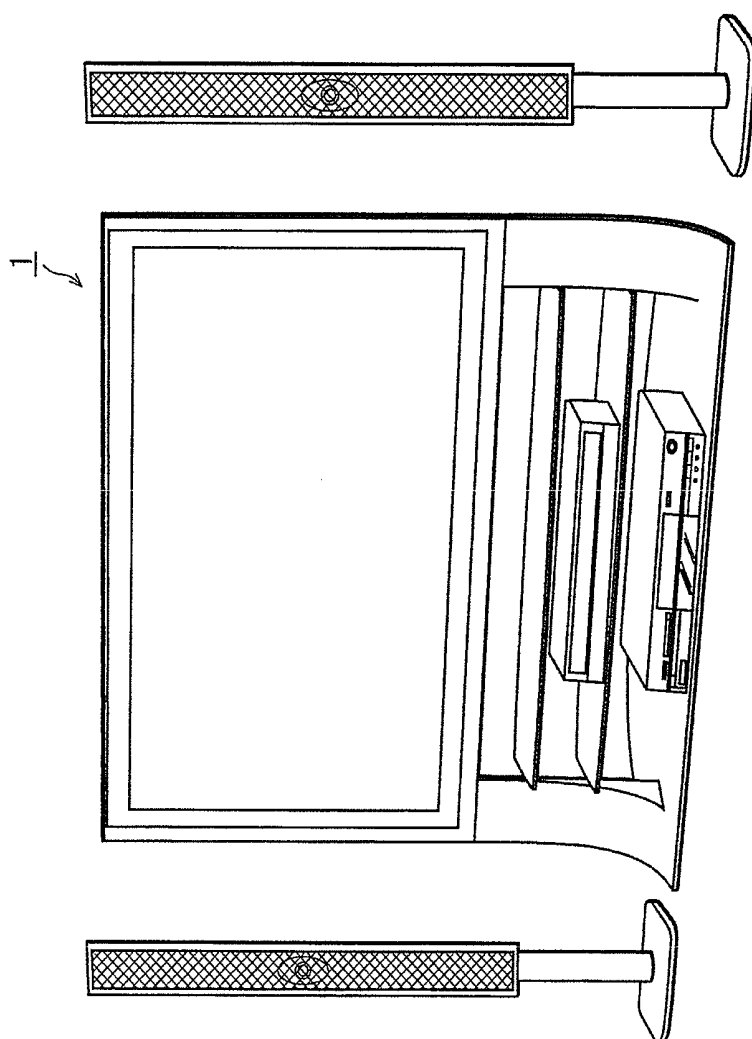


FIG. 22

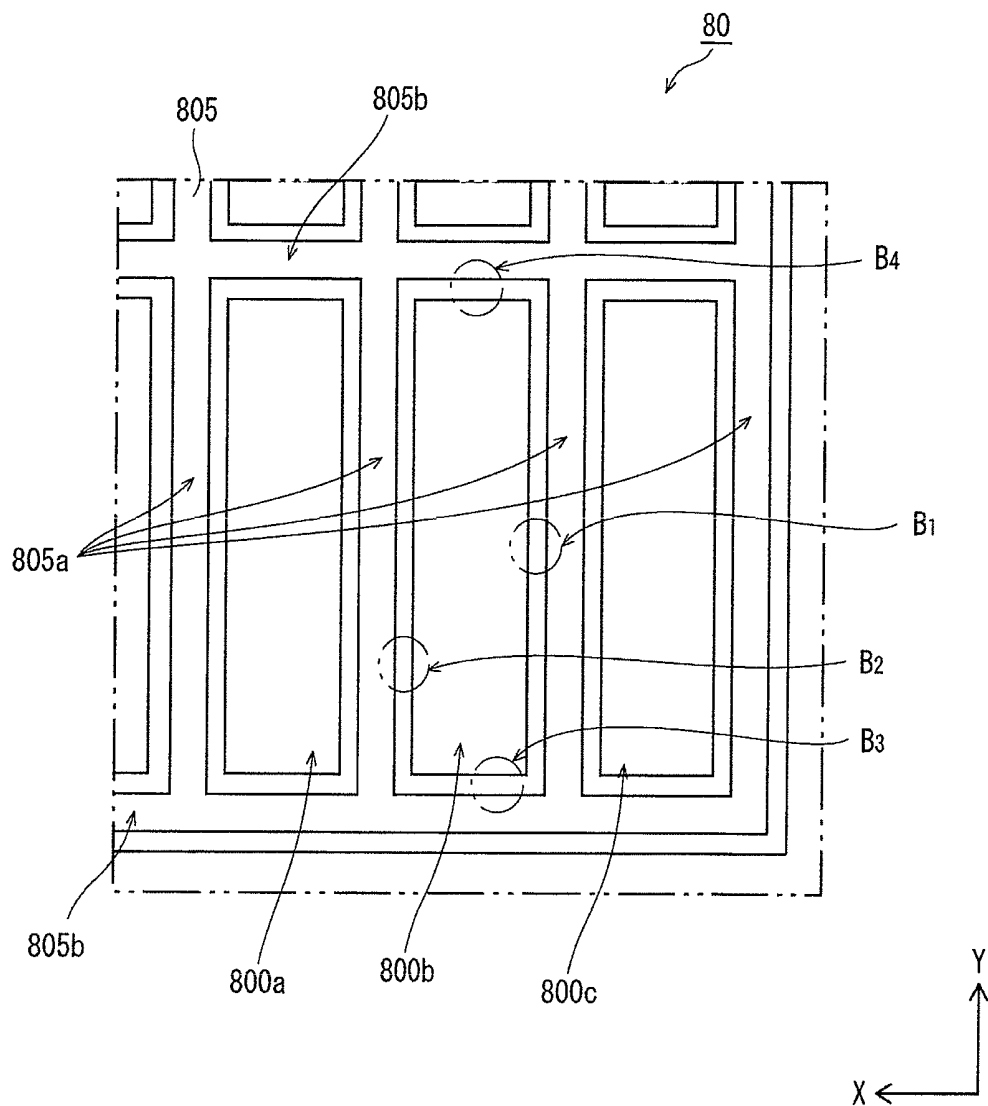


FIG. 23A

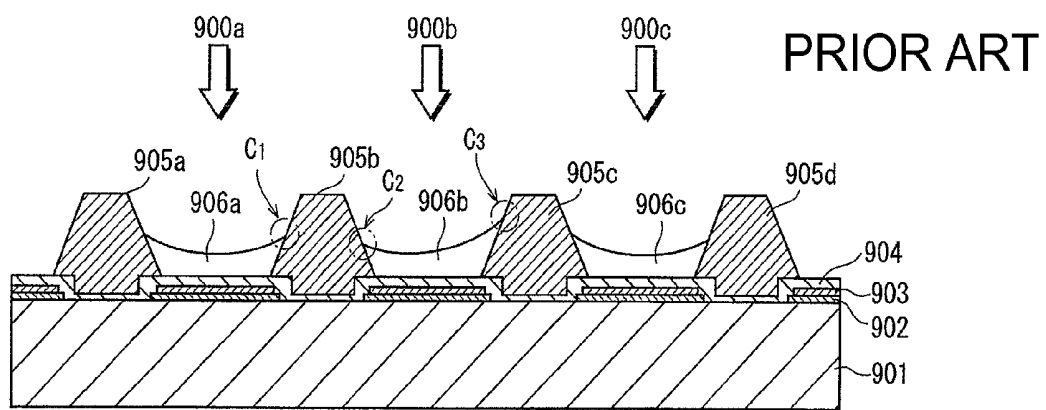


FIG. 23B

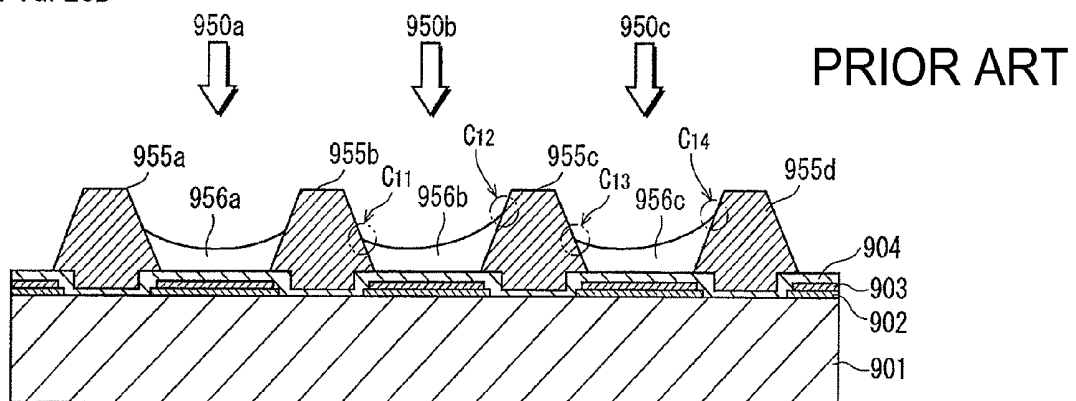
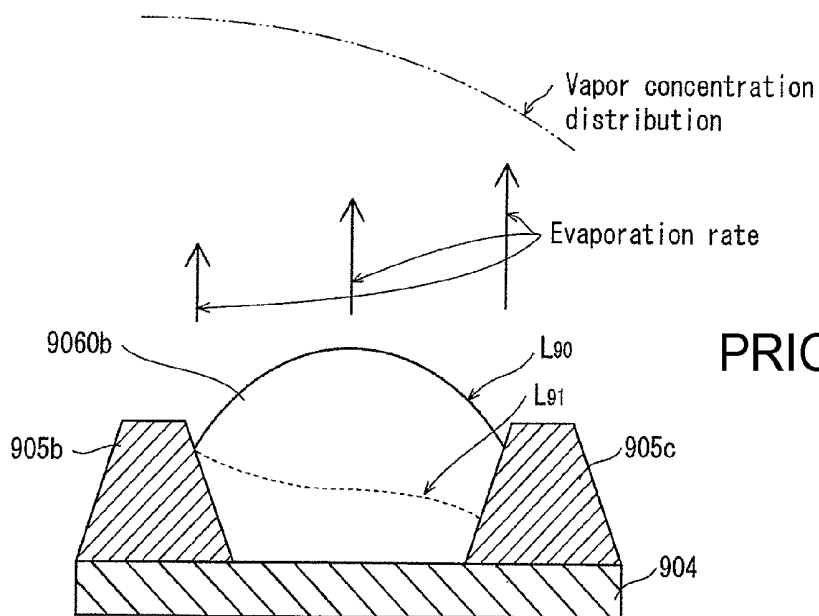
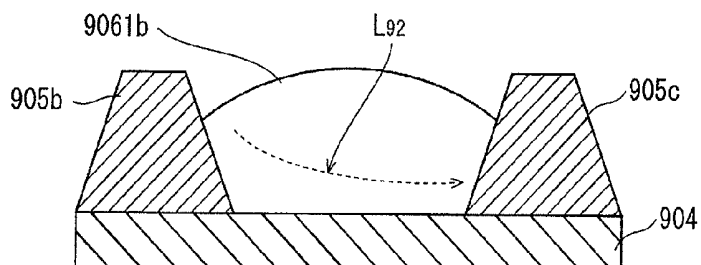


FIG. 24A



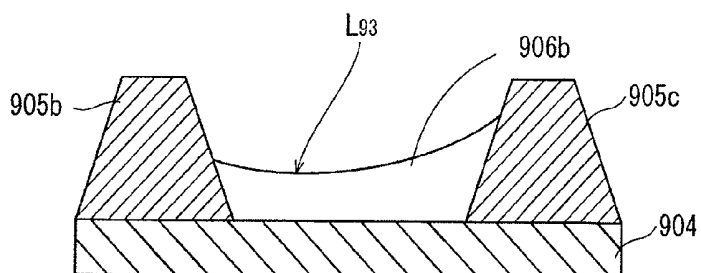
PRIOR ART

FIG. 24B



PRIOR ART

FIG. 24C



PRIOR ART

ORGANIC LIGHT-EMITTING PANEL, MANUFACTURING METHOD THEREOF, AND ORGANIC DISPLAY DEVICE

This is a continuation application of PCT Application No. PCT/JP2010/006125 filed on Oct. 15, 2010, designating the United States of America, the disclosure of which, including the specification, drawings and claims, is incorporated herein by reference in its entirety.

