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(54) **MICRO-LED DISPLAY PANEL AND MANUFACTURING METHOD THEREOF**

(71) Applicant: **PlayNitride Inc.**, Tainan City (TW)

(72) Inventors: **Ying-Tsang Liu**, Tainan City (TW); **Yu-Chu Li**, Tainan City (TW); **Pei-Hsin Chen**, Tainan City (TW); **Yi-Ching Chen**, Tainan City (TW)

(73) Assignee: **PlayNitride Inc.**, Tainan City (TW)

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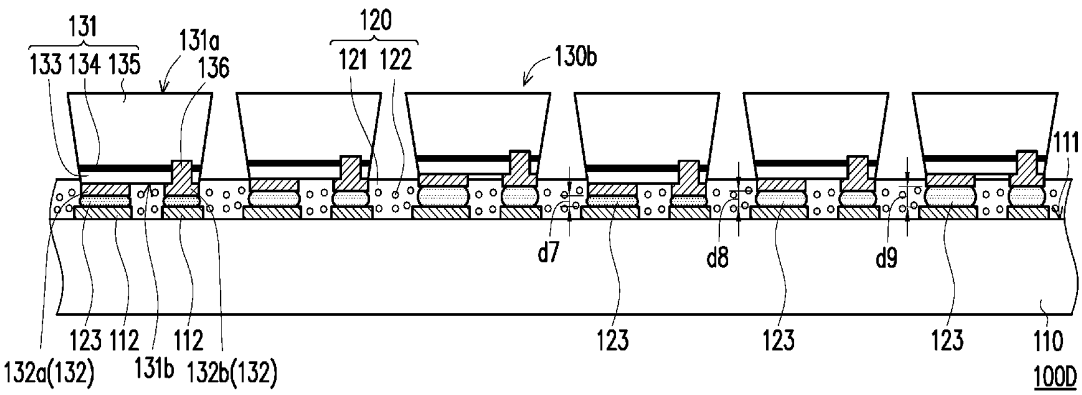
(57) **ABSTRACT**

A micro-LED display panel including a substrate, an anisotropic conductive film, and a plurality of micro-LEDs is provided. The anisotropic conductive film is disposed on the substrate. The micro-LEDs and the anisotropic conductive film are disposed at the same side of the substrate, and the micro-LEDs are electrically connected to the substrate through the anisotropic conductive film. Each of the micro-LEDs includes an epitaxial layer and an electrode layer electrically connected to the epitaxial layer, and the electrode layers comprises a first electrode and a second electrode which are located between the substrate and the corresponding epitaxial layer. A ratio of a thickness of each of the electrode layers to a thickness of the corresponding epitaxial layer ranges from 0.1 to 0.5, and a gap between the first electrode and the second electrode of each of the micro-LEDs is in a range of 1 μm to 30 μm.