TECHNICAL FIELD

The present invention relates an organic light-emitting panel, a manufacturing method thereof, and an organic display device.

BACKGROUND ART

In recent years, progress has been made in the research and development of display devices that use the phenomenon of electroluminescence occurring in organic material. Each light-emitting cell of such a display device is composed of an anode and a cathode with an organic light-emitting layer therebetween. When the display device is driven, holes are injected through the anode, electrons are injected through the cathode, and the holes and electrons recombine within the organic light-emitting layer, thereby emitting the light.

Banks composed of insulating material partition the organic light-emitting layer into light-emitting cells. The organic light-emitting layer is formed by dripping ink, which includes an organic light-emitting material, into each region separated by the banks and drying the ink.

Meanwhile, a problem with the organic light-emitting layer formed in this way is that it is difficult for the layer to have a uniform film thickness.

As one example of technologies for evening out the film thickness of the organic light-emitting layer, Patent Literature 1 discloses providing a convexity on the inner sidewall of the bank in order to control the pinning location of the ink. In other words, according to the technology of Patent Literature 1, the pinning location of the ink dripped in one light-emitting cell can be set to the convexity. With this technology, it is possible to secure a uniform film thickness to a certain degree.

CITATION LIST

Patent Literature

Patent Literature 1: Japanese Patent Application Publication No. 2007-311235

SUMMARY OF INVENTION

Technical Problem

It is considered difficult, however, to use the technology of Patent Literature 1 to detect in advance how the organic light-emitting layer of a display device is uneven in film thickness and, based on the detection results, form a minute convexity for each region or each inner sidewall of the bank to a high degree of precision. Therefore, it is not easy to maintain the organic light-emitting layer at a uniform film thickness over the entire region of the organic light-emitting panel.

It is an object of the present invention to solve the above problems by providing a display device, and a manufacturing method thereof, that has a uniform film thickness in the

organic light-emitting layer across the entire panel and has an even luminance within the panel.

Solution to Problem

In order to solve the above problems, an organic light-emitting panel according to an aspect of the present invention has the following structure.

The organic light-emitting panel according to an aspect of the present invention comprises an array of a plurality of pixels each of which includes three light-emitting cells that are arranged in an alignment and emit light of different colors. Each light-emitting cell includes an underlying layer, a first electrode provided in the underlying layer, an organic light-emitting layer, and a second electrode formed on an opposite side of the organic light-emitting layer from the underlying layer, each organic light-emitting layer being formed by applying, for each pixel, three types of ink respectively to the three light-emitting cells, the three types of ink containing different organic light-emitting materials corresponding one-to-one to the different colors of light.

Also, in the organic light-emitting panel according to an aspect of the present invention, each pixel includes a first light-emitting cell located at an end of the alignment, a second light-emitting cell located at a central portion of the alignment, and a third light-emitting cell located at another end of the alignment, each organic light-emitting layer being formed by applying, for each pixel, the three types of ink respectively to the three light-emitting cells in an order of the first light-emitting cell, the second light-emitting cell and the third light-emitting cell, the three types of ink. The organic light-emitting panel further comprises a plurality of banks which, formed above the underlying layer, define each light-emitting cell by separating the light-emitting cells one from another. In the organic light-emitting panel according to an aspect of the present invention, the plurality of pixels includes a pixel that is structured such that two inner sidewalls, which face each other in two adjacent banks defining the first light-emitting cell, have equal inclination angles, and among two inner sidewalls facing each other in two adjacent banks defining the second light-emitting cell, a sidewall of a bank located on a side of the third light-emitting cell has a larger inclination angle than a sidewall of a bank located on a side of the first light-emitting cell.

Advantageous Effects of Invention

In the above organic light-emitting panel according to an aspect of the present invention, the organic light-emitting layer of the first light-emitting cell has been formed by applying a corresponding ink to the first light-emitting cell in the first round when no ink had been applied to the regions adjacent to the first light-emitting cell and the ink vapor concentrations at both ends of the first light-emitting cell in a direction of the alignment of the cells were "0", namely, equal. As a result, the organic light-emitting layer in the first light-emitting cell is even in film thickness at the two ends thereof. Accordingly, with the above structure where two inner sidewalls facing each other in two adjacent banks defining the first light-emitting cell have equal inclination angles, it is possible to prevent the organic light-emitting layer from becoming uneven in film thickness and provide excellent light-emitting characteristics.

On the other hand, the organic light-emitting layer of the second light-emitting cell has been formed by applying a corresponding ink to the second light-emitting cell in the second round when the two regions adjacent to the second

light-emitting cell had different ink vapor concentrations. More specifically, an end of the second light-emitting cell on the first light-emitting cell side has a higher ink vapor concentration than an end on the third light-emitting cell side. Thus the film thickness of the light-emitting layer tends to be larger at the end on the third light-emitting cell side than at the end on the first light-emitting cell side. Under these conditions, the light-emitting layer of the second light-emitting cell is likely to become uneven in film thickness.

However, in the above organic light-emitting panel according to an aspect of the present invention, among two inner sidewalls facing each other in two adjacent banks defining the second light-emitting cell, a sidewall of a bank located on a side of the third light-emitting cell has a larger inclination angle than a sidewall of a bank located on a side of the first light-emitting cell. With this structure, the pinning location of the ink in the sidewall on the third light-emitting cell side is relatively higher than the pinning location of the ink in the sidewall on the first light-emitting cell side. This enables the film thickness of the organic light-emitting layer in the second light-emitting cell on the third light-emitting cell side to be decreased. As a result, it is possible to prevent the organic light-emitting layer in the second light-emitting cell from becoming uneven in film thickness between two ends thereof (an end on the first light-emitting cell side and an end on the third light-emitting cell side).

As described above, in the above organic light-emitting panel according to an aspect of the present invention, it is possible to prevent the organic light-emitting layer in each light-emitting cell from becoming uneven in film thickness between two opposite ends thereof and provide excellent light-emitting characteristics in the same pixel.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a block diagram showing the configuration of an organic display device 1 according to the Embodiment of the present invention.

FIG. 2 is a schematic cross-sectional view showing a sub-pixel 100 included in a display panel 10.

FIG. 3 is a schematic plan view showing a bank 105 in the display panel 10.

FIG. 4 is a schematic cross-sectional view showing the structure of sub-pixels 100a to 100c included in the display panel 10 and banks 105a to 105d that separate the sub-pixels 100a to 100c from each other.

FIG. 5A is a schematic cross-sectional view showing pinning locations when the taper angle of the bank sidewall is small; FIG. 5B is a schematic cross-sectional view showing pinning locations when the taper angle of the bank sidewall is large; FIG. 5C is a schematic cross-sectional view showing the condition of the organic light-emitting layer after drying when the taper angle of the bank sidewall is small; and FIG. 5D is a schematic cross-sectional view showing the condition of the organic light-emitting layer after drying when the taper angle of the bank sidewall is large.

FIG. 6 summarizes the relationship between the inclination angle of the bank sidewall (taper angle) θ , the pinning height H, and the film thickness 1 of the organic light-emitting layer.

FIG. 7 shows a distribution of film thickness of the organic light-emitting layer in samples 1-3.

FIG. 8 shows a distribution of film thickness of the organic light-emitting layer in samples 4 and 5.

FIGS. 9A-9C are schematic cross-sectional views showing, in order, the main processes in the manufacturing method of the display panel 10.

FIGS. 10A-10C are schematic cross-sectional views showing, in order, the main processes in the manufacturing method of the display panel 10.

FIGS. 11A and 11B are schematic cross-sectional views showing, in order, the main processes in the manufacturing method of the display panel 10.

FIG. 12A is a schematic flowchart showing a procedure of applying and drying the inks 1060a-1060c; and FIG. 12B is a schematic flowchart showing another procedure of applying and drying the inks 1060a-1060c.

FIG. 13 is a schematic cross-sectional view showing the main processes in the manufacturing method of Modification 1.

FIGS. 14A and 14B are schematic cross-sectional views showing the main processes in the manufacturing method of Modification 2.

FIGS. 15A and 15B are schematic cross-sectional views showing the main processes in the manufacturing method of Modification 2.

FIG. 16A shows the relationship between the taper angle of a bank and exposure/developing; and FIG. 16B shows AFM graphs that indicate the shapes of formed banks.

FIG. 17 is a schematic cross-sectional view showing the structure of sub-pixels 300a-300c, non-light-emitting cells 300d and 300e, and banks 305a-305e included in the display panel provided in the organic light-emitting device of Embodiment 2.

FIGS. 18A-18C are schematic cross-sectional views showing, in order, the processes for applying the inks 3060A-3060C.

FIGS. 19A and 19B are schematic cross-sectional views provided for explanation of definition of the taper angle.

FIG. 20 is a schematic plan view showing regions 10a1, 10a2 and 10b in the display panel 10.

FIG. 21 is an external perspective view showing an example of the appearance of a set that includes the organic display device 1.

FIG. 22 is a schematic plan view showing a bank 805 in a display panel 80 of Modification 3.

FIGS. 23A and 23B are schematic cross-sectional views showing how the film thickness distribution of the organic light-emitting layer is uneven in a series of sub-pixels of the display panel.

FIGS. 24A-24C are schematic cross-sectional views showing the vapor concentration distribution during formation of the organic light-emitting layer, and unevenness of film shape in the ink drying process.

DESCRIPTION OF EMBODIMENTS

[Outline of Aspects of Present Invention]

The organic light-emitting panel according to an aspect of the present invention comprises an array of a plurality of pixels each of which includes three light-emitting cells that are arranged in an alignment and emit light of different colors. Each light-emitting cell includes an underlying layer, a first electrode provided in the underlying layer, an organic light-emitting layer, and a second electrode formed on an opposite side of the organic light-emitting layer from the underlying layer, each organic light-emitting layer being formed by applying, for each pixel, three types of ink respectively to the three light-emitting cells, the three types of ink containing different organic light-emitting materials corresponding one-to-one to the different colors of light.

Also, in the organic light-emitting panel according to an aspect of the present invention, each pixel includes a first light-emitting cell located at an end of the alignment, a second

light-emitting cell located at a central portion of the alignment, and a third light-emitting cell located at another end of the alignment, each organic light-emitting layer being formed by applying, for each pixel, the three types of ink respectively to the three light-emitting cells in an order of the first light-emitting cell, the second light-emitting cell and the third light-emitting cell, the three types of ink. The organic light-emitting panel further comprises a plurality of banks which, formed above the underlying layer, define each light-emitting cell by separating the light-emitting cells one from another. In the organic light-emitting panel according to an aspect of the present invention, the plurality of pixels includes a pixel that is structured such that two inner sidewalls, which face each other in two adjacent banks defining the first light-emitting cell, have equal inclination angles, and among two inner sidewalls facing each other in two adjacent banks defining the second light-emitting cell, a sidewall of a bank located on a side of the third light-emitting cell has a larger inclination angle than a sidewall of a bank located on a side of the first light-emitting cell.

In the above organic light-emitting panel according to an aspect of the present invention, the organic light-emitting layer of the first light-emitting cell has been formed by applying a corresponding ink to the first light-emitting cell in the first round when no ink had been applied to the regions adjacent to the first light-emitting cell and the ink vapor concentrations at both ends of the first light-emitting cell in a direction of the alignment of the cells were "0", namely, equal. As a result, the organic light-emitting layer in the first light-emitting cell is even in film thickness at the two ends thereof. Accordingly, with the above structure where two inner sidewalls facing each other in two adjacent banks defining the first light-emitting cell have equal inclination angles, it is possible to prevent the organic light-emitting layer from becoming uneven in film thickness and provide excellent light-emitting characteristics.

On the other hand, the organic light-emitting layer of the second light-emitting cell has been formed by applying a corresponding ink to the second light-emitting cell in the second round when the two regions adjacent to the second light-emitting cell had different ink vapor concentrations. More specifically, an end of the second light-emitting cell on the first light-emitting cell side had a higher ink vapor concentration than an end on the third light-emitting cell side. Thus the film thickness of the light-emitting layer tended to be larger at the end on the third light-emitting cell side than at the end on the first light-emitting cell side. Under these conditions, the light-emitting layer of the second light-emitting cell was likely to become uneven in film thickness.

However, in the above organic light-emitting panel according to an aspect of the present invention, among two inner sidewalls facing each other in two adjacent banks defining the second light-emitting cell, a sidewall of a bank located on a side of the third light-emitting cell has a larger inclination angle than a sidewall of a bank located on a side of the first light-emitting cell. With this structure, the pinning location of the ink in the sidewall on the third light-emitting cell side is relatively higher than the pinning location of the ink in the sidewall on the first light-emitting cell side. This enables the film thickness of the organic light-emitting layer in the second light-emitting cell on the third light-emitting cell side to be decreased. As a result, it is possible to prevent the organic light-emitting layer in the second light-emitting cell from becoming uneven in film thickness between two ends thereof (an end on the first light-emitting cell side and an end on the third light-emitting cell side).

As described above, in the above organic light-emitting panel according to an aspect of the present invention, it is possible to prevent the organic light-emitting layer in each light-emitting cell from becoming uneven in film thickness between two opposite ends thereof and provide excellent light-emitting characteristics in the same pixel.

Note that, in the above description, the "inclination angle" is an angle formed by a side wall of a bank and an upper surface of an underlying layer on which the bank is provided (the underlying layer corresponding to the first electrode, hole injection layer, hole transporting layer, or hole injection transporting layer).

In the above organic light-emitting panel according to an aspect of the present invention, the plurality of pixels may be arranged to be continuously adjacent to each other, and two inner sidewalls, which face each other in two adjacent banks defining the third light-emitting cell, may have equal inclination angles.

With the above-described structure where two inner sidewalls facing each other in two adjacent banks defining the third light-emitting cell have equal inclination angles, it is possible, further to the above-described advantageous effects, to prevent the organic light-emitting layer in the third light-emitting cell from becoming uneven in film thickness and provide excellent light-emitting characteristics. This makes it possible to obtain excellent light-emitting characteristics in a plurality of pixels.

Note that the term "equal" above does not mean exact mathematical equivalence, but rather takes factors such as dimensional error during manufacturing of the display device into account. Specifically, the term "equal" refers to making the inclination angles equal within the range permitted in practice by the difference in luminous efficiency (uneven luminance) between the light-emitting cells in the central region and peripheral region of the panel.

In the above organic light-emitting panel according to an aspect of the present invention, the sidewall of the bank located on the side of the first light-emitting cell among the two inner sidewalls facing each other in the two adjacent banks defining the second light-emitting cell, and the two inner sidewalls facing each other in the two adjacent banks defining the first light-emitting cell, may have equal inclination angles.

In the above organic light-emitting panel, the organic light-emitting layer of the second light-emitting cell has been formed by applying ink to the second light-emitting cell in the second round when ink had already been applied to the first light-emitting cell in the first round, and an end of the second light-emitting cell on the first light-emitting cell side had a higher ink vapor concentration than an end on the third light-emitting cell side. However, with the above structure where the sidewall of the bank located on the side of the first light-emitting cell among the two inner sidewalls facing each other in the two adjacent banks defining the second light-emitting cell, and the two inner sidewalls facing each other in the two adjacent banks defining the first light-emitting cell, have equal inclination angles, it is possible to prevent the organic light-emitting layer from becoming uneven in film thickness.

In the above organic light-emitting panel according to an aspect of the present invention, the sidewall of the bank located on the side of the first light-emitting cell among the two inner sidewalls facing each other in the two adjacent banks defining the second light-emitting cell, and the two inner sidewalls facing each other in the two adjacent banks defining the third light-emitting cell, may have equal inclination angles.

In the above organic light-emitting panel, the organic light-emitting layer of the second light-emitting cell has been formed by applying ink to the second light-emitting cell in the second round when ink had already been applied to the first light-emitting cell in the first round, and an end of the second light-emitting cell on the first light-emitting cell side had a higher ink vapor concentration than an end on the third light-emitting cell side. However, with the above structure where the sidewall of the bank located on the side of the first light-emitting cell among the two inner sidewalls facing each other in the two adjacent banks defining the second light-emitting cell, and the two inner sidewalls facing each other in the two adjacent banks defining the third light-emitting cell, have equal inclination angles, it is possible to prevent the organic light-emitting layer from becoming uneven in film thickness.

Note that, in the above-described structure, the plurality of pixels are continuously adjacent to one another, and a non-light-emitting cell, which is formed to provide a bus bar between pixels, is not formed between each pair of adjacent pixels. Thus when ink is applied to the third light-emitting cell in the third round, the ink vapor concentrations at both ends of the third light-emitting cell are equal. For this reason, the two inner sidewalls facing each other in two adjacent banks defining the third light-emitting cell have equal inclination angles.

In the above organic light-emitting panel according to an aspect of the present invention where the plurality of pixels are continuously adjacent to one another, the inclination angles of the sidewalls of the banks can be set to the following ranges:

(a1) among the two inner sidewalls facing each other in the two adjacent banks defining the second light-emitting cell, the sidewall of the bank located on the side of the third light-emitting cell has an inclination angle of at least 35 degrees and at most 45 degrees;

(a2) among the two inner sidewalls facing each other in the two adjacent banks defining the second light-emitting cell, the sidewall of the bank located on the side of the first light-emitting cell has an inclination angle of at least 25 degrees and at most 35 degrees;

(a3) each of the two inner sidewalls facing each other in the two adjacent banks defining the first light-emitting cell has an inclination angle of at least 25 degrees and at most 35 degrees; and

(a4) each of the two inner sidewalls facing each other in the two adjacent banks defining the third light-emitting cell has an inclination angle of at least 25 degrees and at most 35 degrees.

In the above organic light-emitting panel according to an aspect of the present invention, a non-light-emitting cell may be provided between each pair of adjacent pixels, a bank may be provided between each pair of a pixel and a non-light-emitting cell that are adjacent to each other, the bank separating the pixel from the non-light-emitting cell, and in each pixel, among two inner sidewalls facing each other in two adjacent banks defining the third light-emitting cell, a sidewall of a bank located on a side of the non-light-emitting cell may have a larger inclination angle than a sidewall of a bank located on a side of the second light-emitting cell.

In the case of this structure where a non-light-emitting cell is formed between each pair of adjacent pixels, when ink is applied to the third light-emitting cell in the third round, the ink vapor concentrations at both ends of the third light-emitting cell are different. However, in the above organic light-emitting panel, among two inner sidewalls facing each other in two adjacent banks defining the third light-emitting cell, a sidewall of a bank located on a side of the non-light-emitting cell has a larger inclination angle than a sidewall of a bank

located on a side of the second light-emitting cell. This structure enables the relative pinning locations of the ink to be adjusted, thereby preventing the organic light-emitting layer from having an uneven film thickness.

In the above organic light-emitting panel according to an aspect of the present invention, each non-light-emitting cell may include none of the organic light-emitting layers and may include the second electrode and a third electrode that is made of a same material as the first electrode, the third electrode and the second electrode being electrically connected with each other.

For example, in a top-emission-type organic light-emitting panel, the second electrode, which is provided at a location upper (closer to the light extraction side) than the organic light-emitting layer, is normally made of a light-transmissive material (such as ITO or IZO). However, these materials have high electric resistance. These matters taken into account, the second electrode and the third electrode are connected in the non-light-emitting cell to reduce the electric resistance so that high light-transmissivity can be maintained to prevent a voltage drop from occurring even in a panel of a large size. The third electrode is, for example, a bus bar.

In the above organic light-emitting panel according to an aspect of the present invention, among the two inner sidewalls facing each other in the two adjacent banks defining the second light-emitting cell, the sidewall of the bank located on the side of the third light-emitting cell may have a larger inclination angle than the sidewall of the bank located on the side of the first light-emitting cell, and among the two inner sidewalls facing each other in the two adjacent banks defining the third light-emitting cell, the sidewall of the bank located on the side of the non-light-emitting cell may have a larger inclination angle than the sidewall of the bank located on the side of the second light-emitting cell.

With this structure where, among the two inner sidewalls facing each other in the two adjacent banks defining the second light-emitting cell, the sidewall of the bank located on the side of the third light-emitting cell has a larger inclination angle than the sidewall of the bank located on the side of the first light-emitting cell, the pinning location of the ink in the sidewall on the third light-emitting cell side becomes relatively higher than the pinning location of the ink in the sidewall on the first light-emitting cell side among the two inner sidewalls facing each other in the two adjacent banks defining the second light-emitting cell, and it is possible to prevent the organic light-emitting layer from becoming uneven in film thickness.

In the above organic light-emitting panel according to an aspect of the present invention, the sidewall of the bank located on the side of the third light-emitting cell among the two inner sidewalls facing each other in the two adjacent banks defining the second light-emitting cell, and the sidewall of the bank located on the side of the non-light-emitting cell among the inner sidewalls facing each other in the two adjacent banks defining the third light-emitting cell, may have equal inclination angles.

In the above organic light-emitting panel where the third light-emitting cell is adjacent to the non-light-emitting cell, the organic light-emitting layer of the third light-emitting cell has been formed by applying ink to the third light-emitting cell in the third round when an end of the third light-emitting cell on the second light-emitting cell side had a lower ink vapor concentration than an end on the non-light-emitting cell side. However, with the above structure where the sidewall of the bank located on the side of the third light-emitting cell among the two inner sidewalls facing each other in the two adjacent banks defining the second light-emitting cell, and the

sidewall of the bank located on the side of the non-light-emitting cell among the inner sidewalls facing each other in the two adjacent banks defining the third light-emitting cell, have equal inclination angles, it is possible to prevent the organic light-emitting layer from becoming uneven in film thickness in the third light-emitting cell as in the second light-emitting cell.

In the above organic light-emitting panel according to an aspect of the present invention, the sidewall of the bank located on the side of the first light-emitting cell among the two inner sidewalls facing each other in the two adjacent banks defining the second light-emitting cell, and the two inner sidewalls facing each other in the two adjacent banks defining the first light-emitting cell, may have equal inclination angles.

In the above organic light-emitting panel, the organic light-emitting layer of the second light-emitting cell has been formed by applying ink to the second light-emitting cell in the second round when ink had already been applied to the first light-emitting cell in the first round, and an end of the second light-emitting cell on the first light-emitting cell side had a higher ink vapor concentration than an end on the third light-emitting cell side. The end on the third light-emitting cell side tends to have a greater film thickness, but the end on the first light-emitting cell side is not likely to have such a tendency. Accordingly, with regard to the above-described structure, it is possible to prevent the organic light-emitting layer in the second light-emitting cell from becoming relatively uneven in film thickness by setting the inclination angles of the sidewalls of the banks to satisfy the above relationships.

In the above organic light-emitting panel according to an aspect of the present invention, the sidewall of the bank located on the side of the second light-emitting cell among the two inner sidewalls facing each other in the two adjacent banks defining the third light-emitting cell, and the two inner sidewalls facing each other in the two adjacent banks defining the first light-emitting cell, may have equal inclination angles.