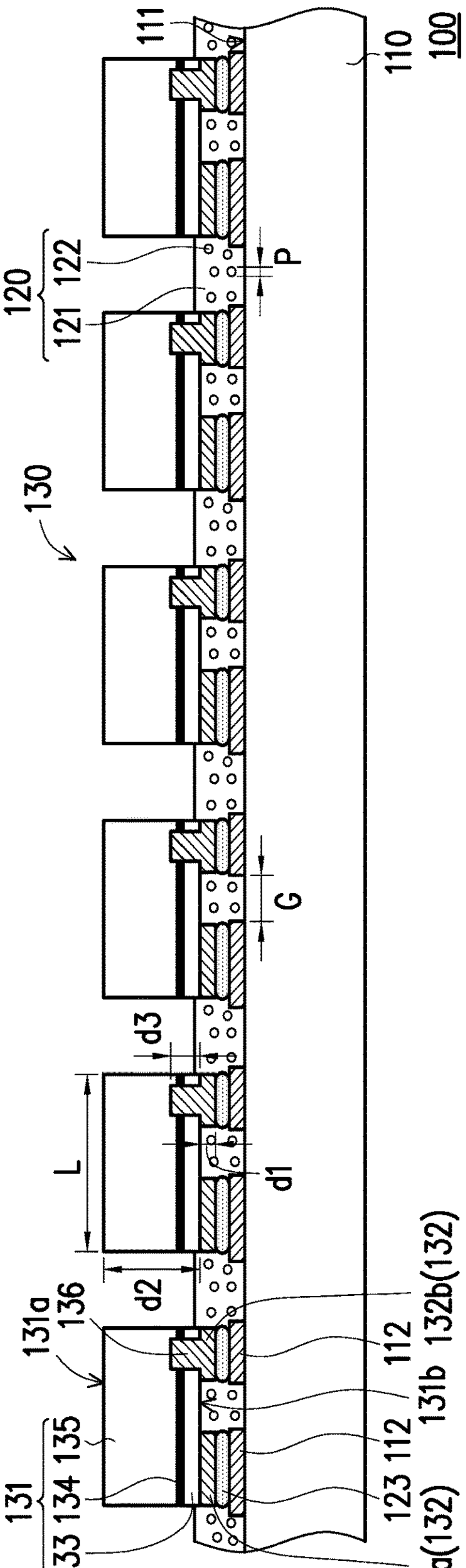

111
110
100
120
121
122
P
130
G
d3
L
d1
d2
131a
136
131
133
134
135
112
131b
112
123
132a(132)
132b(132)