With regard to the application of ink to the third light-emitting cell, also due to the uneven ink vapor concentrations, the end on the non-light-emitting cell side tends to have a greater film thickness, but the end on the second light-emitting cell side is not likely to have such a tendency. Accordingly, with regard to the above-described structure, it is possible to prevent the organic light-emitting layer in the third light-emitting cell from becoming relatively uneven in film thickness by setting the inclination angles of the sidewalls of the banks to satisfy the above relationships.

In the above organic light-emitting panel according to an aspect of the present invention where a non-light-emitting cell is formed between each pair of adjacent pixels, the inclination angles of the sidewalls of the banks can be set to the following ranges:

(b1) among the two inner sidewalls facing each other in the two adjacent banks defining the second light-emitting cell, the sidewall of the bank located on the side of the third light-emitting cell has an inclination angle of at least 35 degrees and at most 45 degrees;

(b2) among the two inner sidewalls facing each other in the two adjacent banks defining the third light-emitting cell, the sidewall of the bank located on the side of the non-light-emitting cell has an inclination angle of at least 35 degrees and at most 45 degrees;

(b3) among the two inner sidewalls facing each other in the two adjacent banks defining the second light-emitting cell, the sidewall of the bank located on the side of the first light-emitting cell has an inclination angle of at least 25 degrees and at most 35 degrees;

(b4) among the two inner sidewalls facing each other in the two adjacent banks defining the third light-emitting cell, the sidewall of the bank located on the side of the second light-emitting cell has an inclination angle of at least 25 degrees and at most 35 degrees; and

(b5) each of the two inner sidewalls facing each other in the two adjacent banks defining the first light-emitting cell has an inclination angle of at least 25 degrees and at most 35 degrees.

In the above organic light-emitting panel according to an aspect of the present invention, each inclination angle may be an angle formed between a sidewall of a bank and a surface of the underlying layer.

Note that, in the organic light-emitting panel according to an aspect of the present invention, the underlying layer may include a TFT (Thin Film Transistor) layer that is formed below the first electrode, and the first electrode may be electrically connected with the TFT layer in each pixel.

An organic display device according to another aspect of the present invention includes any one of the above organic light-emitting panels according to an aspect of the present invention. Therefore, the organic display device according to another aspect of the present invention produces the same advantageous effect as the organic light-emitting panel according to an aspect of the present invention.

A manufacturing method of an organic light-emitting panel according to a further aspect of the present invention is a manufacturing method of an organic light-emitting panel including an array of a plurality of pixels and the manufacturing method comprises the following steps:

(first step) forming, on a substrate, an underlying layer including a plurality of first electrodes;

(second step) layering a photoresist material on the underlying layer;

(third step) forming, for each pixel, a plurality of openings corresponding to a plurality of light-emitting cells by performing an exposure with a mask laid on the layered photoresist material to form a pattern, and forming a plurality of banks to define each light-emitting cell by separating the light-emitting cells one from another;

(fourth step) forming a plurality of organic light-emitting layers by dripping ink that includes organic light-emitting materials into the plurality of openings corresponding to the plurality of light-emitting cells, and drying the ink; and

(fifth step) forming a second electrode above each organic light-emitting layer.

In the manufacturing method of an organic light-emitting panel according to a further aspect of the present invention, in the third step, for each pixel, a first opening corresponding to a first light-emitting cell located at an end of an alignment, a second opening corresponding to a second light-emitting cell located at a central portion of the alignment, and a third opening corresponding to a third light-emitting cell located at another end of the alignment, are formed, and two inner sidewalls facing each other in two adjacent banks defining the first light-emitting cell are formed to have equal inclination angles.

Also, in the manufacturing method of an organic light-emitting panel according to a further aspect of the present invention, in the third step, among inner sidewalls of the second light-emitting cell and the third light-emitting cell, at least two inner sidewalls facing each other in two adjacent banks defining the second light-emitting cell are formed to have different inclination angles, and a sidewall of a bank located on a side of the third light-emitting cell is formed to have a larger inclination angle than a sidewall of a bank located on a side of the first light-emitting cell.

Furthermore, in the manufacturing method of an organic light-emitting panel according to a further aspect of the present invention, in the fourth step, the organic light-emitting layers are formed by dripping three types of ink corresponding one-to-one to three colors of light into the first opening, the second opening and the third opening one by one in a stated order.

When the above manufacturing method of an organic light-emitting panel according to a further aspect of the present invention is adopted, at least two inner sidewalls facing each other in two adjacent banks defining the second light-emitting cell can be formed to have different inclination angles, and a sidewall of a bank located on a side of the third light-emitting cell is formed to have a larger inclination angle than a sidewall of a bank located on a side of the first light-emitting cell. This makes it possible to prevent the organic light-emitting layer from becoming uneven in film thickness, which is caused by a non-uniform vapor concentration distribution during from dripping (applying) to drying of the ink. Thus the manufacturing method makes it possible to manufacture an organic light-emitting panel having excellent light-emitting characteristics.

In the above manufacturing method according to an aspect of the present invention, in the third step, when the exposure of the photoresist material is performed, among the two inner sidewalls facing each other in the two adjacent banks defining the second light-emitting cell, the sidewall of the bank located on the side of the third light-emitting cell is formed to have a larger inclination angle than the sidewall located on the side of the first light-emitting cell, by causing a portion of the photoresist material corresponding to the sidewall of the bank located on the side of the third light-emitting cell to be exposed to a larger amount of light than a portion of the photoresist material corresponding to the sidewall of the bank located on the side of the first light-emitting cell.

With the above structure, it is possible to set a desired inclination angle for a given portion of a side wall of a bank by adjusting the exposure amount, thereby adjusting the pinning location of when the ink is dripped. Thus the manufacturing method makes it possible to manufacture an organic light-emitting panel having excellent light-emitting characteristics.

In the above manufacturing method according to an aspect of the present invention, in the third step, when the exposure of the photoresist material is performed, among the two inner sidewalls facing each other in the two adjacent banks defining the second light-emitting cell, the sidewall of the bank located on the side of the third light-emitting cell is formed to have a larger inclination angle than the sidewall located on the side of the first light-emitting cell, by using different masks for respective portions of the photoresist material corresponding to the two sidewalls so that a light transmissivity at a portion of the photoresist material corresponding to the sidewall of the bank located on the side of the third light-emitting cell is lower than a light transmissivity at a portion of the photoresist material corresponding to the sidewall of the bank located on the side of the first light-emitting cell.

With the above structure, it is possible to set a desired inclination angle for a given portion of a side wall of a bank by adjusting the light transmissivity, thereby adjusting the pinning location of when the ink is dripped. Thus the manufacturing method makes it possible to manufacture an organic light-emitting panel having excellent light-emitting characteristics.

In the above manufacturing method according to an aspect of the present invention, in the third step, after the photoresist material is exposed and developed, among the two inner

sidewalls facing each other in the two adjacent banks defining the second light-emitting cell, the sidewall of the bank located on the side of the third light-emitting cell is formed to have a larger inclination angle than the sidewall located on the side of the first light-emitting cell, by additionally performing an exposure process onto a portion of the photoresist material corresponding to the sidewall of the bank located on the side of the third light-emitting cell.

With the above structure, it is possible to set a desired inclination angle for a given portion of a side wall of a bank by additionally performing an exposure process onto a certain portion, and not onto another portion, thereby adjusting the pinning location of when the ink is dripped. Thus the manufacturing method makes it possible to manufacture an organic light-emitting panel having excellent light-emitting characteristics.

An organic display device according to a still further aspect of the present invention includes an organic light-emitting panel manufactured by any one of the above-described manufacturing methods of the present invention.

The organic display device obtained in this way produces the same advantageous effect as the organic light-emitting panel manufactured by the manufacturing method of the present invention.

[Embodiment]

The following describes an example of an embodiment of the present invention with reference to the drawings.

Note that the following Embodiment is simply an example to clearly illustrate a structure of the present invention and the acts and effects thereof. The present invention is in no way limited to the following Embodiment except in its essential characteristic elements.

Process by which the Embodiment According to the Present Invention was Achieved

As a result of intense study, the inventor of the present invention discovered the following with regard to the organic light-emitting panel recited in the Background Art and the organic display device provided with the organic light-emitting panel.

Typically, as shown in FIG. 23A, an anode 902 and an electrode coating layer 903 covering the anode 902 are formed on a substrate 901, for each of sub-pixels 900a, 900b, and 900c. A hole injection layer 904 is then formed to cover the entire surface of the electrode coating layer 903 and the substrate 901, and on the hole injection layer 904, organic light-emitting layers 906a, 906b, and 906c of different colors are formed one-to-one in sub-pixels 900a, 900b, and 900c. The organic light-emitting layers 906a, 906b, and 906c are separated from each other by banks 905a to 905d formed to stand on the hole injection layer 904.

As shown in FIG. 23A, in an organic light-emitting panel of a conventional technology, an uneven film thickness is observed in the organic light-emitting layer 906b of the sub-pixel 900b that is located in a central region of the array. Specifically, the following phenomenon occurs. That is to say, the surface level of the organic light-emitting layer 906b is higher at location C₃ in the bank 905c than at location C₂ in the bank 905b. Also, the surface level of the organic light-emitting layer 906b is higher than the surface level of the organic light-emitting layer 906a at location C₁ in the bank 905b.

Also, as another example, as shown in FIG. 23B, a phenomenon occurs in which the surface levels of the organic light-emitting layers 956b and 956c in the sub-pixels 950b and 950c at locations C₁₂ and C₁₄ in the banks 955c and 955d are higher than the surface levels of the organic light-emitting layers 956b and 956c at locations C₁₁ and C₁₃ in the banks

955b and 955c, respectively. Note that, as shown in FIG. 23B, the surface levels of the organic light-emitting layer 956a in the sub-pixel 950a at respective locations in the bank 955a and the bank 955b are approximately the same, and a large amount of unevenness in film thickness is not observed.

After repeated examination of the above phenomenon, the inventor determined that reduction in uniformity of film thickness in the organic light-emitting layer causes a non-uniform vapor concentration distribution during ink drying, as described below. That is to say, as shown in FIG. 24A, suppose a state in which ink 9060c for forming the organic light-emitting layer has been applied in an area between the bank 905b and the bank 905c, and the right-hand side of FIG. 24A is lower than the left-hand side in vapor concentration distribution as indicated by the two-dot chain line. In this case, the film thickness in the organic light-emitting layer becomes uneven for the following reasons.

As shown in FIG. 24A, a surface profile L_{90} of ink 9060b has been swollen up in the central region of the sub-pixel immediately after the ink 9060b is dripped. When drying the ink, due to the non-uniform vapor concentration distribution as mentioned above, the evaporation rate varies in reverse proportion to the vapor concentration, and therefore it can be theoretically considered that the ink changes to have a surface profile L_{91} .

However, as shown in FIG. 24B, solvent in the ink 9061b flows during drying as shown by the dotted-line arrow L_{92} . This is because solvent flows to compensate for solvent that has evaporated (i.e. flows to minimize surface free energy), and along with the flow of the solvent, the solute (organic light-emitting material) also flows. Therefore, as shown in FIG. 24C, if the vapor concentration distribution is not uniform, the organic light-emitting layer 906b is formed to have a surface profile L_{93} in which the closer to the right-hand side the layer is, the higher the layer is.

The inventor therefore deduced that, in an organic light-emitting panel, uniformity of film thickness of the organic light-emitting layer decreases due to non-uniformity of vapor concentration distribution during ink drying.

The inventor also discovered technology to vary, within the panel, the pinning location of ink on a bank side wall by varying the inclination angle of the bank side wall, which improves uniformity of film thickness in the organic light-emitting layer.

[Embodiment 1]

1. Configuration of Display Device 1

The overall structure of the display device 1 according to the present Embodiment is described with reference to FIG. 1.

As shown in FIG. 1, the display device (organic display device) 1 includes a display panel unit 10 and a drive control unit 20 connected to the display panel unit 10. The display panel unit 10 is an organic light-emitting panel that used the phenomenon of electroluminescence occurring in organic material and is composed of a plurality of pixels arrayed two-dimensionally in the X-Y plane direction.

The drive control unit 20 is composed of four drive circuits 21-24 and a control circuit 25.

Note that in an actual display device 1, the placement of the drive control unit 20 with respect to the display panel unit 10 is not limited in this way.

2. Structure of Display Panel 10

The structure of the display panel 10 is described with reference to FIG. 2. Note that, as an example, the display panel 10 in the present Embodiment is a top emission type organic light-emitting panel including a plurality of pixels arranged in a matrix, each pixel including sub-pixels that are

each provided with an organic light-emitting layer having a luminescent color of either red (R), green (G), or blue (B). FIG. 2 depicts one sub-pixel 100 in a pixel.

As shown in FIG. 2, in the display panel 10, anodes 102 are formed above a TFT substrate (hereinafter simply referred to as a "substrate") 101 in one-to-one correspondence with the sub-pixels 300a, 300b and 300c, and on each of the anodes 102, an electrode coating layer 103 is formed, and a hole injection transporting layer 104 is layered on the electrode coating layers 103.

Above the hole injection transporting layer 104, banks 105, made of insulating material, are provided to stand to separate the sub-pixels 100 from each other. An organic light-emitting layer 106 is formed in the region in each sub-pixel 100 separated by the banks 105, and an electron injection layer 107, cathode 108, and passivation layer 109 are layered above the organic light-emitting layer 106 in this order.

a) Substrate 101

The substrate 101 is made of a base of an insulating material such as alkali-free glass, soda glass, non-fluorescent glass, phosphate glass, borate glass, quartz, acrylic resin, styrenic resin, polycarbonate resin, epoxy resin, polyethylene, polyester, silicone resin, alumina, etc. Although not illustrated, in the substrate 101, a TFT layer, a passivation film, an interlayer insulation film, etc. are laminated.

b) Anode 102

The anode 102 is composed of a single layer or of a laminate of a plurality of layers, either being made of a conductive material, such as aluminum (Al), alloy including Al, silver (Ag), alloy of silver, palladium, and copper (APC), alloy of silver, rubidium, and gold (ARA), alloy of molybdenum and chromium (MoCr), alloy of nickel and chromium (NiCr), etc. Note that in the case of a top emission type panel such as the panel in the Embodiment, it is preferable that the anode 102 be made of a highly reflective material.

c) Electrode Coating Layer 103

The electrode coating layer 103 is made of, for example, indium tin oxide (ITO) and covers at least a part of the top surface the anode 102 in the Z axis direction.

d) Hole Injection Transporting Layer 104

The hole injection transporting layer 104 is a layer formed from an oxide of a metal such as silver (Ag), molybdenum (Mo), chromium (Cr), vanadium (V), tungsten (W), nickel (Ni), or iridium (Ir), or formed from a conductive polymer material, such as PEDOT (a mixture of polythiophene and polystyrene sulfonate). The hole injection transporting layer 104 formed from such a metal oxide, among the above materials, has the function of assisting with generation of holes and injecting and transporting the holes stably into the organic light-emitting layer 106. The hole injection transporting layer 104 has a high work function.

When the hole injection transporting layer 104 is made of an oxide of a transition metal, a plurality of levels can be occupied since there are a plurality of oxidation numbers. This makes hole injection easy and allows for reduction of driving voltage.

e) Banks 105

The banks 105 are made of an organic material such as resin and have insulating properties. Examples of the organic material used to form the banks 105 include acrylic resin, polyimide resin, novolac-type phenolic resin, etc. It is also preferable that the banks 105 have organic solvent resistance.

Furthermore, since the banks 105 are etched and baked when formed, it is preferable that the banks be made of a highly resistant material that will not change in shape or

quality during the etching and baking processes. To provide the banks with liquid repellency, the sidewalls can be fluorinated.

Note that as the insulating material used in forming the banks **105**, any liquid repellent material with a resistivity of $10^5 \Omega\cdot\text{cm}$ can be used, starting with the above materials. Using a material with a resistivity of less than $10^5 \Omega\cdot\text{cm}$ leads to production of leak current between the anode **102** and the cathode **108**, or between adjacent sub-pixels **100**, which causes a variety of problems such as increased power consumption.

Furthermore, if a hydrophilic material is used to form the banks **105**, the difference in affinity/liquid repellency between the sidewall of the banks **105** and the surface of the hole injection transporting layer **104** becomes small, and it thus becomes difficult to selectively maintain the ink, which includes an organic substance for forming the organic light-emitting layer **106**, at the opening of the banks **105**.

The structure of the banks **105** need not be a single layer as shown in FIG. 2, but may adopt a multi-layered structure composed of two or more layers. In such a case, the above materials may be combined for each layer, or layers may alternate between non-organic and organic material.

f) Organic Light-emitting Layer **106**

The organic light-emitting layer **106** has a function to emit light when an excitation state is produced by the recombination of holes injected through the anode **102** with electrons injected through the cathode **108**. The material used to form the organic light-emitting layer **106** needs to be a light-emitting organic material, a film of which can be formed by wet printing.

More specifically, it is preferable that the organic light-emitting layer **106** be made of a fluorescent material such as an oxinoid 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, telluropirylium compound, aromatic aldadiene compound, oligophenylene compound, thioxanthene compound, anthracene 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 three metal, metal complex of oxine, rare earth metal complex, etc., as recited in Japanese Patent Application Publication No. H5-163488.

g) Electron Injection Layer **107**

The electron injection layer **107** has a function to transport electrons injected through the cathode **108** to the organic light-emitting layer **106** and is preferably made of, for example, barium, phthalocyanine, lithium fluoride, or a combination thereof.

h) Cathode **108**

The cathode **108** is made of, for example, ITO, indium zinc oxide (IZO), etc. When the display panel **10** is a top-emission type, it is preferable that the cathode **108** be made of a light-transmissive material. It is preferable that the light transmissivity be 80% or greater.

The material used to form the cathode **108** may be, in addition to the above materials, for example, an alkali metal, alkali earth metal, or a laminate structure having, in the following order, a layer that includes a halide of an alkali metal or alkali earth metal and a layer that includes silver. The layer that includes silver may be made of silver alone, or from a silver alloy. Also, in order to increase light extraction efficiency, a highly-transparent refraction index adjustment layer may be provided above the layer that includes silver.

i) Passivation Layer **109**

The passivation layer **109** has a function to control the organic light-emitting layer **106** or other layers from being exposed to water or air and is made of, for example, silicon nitride (SiN), silicon oxynitride (SiON) etc. When the display panel **10** is a top-emission type, it is preferable that the passivation layer **109** be made of a light-transmissive material.

3. Structure of Banks **105**

As shown in FIG. 3, in the display panel **10** of the present Embodiment, the banks **105** are arranged in lines, as one example. More specifically, the banks **105** each extend along the Y axis and separate the adjacent sub-pixels **100** in the X axis direction. The sub-pixels **100** are formed so that each of the regions separated by the banks **105** in each pixel emits a different color. For example, one pixel is composed of three sub-pixels that emit light of red (R), green (G), and blue (B), respectively.

4. Structure of Banks **105** in Each Region

The structure of the banks **105** in each region is described with reference to FIG. 4. Note that FIG. 4 is a schematic cross-sectional view taken along line A-A' passing through the display panel **10** in FIG. 1, and schematically illustrating some parts thereof.

As shown in FIG. 4, sub-pixels **100a**, **100b**, and **100c** are arranged continuously in this order from left to right along the X axis direction. Note that in the display panel **10** of the present embodiment, the sub-pixels are arranged to be continuously adjacent to each other.

The sub-pixel **100a** is defined by banks **105a** and **105b**; the sub-pixel **100b** is defined by banks **105b** and **105c**; and the sub-pixel **100c** is defined by banks **105c** and **105d**. Sidewalls **105aa**, **105ba**, **105bb**, **105cb**, **105cc**, and **105dc** of the banks **105a**, **105b**, **105c** and **105d** respectively form angles θ_{aa} , θ_{ba} , θ_{bb} , θ_{cb} , θ_{cc} , and θ_{dc} with the surface of the hole injection transporting layer **104**, which is an underlying layer.

In the present Embodiment, the angles θ_{aa} , θ_{ba} , θ_{bb} , θ_{cb} , θ_{cc} , and θ_{dc} satisfy the relationships indicated by the following expressions.

$$\theta_{cb} > \theta_{aa} = \theta_{ba} = \theta_{bb} = \theta_{cc} = \theta_{dc} \quad [\text{Expression 1}]$$

Note that in the present Embodiment, it is preferable that the angles θ_{aa} , θ_{ba} , θ_{bb} , θ_{cb} , θ_{cc} , and θ_{dc} satisfy the relationships indicated by the above Expression 1 and are set to the following ranges.

$$25^\circ < \theta_{aa} = \theta_{ba} = \theta_{bb} = \theta_{cc} = \theta_{dc} < 35^\circ \quad [\text{Expression 2}]$$

$$35^\circ < \theta_{cb} < 45^\circ \quad [\text{Expression 3}]$$

5. Relationship Between Inclination Angle θ of Sidewall of Banks **105** and Film Thickness of Organic Light-emitting Layer **106**

The relationship between the inclination angles θ of the sidewalls of the banks **105** and the film thickness of the organic light-emitting layer **106** is described with reference to FIGS. 5 and 6. Note that FIG. 5 is a schematic rendering of the structure of a sub-pixel.

As shown in FIG. 5A, the inclination angle of the sidewall of bank **105x** (the angle formed between the sidewall and the

surface of the hole injection transporting layer **104**) is represented by angle θ_x , and as shown in FIG. 5B, the inclination angle of the sidewall of bank **105y** (the angle formed between the sidewall and the surface of the hole injection transporting layer **104**) is represented by angle θ_y . Here, the angles θ_x and θ_y satisfy the following relationship.

$$\theta_y > \theta_x \quad [\text{Expression 4}]$$

When ink **1060x** and ink **1060y**, which include an organic light-emitting material, are each dripped into the openings defined by the banks **105x** and **105y**, respectively, the pinning locations P_x and P_y respectively have heights H_x and H_y that satisfy the following relationship.

$$H_y > H_x \quad [\text{Expression 5}]$$

As shown in FIG. 5C, after drying the ink **1060x**, the height H_x of the pinning location P_x is relatively low, which causes the organic light-emitting layer **106x** to swell at the central portion of the sub-pixel to a film thickness of T_x .

On the other hand, as shown in FIG. 5D, after drying the ink **1060y**, the height H_y of the pinning location P_y is relatively high, which causes the organic light-emitting layer **106y** to sag at the central portion of the sub-pixel to a film thickness of T_y .

The thicknesses T_x and T_y satisfy the following relationship.

$$T_x > T_y \quad [\text{Expression 6}]$$

FIG. 6 summarizes the above relationships. As shown in FIG. 6, as the inclination angle (taper angle) θ of the bank **105** grows smaller, the pinning height H lowers, and as a result, the film thickness T of the organic light-emitting layer **106** becomes thicker. Conversely, as the inclination angle (taper angle) θ of the bank **105** grows larger, the pinning height H becomes higher, and as a result, the film thickness T of the organic light-emitting layer **106** becomes thinner.

Based on the above factors, five samples were created and evaluated. FIGS. 7 and 8 show the results.

As shown in FIGS. 7 and 8, as compared to the distribution of film thickness of sample 2, the pinning location is higher in samples 3 and 4, which have a larger taper angle. Note that in FIGS. 7 and 8, the horizontal axis represents the horizontal direction, and the vertical axis represents the direction of height.

In sample 5, however, in which the bank has a taper angle (inclination angle) of 50° , the film thickness is less uniform than in sample 2.

6. Manufacturing Method of Display Panel 10

The following describes the characteristic processes of the manufacturing method of the display panel **10** according to the present Embodiment with reference to FIGS. 9 and 10. Note that with regard to the manufacturing processes that are omitted in the following description, any of the variety of processes suggested by conventional technologies may be used.

First, as shown in FIG. 9A, above the substrate **101** in the direction of the Z axis, anodes **102** and electrode coating layers **103** are layered in this order in regions in which sub-pixels **1000a**, **1000b**, and **1000c** are to be formed. Furthermore, a hole injection transporting layer **104** is then layered thereon so as to cover the entire surface. The anodes **102** is formed, for example, by first forming a thin film made of Al or Al alloy or a thin Ag film by the sputtering method or vacuum deposition method and then patterning the thin Ag film by the photolithography method.

The electrode coating layers **103** is formed, for example, by forming a thin ITO film on the surface of the anodes **102** using

a method such as the sputtering method and then patterning the thin ITO film by a method such as photolithography. To form the hole injection transporting layer **104**, first a metal film is formed on the surface of the substrate **101**, including the surface of the electrode coating layer **103**, by a method such as the sputtering method. Subsequently, the metal film is oxidized to form the hole injection transporting layer **104**.

Next, as shown in FIG. 9B, the spin coat method, for example, is used to form a bank material layer **1050** so as to cover the top of the hole injection transporting layer **104**. A photoresist material is used to form the bank material layer **1050**. Specifically, as described above, an organic material having insulating properties such as acrylic resin, polyimide resin, novolac-type phenolic resin, etc. can be used.

Subsequently, as shown in FIG. 9C, a mask **501** is placed above the bank material layer **1050**, the mask **501** having openings **501a**, **501b**, **501c**, and **501d** at the locations for forming the banks. In this state, exposure is performed via the openings **501a**, **501b**, **501c**, and **501d** of the mask **501**.

Note that, as shown in FIG. 9C, in the mask **501**, a width W_a of the opening **501a** located on the left-hand side of a region **1000a** in which a sub-pixel is to be formed (hereinafter, such a region is referred to as "planned sub-pixel formation region"), is defined by points Pa_1 and Pa_2 positioned at the foots of the sidewalls **105aa**, . . . of the bank **105a** that is to be formed (see FIG. 4).

On the other hand, a width W_{c1} of the opening **501c** located between the planned sub-pixel formation regions **1000b** and **1000c** is defined by a point Pc_1 being at the upper edge of the sidewall **105cb** of the bank **105c** that is to be formed (see FIG. 4) and a point Pc_2 being at the foot of the sidewall **105cc** of the bank **105c** that is to be formed (see FIG. 4).

Next, as shown in FIG. 10A, a mask **502** is placed above the bank material layer **1050**, the mask **502** having opening **502c** at the location corresponding to the sidewall **105cb** of the bank **105c** (see FIG. 4). In this state, the second exposure is performed via the opening **502c** of the mask **502**.

Note that, as shown in FIG. 10A, in the mask **502**, a width W_{c2} of the opening **502c** is defined by points Pc_3 and Pe_1 being at the foot and the upper edge of the sidewall **105cb** of the bank **105c** that is to be formed.

Next, the development and baking are performed to form the banks **105a**, **105b**, **105c**, and **105d** as shown in FIG. 10B. As described above, the sidewall **105cb** of the bank **105c** on the planned sub-pixel formation region **1000b** side is larger than the sidewalls **105aa**, **105ba**, **105bb**, and **105dc** of the banks **105a**, **105b** and **105d** and the sidewall **105cc** of the bank **105c** on the planned sub-pixel formation region **1000c** side.

After this, as shown in FIG. 10C, ink **1060a** including an organic light-emitting material is applied to an opening (the planned sub-pixel formation region **1000a**) defined by the banks **105a** and **105b** by the inkjet method or the like.

Subsequently, as shown in FIG. 11A, ink **1060b** including an organic light-emitting material is applied to an opening (the planned sub-pixel formation region **1000b**) defined by the banks **105b** and **105c** by the inkjet method or the like. Here, since, as described above, the inclination angle of the sidewall **105cb** of the bank **105c** is set to be larger than the inclination angles of the other sidewalls, the pinning location Q_{cb} of the ink **1060b** in the sidewall **105cb** of the bank **105c** becomes higher in position than the other pinning locations Q_{aa} , Q_{ba} , and Q_{bb} .

Subsequently, as shown in FIG. 11B, ink **1060c** including an organic light-emitting material is applied to an opening (the planned sub-pixel formation region **1000c**) defined by

the banks **105c** and **105d** by the inkjet method or the like. Here, since ink has already been applied to the planned sub-pixel formation region adjacent, on the right-hand side, to the bank **105d**, two ends of the applied ink **1060c** in the X axis direction have the same ink vapor concentration, and the organic light-emitting layer has even film thickness without adjustment of the inclination angles of the sidewalls of the banks. This is clear from the above.

Note that, although not illustrated, subsequently the ink is dried, and the electron injection layer **107**, cathode **108**, passivation layer **109**, etc. are layered in this order to form the display panel **10**.

7. Ink Applying Process and Drying Process

The following describes the relationships between the ink applying process and the ink drying process with reference to FIGS. **12A** and **12B**.

As illustrated in FIG. **12A**, in the present embodiment, firstly red ink (the ink **1060a**) is applied (step **S1**), then green ink (the ink **1060b**) is applied (step **S2**), and blue ink (the ink **1060c**) is applied (step **S3**). After this, ink drying process is performed to dry all the applied inks at once (step **S4**).

As an alternative to the above method, as illustrated in FIG. **12B**, the following processes may be performed in sequence in the stated order: applying red ink (the ink **1060a**) (step **S11**) and drying the applied red ink (step **S12**); applying green ink (the ink **1060b**) (step **S21**) and drying the applied green ink (step **S22**); and applying blue ink (the ink **1060c**) (step **S31**) and drying the applied blue ink (step **S32**). In this case, the relationships in inclination angle among the side walls **105aa**, **105ba**, **105bb**, **105cb**, **105cc**, and **105dc** of the banks **105a**, **105b**, **105c**, and **105d** may be the same as those described above. This structure also can restrict the film thickness of the formed organic light-emitting layer **106** from becoming uneven.

8. Advantageous Effects

As shown in FIG. **4**, in the display panel **10** of the display device **1** according to the present Embodiment, inclination angle θ_{cb} of the sidewall **105cb** of the bank **105c** positioned on the sub-pixel **100c** side is set larger than the inclination angles θ_{aa} , θ_{ba} , θ_{bb} , θ_{cc} , and θ_{dc} of other sidewalls **105aa**, **105ba**, **105bb**, **105cc**, and **105dc**. As a result, as shown in FIG. **11A**, when the ink **1060b** is applied in the planned sub-pixel formation region **1000b**, the pinning location Q_{cb} is higher in position than the other pinning locations Q_{aa} , Q_{ba} , and Q_{bb} .

On the other hand, the inclination angles θ_{aa} , θ_{ba} , θ_{bb} , θ_{cc} , and θ_{de} of the other sidewalls **105aa**, **105ba**, **105bb**, **105cc**, and **105dc** are equal.

This enables sub-pixels **100a**, **100b**, and **100c** to have a uniform film thickness in the organic light-emitting layer **106** of the display panel **10** after drying, which produces an advantageous effect of having little luminance unevenness.

Note that, by using the manufacturing method of the display device **1** in the present Embodiment, which has been described with reference to FIGS. **9**, **10**, and **11**, the display device **1** having the above advantageous effect can be manufactured.

Also, the term "equal" does not necessarily mean that the targets are completely equal with each other in numerical value, but includes, for example, a measurement error in manufacturing of the display device **1**. More specifically, it is suggested that, in the display panel **10**, the inclination angles are recognized as being equal as far as the difference in luminous efficiency (luminance unevenness) between sub-pixels **100a**, **100b**, and **100c**, which correspond to the inclination angles, falls in an acceptable range.

[Modification 1]

Next, with reference to FIG. **13**, Modification 1 of the manufacturing method of the display device **1** is described. FIG. **13** illustrates processes corresponding to processes illustrated in FIGS. **9C** to **10A**.

As shown in FIG. **13**, first a bank material layer **1050** is formed to cover the hole injection transporting layer **104**, and then a mask **503** is placed above the bank material layer **1050**. The mask **503** is provided with light transmissive portions **503a**, **503b**, **503c1**, **503c2**, and **503d**. The light transmissive portions **503a**, **503b**, **503c1**, **503c2**, and **503d** are provided at locations corresponding to portions in which the banks **105a**, **105b**, **105c**, and **105d** are to be formed.

In the manufacturing method of the display device **1** in Modification 1, width W_a of the light transmissive portion **503a**, which corresponds to the left-hand side of the planned sub-pixel formation region **1000a**, is defined by points $Pa1$ and $Pa2$ at the feet of the sidewalls **105aa**, . . . of the bank **105a** (see FIG. **4**) that is to be formed.

On the other hand, width W_{c2} of the light transmissive portion **503c1**, which corresponds to a region between the planned sub-pixel formation regions **1000b** and **1000c**, is defined by points $Pc2$ and $Pc1$ that are respectively positioned at the foot and upper edge of the bank **105c** to be formed (see FIG. **4**). Also, the light transmissive portion **503c2** is defined by points $Pc3$ and $Pc1$ that are respectively positioned at the foot and upper edge of the sidewall **105cb** of the bank **105c** to be formed (see FIG. **4**).

The mask **503** is made from a half-tone or the like, and the light transmissive portions **503a**, **503b**, **503c1**, and **503d** differ from the light transmissive portion **503c2** in light transmissivity. More specifically, the light transmissive portion **503c2** is larger than the light transmissive portions **503a**, **503b**, **503c1**, and **503d** in light transmissivity.

In the state where the mask **503** having the above structure is set in place, the exposure and development, and then baking are performed to form the banks **105a**, **105b**, **105c**, and **105d** as shown in FIG. **10B**. That is to say, sidewalls having larger inclination angles are formed at locations which are exposed to light via the light transmissive portion **503c2** having a larger light transmissivity than the light transmissive portions **503a**, **503b**, **503c1**, and **503d**, in accordance with the relationship indicated by the above-described Expression 1.

Note that subsequent processes are the same as those in the above Embodiment.

The display device **1** can be manufactured by the above manufacturing method as well.

[Modification 2]

Next, with reference to FIGS. **14A** to **15B**, Modification 2 of the manufacturing method of the display device **1** is described. FIGS. **14A** to **15B** illustrate processes corresponding to the processes illustrated in FIGS. **9C** to **10B**.

As shown in FIG. **14A**, first a bank material layer **1050** is formed to cover the hole injection transporting layer **104**, and then a mask **504** is placed above the bank material layer **1050**. The mask **504** has openings **504a**, **504b**, **504c**, and **504d** corresponding to the portions at which banks **105** are to be formed.

The openings **504a**, **504b**, and **504d** are formed to have the same width as the opening **501a** in the mask **501** used in the manufacturing method of the above Embodiment.

On the other hand, a width W_{c3} of the opening **504c** located between the planned sub-pixel formation regions **1000b** and **1000d** in correspondence with the bank **105c** that is to be formed (see FIG. **4**) is set to be larger than a width that is defined by points $Pc3$ and $Pc2$ being at the feet of the bank **105c** that is to be formed (see FIG. **4**), as indicated by the

two-dot chain line in FIG. 14A. More specifically, the width is made larger at the portions where the inclination angles are to be larger.

In the state where the mask 504 is set in place as shown in FIG. 14A, the exposure and development in the first round are performed. After this process is performed, as shown in FIG. 14B, bank material layers 1051a, 1051b, 1051c, and 1051d remain in the locations corresponding to the openings 504a, 504b, 504c, and 504d.

Note that, as shown in FIG. 14B, the inclination angles of the sidewalls in the bank material layers 1051a, 1051b, 1051c, and 1051d are uniform after the first exposure and development are performed. In Modification 2, the baking is not performed at this point in time.

As shown in FIG. 15A, a mask 505 is placed above the bank material layers 1051a, 1051b, 1051c, and 1051d after they are formed. In the mask 505, an opening 505c is provided only at the location where the inclination angle is to be larger (sidewall 105cb of the bank 105c) among the locations in the mask 505 corresponding to the sidewalls of the banks 105a, 105b, 105c, and 105d that are to be formed.

In the state where the mask 505 is set in place, the exposure and development in the second round are performed, and then the baking is performed to form the banks 105a, 105b, 105c, and 105d as shown in FIG. 15B.

Subsequently, the display device 1 can be manufactured by performing the same processes as in the above Embodiment or the like.

[Verification of Manufacturing Method]

Using a concrete example, the shape of the banks after formation was verified for the manufacturing methods of the above Embodiment and Modifications 1 and 2. The results are described with reference to FIGS. 16A and 16B.

As shown in FIG. 16A, the larger the amount of exposure is, the larger the inclination angle of a sidewall of a formed bank is. More specifically, when the exposure and development are performed with 200 mJ of exposure amount, the inclination angle of a sidewall of the formed bank is 23°, whereas when the exposure and development are performed with 300 mJ of exposure amount, the inclination angle of a sidewall of the formed bank is 38°. The results are also shown by the Atomic Force Microscope (AFM) in FIG. 16B.

Furthermore, as shown in FIGS. 16A and 16B, when the exposure and development in the first round is performed with 200 mJ of exposure amount and then the exposure and development in the second round is performed with 100 mJ of exposure amount, the inclination angle of a sidewall of the formed bank is 50°. This corresponds to the manufacturing method of Modification 2 and is considered to be effective in creating a large inclination angle of the bank sidewall.

Note that in FIG. 16B, the horizontal axis represents the horizontal direction, and the vertical axis represents the direction of height.

[Embodiment 2]

The following describes an overall structure of the display device in Embodiment 2 with reference to FIGS. 17 and 18.

1. Structure of Display Panel 30

As shown in FIG. 17, in the display panel 30, as in the display panel 10 in Embodiment 1, anodes 102 are formed above a TFT substrate (hereinafter simply referred to as a "substrate") 101 in one-to-one correspondence with the sub-pixels 300a, 300b and 300c, and on each of the anodes 102, an electrode coating layer 103 is formed, and a hole injection transporting layer 104 is layered on the electrode coating layers 103.

Above the hole injection transporting layer 104, banks 305a, 305b, 305c, and 305d are formed from insulating mate-

rial to define the sub-pixels 300a, 300b, and 300c. An organic light-emitting layer is formed in each region of the sub-pixels 300a, 300b, and 300c defined by the banks 305a, 305b, 305c, 305d, and an electron injection layer, a cathode, and a passivation layer are layered above the organic light-emitting layer in this order (illustration of these is omitted in FIG. 17).

In the display panel 30 of the present embodiment, as is the case with the display panel 10 in the above-described Embodiment 1, a pixel is composed of three sub-pixels 300a, 300b, and 300c. In addition, in the display panel 30 of the present embodiment, non-light-emitting cells 300d and 300e are provided between the pixel and the adjacent pixels on both sides.

More specifically, as illustrated in FIG. 17, each of the non-light-emitting cells 300d and 300e has an electrode (bus bar) 302, which is made of the same material as the anode 102, and an electrode coating layer 303 covering the electrode 302. A hole injection transporting layer 104 is formed to cover each stack of the layers including the electrode coating layer 303. A cathode 108 (not illustrated) is formed on the hole injection transporting layer 104 such that the electrode 302 and the cathode 108 are electrically connected. Note that the organic light-emitting layer 106 is not formed in the non-light-emitting cells 300d and 300e. The above structure makes it possible to lower the electric resistance of the cathode 108 that is composed of ITO and the like, thereby preventing a voltage drop from occurring.

As illustrated in FIG. 17, in the display panel 30 of the present embodiment, side walls 305aa, 305ba, 305bb, 305cb, 305cc, and 305dc of the banks 305a, 305b, 305c, and 305d respectively form angles $\theta 3aa$, $\theta 3ba$, $\theta 3bb$, $\theta 3cb$, $\theta 3cc$, and $\theta 3dc$ with the surface of the hole injection transporting layer 104 as an underlying layer.

Here, in the present embodiment, the angles $\theta 3aa$, $\theta 3ba$, $\theta 3bb$, $\theta 3cb$, $\theta 3cc$, and $\theta 3dc$ satisfy the relationships represented by the following expressions.

$$\theta 3cb > \theta 3aa = \theta 3ba = \theta 3bb = \theta 3cc \quad [\text{Expression 7}]$$

$$\theta 3dc > \theta 3aa = \theta 3ba = \theta 3bb = \theta 3cc \quad [\text{Expression 8}]$$

Note that, in the present embodiment, the angles $\theta 3aa$, $\theta 3ba$, $\theta 3bb$, $\theta 3cb$, $\theta 3cc$, and $\theta 3dc$ are preferably set to the following ranges.

$$25^\circ < \theta 3aa = \theta 3ba = \theta 3bb = \theta 3cc < 35^\circ \quad [\text{Expression 9}]$$

$$35^\circ < \theta 3cb < 45^\circ \quad [\text{Expression 10}]$$

$$35^\circ < \theta 3dc < 45^\circ \quad [\text{Expression 11}]$$

The reason why the inclination angles $\theta 3aa$, $\theta 3ba$, $\theta 3bb$, $\theta 3cb$, $\theta 3cc$, and $\theta 3dc$ of the side walls 305aa, 305ba, 305bb, 305cb, 305cc, and 305dc of the banks 305a, 305b, 305c, and 305d are defined by the above-described Expressions 7 to 11 is that the non-light-emitting cells 300d and 300e are provided between a pixel and the adjacent pixels on both sides. Description of this is provided in connection with application of inks 3060a, 3060b, and 3060c.

2. Manufacturing Method of Display Panel 30

The following describes the characteristic steps of the manufacturing method of the display panel 30 according to the present Embodiment with reference to FIGS. 18A to 18C. Note that the steps other than those illustrated in FIGS. 18A to 18C are the same as those of Embodiment 1.

As shown in FIG. 18A, ink 3060a that includes an organic light-emitting material is dripped into the opening (planned sub-pixel formation region 3000a) defined by the banks 305a and 305b by the inkjet method or other method. When the ink 3060a is applied to the region between the banks 305a and

305b, ink has not been applied to the left-hand side of the bank **305a** and the right-hand side of the bank **305b**, and thus the vapor concentration distribution is substantially uniform.

Following this, as shown in FIG. 18B, ink **3060b** that includes an organic light-emitting material is dripped into the opening (planned sub-pixel formation region **3000b**) defined by the banks **305b** and **305c** by the inkjet method or other method. Here, as described above, inclination angle θ_{3cb} of the sidewall **305cb** of the bank **305c** (see FIG. 17) is set to satisfy the relationships represented by the above-described Expression 7 (to be relatively larger than the other inclination angles). As a result, the pinning location **Q3cb** of the ink **3060b** in the side wall **305cb** of the bank **305c** is higher in position than the pinning locations **Q3aa**, **Q3ba**, and **Q3bb**.

Subsequently, as shown in FIG. 18C, ink **3060c** that includes an organic light-emitting material is dripped into the opening (planned sub-pixel formation region **3000c**) defined by the banks **305c** and **305d** by the inkjet method or other method. Here, in the present embodiment, the non-light-emitting cell **3000d**, to which ink is not applied, is present on the right-hand side of the planned sub-pixel formation region **3000c**. Accordingly, the vapor concentration is lower in the right-hand side of the planned sub-pixel formation region **3000c** than in the left-hand side. For this reason, as is the case with the inclination angle θ_{3cb} of the sidewall **305cb** of the bank **305c**, the inclination angle θ_{3dc} of the sidewall **305dc** of the bank **305d** on the planned sub-pixel formation region **3000c** side (see FIG. 17) is set to satisfy the relationships represented by the above-described Expressions 7 and 8 (to be relatively larger than the other inclination angles). As a result, the pinning location **Q3dc** of the ink **3060c** in the side wall **305dc** of the bank **305d**, as well as the pinning location **Q3cb** of the ink **3060b**, is higher in position than the other pinning locations.

Note that, although omitted from the drawings, subsequently, the display panel **30** is formed by layering, in order, the electron injection layer, cathode, passivation layer, etc.

With the above-described structure, even in the case where the non-light-emitting cells **300d** and **300e** are provided between a pixel and the adjacent pixels on both sides, it is possible to prevent the organic light-emitting layer from becoming uneven in film thickness in all sub-pixels **300a**, **300b**, and **300c**, and thus it is possible to provide the display panel **30** having high light transmissivity.

Note that the structures other than those described in the present embodiment are the same as those of Embodiment 1. [Other Considerations]

Firstly, in the above Embodiment and Modifications 1 and 2, it is schematically illustrated that the surface of each sidewall of the banks **105**, **105a-105d**, **105x**, **105y**, and **305a-305e** is planar. However, the surface of each sidewall of the banks may not necessarily be planar. For example, FIG. 19A illustrates a bank **605** whose sidewall has two surfaces: a surface extending from a point P_{61} to a point P_{62} ; and a surface extending from the point P_{62} to a point P_{63} . In this case, a pinning location **Qy1** during ink application is present on the surface between the points P_{62} and P_{63} . Here, an inclination angle $\theta y2$ formed between this the surface and a virtual straight line L_1 passing through the point P_{62} is important in the relationship with the pinning location.

However, the angle $\theta y2$ can be controlled by controlling an angle $\theta y1$, which is formed between the surface of the underlying layer, namely the hole injection transporting layer **104**, and the surface between points P_{61} and P_{62} of the sidewall of the bank **605**, when the bank **605** is formed. Thus, in the actuality, the above effects can be obtained by controlling the inclination angle $\theta y1$. For example, if a bank **705** is formed

such that an angle $\theta y11$ formed between the surface of the hole injection transporting layer **104** and a surface between points P_{71} and P_{72} is larger than the angle $\theta y1$ shown in FIG. 19A (see FIG. 19B), then, as shown in FIG. 19B, an angle $\theta y12$ formed between a surface between points P_{72} and P_{73} and a virtual straight line L_2 also becomes larger than the angle $\theta y2$ shown in FIG. 19A.

Secondly, in the above Embodiments 1 and 2 and Modifications 1 and 2, it is not specified to what part of the region of the display panel **10** or **30** the above-described structure can be applied. However, the above-described structure may be applied to the entire region of the display panel, or may be applied to a part of the region. As shown in FIG. 20, the display panel **10** can be divided formally into areas **10a** and **10b** in a direction along the surface of the display panel **10**, wherein the area **10a** is located at the center, and the area **10b** surrounds the area **10a**. The area **10a** is connected to a source electrode or a drain electrode of the TFT layer below which the anodes are formed, and contributes to the emission of light. On the other hand, the area **10b** is not connected to any of the source electrode and drain electrode of the TFT layer below which the anodes are formed, and does not contribute to the emission of light. It is considered that, if the area **10a** is further divided formally into a central area **10a1** and a surrounding area **10a2**, the uneven film thickness in the organic light-emitting layers of the sub-pixels in the surrounding area **10a2** would be more prominent due to the state of vapor concentration distribution during the application of ink.

Note that the combined area of the surrounding area **10a2** and the area **10b** may occupy approximately 0.5% to several percent (for example, 1%) of the total area of the panel. This range is determined by taking account of the variation in film thickness of the organic light-emitting layers when the inclination angles of the bank sidewalls are not adjusted.

In the above Embodiments 1 and 2 and Modifications 1 and 2, the structures are adopted by way of example to clearly explain the structure, acts and effects of the present invention. Accordingly, the present invention is not limited to the above structures, except for such portions that are essential to the present invention. For example, the above Embodiment has adopted, as one example, a structure in which the anodes **102** are located below the organic light-emitting layers **106** in the Z axis direction, as shown in FIG. 2. However, not limited to this structure, the present invention may adopt a structure in which the cathodes **108** are located below the organic light-emitting layers **106** in the Z axis direction.

The display panel has the top-emission structure when it adopts the structure in which the cathodes **108** are located below the organic light-emitting layers **106** in the Z axis direction. In that case, the cathodes **108** become the reflecting electrode layers, and the electrode coating layers **103** are formed above the cathodes **108**.

Furthermore, the above Embodiments 1 and 2 and Modifications do not provide a specific example of the appearance of the display device **1**. However, the display device **1** may be formed as a part of a system illustrated in FIG. 18, for example. Note that an organic EL display device does not require a backlight as a liquid crystal display device does, and thus is suitable for thin display devices and has excellent characteristics from the view point of system design.

Also, in the above Embodiments 1 and 2 and Modifications 1 and 2, a so-called line bank structure is adopted for the banks **105**, **105a-105f**, **105x**, **105y**, **305a-305e**, **605**, and **705**, as shown in FIG. 3. However, not limited to this, the structure of pixel bank **805** shown in FIG. 22 may be adopted. In this structure, a display panel **80** includes the pixel bank **805** which is composed of bank elements **805a** and bank elements

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805b, wherein the bank elements **805a** extend in the Y axis direction and the bank elements **805b** extend in the X axis direction.

As shown in FIG. 22, when the structure of pixel bank **805** is adopted, the same advantageous effects as the above ones can be obtained by increasing the inclination angles of the sidewalls of the bank **805** in the X and Y axis directions defining the sub-pixels **800a**, **800b**, and **800c**. More specifically, the above advantageous effects can be obtained by appropriately adjusting the inclination angles of the sidewalls indicated by the arrows **B₁**, **B₂**, **B₃**, and **B₄**.

Also, the inclination angles of the sidewalls of the banks adopted in the above Embodiments 1 and 2 and Modifications 1 and 2 may be individually adjusted depending on the vapor concentration distribution observed in the ink application process and drying process when the organic light-emitting layers are formed in the manufacturing process. For example, if the drying device used in the ink drying process has a structure where the vapor flows from the outer circumference of the panel toward the center of the panel, bank sidewalls where the organic light-emitting layers are large in film thickness may have increased inclination angles. This enables the film thickness of the organic light-emitting layers to be uniform, thereby reducing the unevenness in luminance over the entire panel.

In the above Embodiments 1 and 2 and in Modifications 1 and 2, the inclination angle of bank sidewalls is set in the same manner, without distinction between the luminescent colors (red, green, and blue). However, there may be a case where the organic light-emitting materials of the ink for the respective luminescent colors have different characteristics. In that case, the inclination angles of the bank sidewalls may be defined in accordance with the ink characteristics of each luminescent color.

[Industrial Applicability]

The present invention is useful for providing an organic light-emitting panel and an organic display device that exhibit substantially even luminance and are capable of displaying high-quality images.

REFERENCE SIGNS LIST

1 display device
10, 30, 80 display panel
10a1 light-emitting central area
10a2 light-emitting surrounding area
10b dummy area
20 drive control unit
21-24 drive circuit
25 control circuit
100, 100a-100c, 300a-300c sub-pixel
101 substrate
102 anode
103 electrode coating layer
104 hole injection layer
105, 105a-105d, 105x, 105y, 305a-305e, 605, 705, 805 bank
106, 106a, 106c, 106x, 106y organic light-emitting layer
107 electron injection layer
108 cathode
109 passivation layer
300d, 300e non-light-emitting cell
501-505 mask
1000a-1000c, 3000a-3000c region in which sub-pixel is to be formed

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1050, 1051a, 1051b, 1051e, 1051f bank material layer
1060a-1060c, 1060x, 1060y, 3060a-3060c ink
3000d, 3000e region in which non-light-emitting cell is to be formed

The invention claimed is:

1. An organic light-emitting panel comprising:

an array of a plurality of pixels;

a plurality of light-emitting cells provided in such a manner that each pixel includes three light-emitting cells that are arranged in an alignment and emit light of different colors, the three light-emitting cells including a first light-emitting cell located at an end of the alignment, a second light-emitting cell located at a central portion of the alignment, and a third light-emitting cell located at another end of the alignment, each light-emitting cell including an underlying layer, a first electrode provided in the underlying layer, an organic light-emitting layer, and a second electrode formed on an opposite side of the organic light-emitting layer from the underlying layer, each organic light-emitting layer being formed by applying, for each pixel, three types of ink respectively to the three light-emitting cells in an order of the first light-emitting cell, the second light-emitting cell and the third light-emitting cell, the three types of ink containing different organic light-emitting materials corresponding one-to-one to the different colors of light; and

a plurality of banks which, formed above the underlying layer, define each light-emitting cell by separating the light-emitting cells one from another,

the plurality of pixels including a pixel that is structured such that

two inner sidewalls, which face each other in two adjacent banks defining the first light-emitting cell, have equal inclination angles, and

among two inner sidewalls facing each other in two adjacent banks defining the second light-emitting cell, a sidewall of a bank located on a side of the third light-emitting cell has a larger inclination angle than a sidewall of a bank located on a side of the first light-emitting cell,

wherein the organic light-emitting layer has a uniform film thickness across the organic-light emitting panel.

2. The organic light-emitting panel of claim 1, wherein the plurality of pixels are arranged to be continuously adjacent to each other, and

two inner sidewalls, which face each other in two adjacent banks defining the third light-emitting cell, have equal inclination angles.

3. The organic light-emitting panel of claim 2, wherein the sidewall of the bank located on the side of the first light-emitting cell among the two inner sidewalls facing each other in the two adjacent banks defining the second light-emitting cell, and the two inner sidewalls facing each other in the two adjacent banks defining the first light-emitting cell, have equal inclination angles.

4. The organic light-emitting panel of claim 3, wherein the sidewall of the bank located on the side of the first light-emitting cell among the two inner sidewalls facing each other in the two adjacent banks defining the second light-emitting cell, and the two inner sidewalls facing each other in the two adjacent banks defining the third light-emitting cell, have equal inclination angles.

5. The organic light-emitting panel of claim 4, wherein among the two inner sidewalls facing each other in the two adjacent banks defining the second light-emitting cell, the sidewall of the bank located on the side of the third

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light-emitting cell has an inclination angle of at least 35 degrees and at most 45 degrees,
among the two inner sidewalls facing each other in the two adjacent banks defining the second light-emitting cell, the sidewall of the bank located on the side of the first light-emitting cell has an inclination angle of at least 25 degrees and at most 35 degrees, each of the two inner sidewalls facing each other in the two adjacent banks defining the first light-emitting cell has an inclination angle of at least 25 degrees and at most 35 degrees, and each of the two inner sidewalls facing each other in the two adjacent banks defining the third light-emitting cell has an inclination angle of at least 25 degrees and at most 35 degrees.

6. The organic light-emitting panel of claim 1, wherein a non-light-emitting cell is provided between each pair of adjacent pixels,
a bank is provided between each pair of a pixel and a non-light-emitting cell that are adjacent to each other, the bank separating the pixel from the non-light-emitting cell, and
in each pixel,
among two inner sidewalls facing each other in two adjacent banks defining the third light-emitting cell, a sidewall of a bank located on a side of the non-light-emitting cell has a larger inclination angle than a sidewall of a bank located on a side of the second light-emitting cell.

7. The organic light-emitting panel of claim 6, wherein each non-light-emitting cell includes none of the organic light-emitting layers and includes the second electrode and a third electrode that is made of a same material as the first electrode, the third electrode and the second electrode being electrically connected with each other.

8. The organic light-emitting panel of claim 6, wherein among the two inner sidewalls facing each other in the two adjacent banks defining the second light-emitting cell, the sidewall of the bank located on the side of the third light-emitting cell has a larger inclination angle than the sidewall of the bank located on the side of the first light-emitting cell, and
among the two inner sidewalls facing each other in the two adjacent banks defining the third light-emitting cell, the sidewall of the bank located on the side of the non-light-emitting cell has a larger inclination angle than the sidewall of the bank located on the side of the second light-emitting cell.

9. The organic light-emitting panel of claim 8, wherein the sidewall of the bank located on the side of the third light-emitting cell among the two inner sidewalls facing each other in the two adjacent banks defining the second

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light-emitting cell, and the sidewall of the bank located on the side of the non-light-emitting cell among the inner sidewalls facing each other in the two adjacent banks defining the third light-emitting cell, have equal inclination angles.

10. The organic light-emitting panel of claim 6, wherein the sidewall of the bank located on the side of the first light-emitting cell among the two inner sidewalls facing each other in the two adjacent banks defining the second light-emitting cell, and the two inner sidewalls facing each other in the two adjacent banks defining the first light-emitting cell, have equal inclination angles.

11. The organic light-emitting panel of claim 10, wherein the sidewall of the bank located on the side of the second light-emitting cell among the two inner sidewalls facing each other in the two adjacent banks defining the third light-emitting cell, and the two inner sidewalls facing each other in the two adjacent banks defining the first light-emitting cell, have equal inclination angles.

12. The organic light-emitting panel of claim 11, wherein among the two inner sidewalls facing each other in the two adjacent banks defining the second light-emitting cell, the sidewall of the bank located on the side of the third light-emitting cell has an inclination angle of at least 35 degrees and at most 45 degrees,
among the two inner sidewalls facing each other in the two adjacent banks defining the third light-emitting cell, the sidewall of the bank located on the side of the non-light-emitting cell has an inclination angle of at least 35 degrees and at most 45 degrees,
among the two inner sidewalls facing each other in the two adjacent banks defining the second light-emitting cell, the sidewall of the bank located on the side of the first light-emitting cell has an inclination angle of at least 25 degrees and at most 35 degrees,
among the two inner sidewalls facing each other in the two adjacent banks defining the third light-emitting cell, the sidewall of the bank located on the side of the second light-emitting cell has an inclination angle of at least 25 degrees and at most 35 degrees, and
each of the two inner sidewalls facing each other in the two adjacent banks defining the first light-emitting cell has an inclination angle of at least 25 degrees and at most 35 degrees.

13. The organic light-emitting panel of claim 1, wherein each inclination angle is an angle formed between a sidewall of a bank and a surface of the underlying layer.

14. An organic display device including the organic light-emitting panel defined in claim 1.

* * * * *

专利名称(译)	有机发光面板，其制造方法以及有机显示装置		
公开(公告)号	US8901546	公开(公告)日	2014-12-02
申请号	US13/717930	申请日	2012-12-18
申请(专利权)人(译)	松下电器产业株式会社，		
当前申请(专利权)人(译)	松下电器产业株式会社		
[标]发明人	MATSUSHIMA HIDEAKI		
发明人	MATSUSHIMA, HIDEAKI		
IPC分类号	H01L51/56 H01L51/50 H01L33/08 H01L29/08 H01L51/00 H01L27/32		
CPC分类号	H01L27/3246 H01L51/0005 H01L51/56 H01L51/50 H01L33/08		
代理机构(译)	GREENBLUM与伯恩斯坦，P.L.C.		
其他公开文献	US20130126839A1		
外部链接	Espacenet USPTO		

摘要(译)

面板中的像素包括子像素 100 100 b，并且 100 C 的。子像素 100 a 由银行 105 和 105 b 和 105 c。子像素 100 b 由存储体 105 和 105 C 的。子像素 100 c 由银行 105 和 105 d 的。对于每个像素，有机发光层形成在子像素中，将油墨施加到子像素 100 100 b 和 100 c 并干燥所涂的油墨。关于堤 105 的侧壁 105，侧壁 105 银行 105 b 105 bb，c c c 相等，倾斜角 θ_{cb} 大于倾斜角 θ_{bb} 。