FIG. 1A

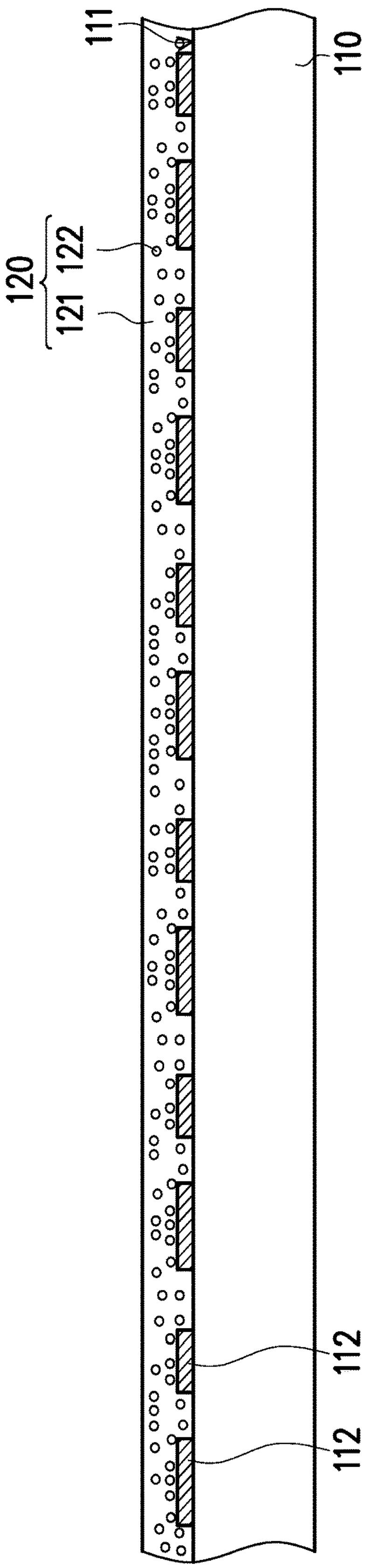

111
110
120
121
122
112
112

FIG. 1B

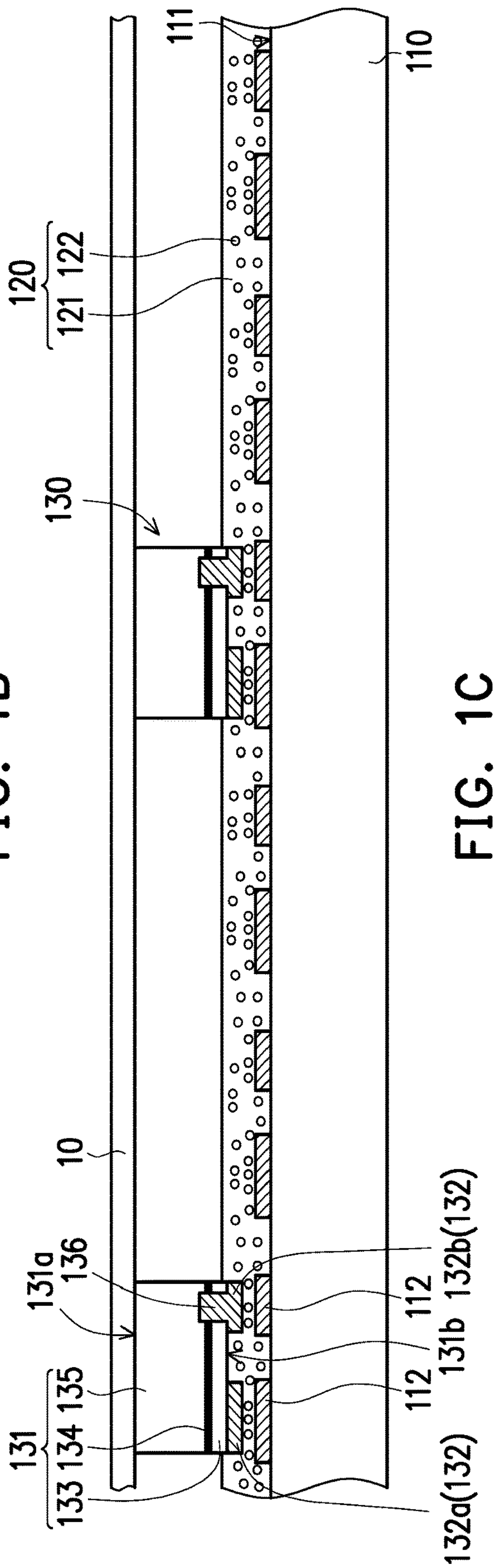

111
110
120
121
122
130
10
131a
136
132b(132)
112
131b
112
131
133
134
135
132a(132)

FIG. 1C

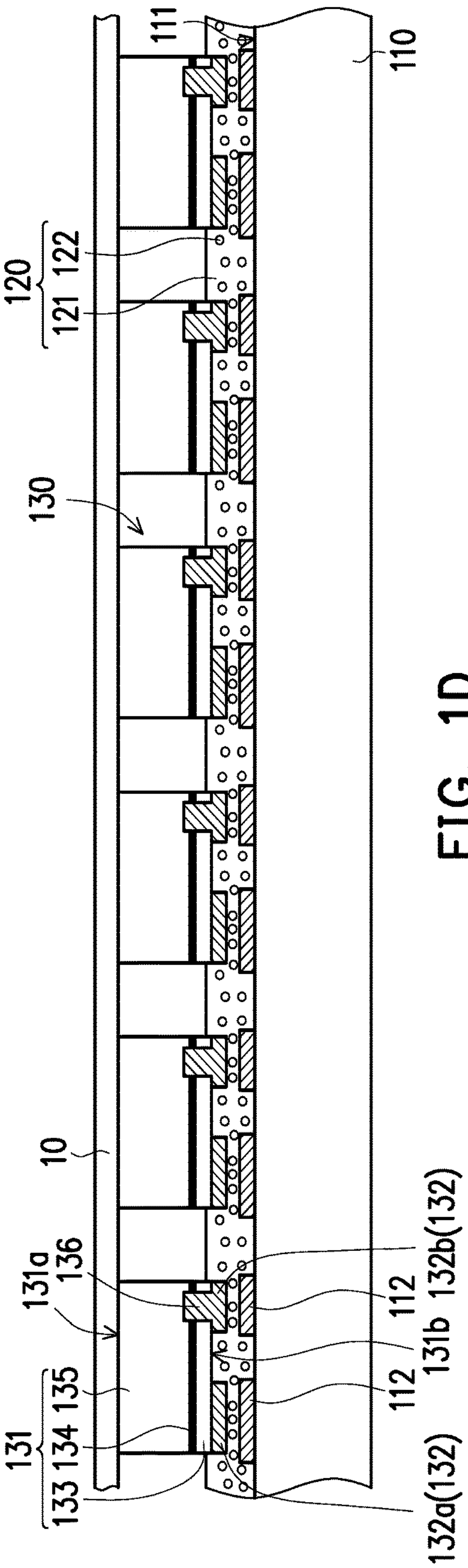

111
110
120
121
122
130
10
131a
136
131
133
134
135
131b
112
132b(132)
112
132a(132)

FIG. 1D

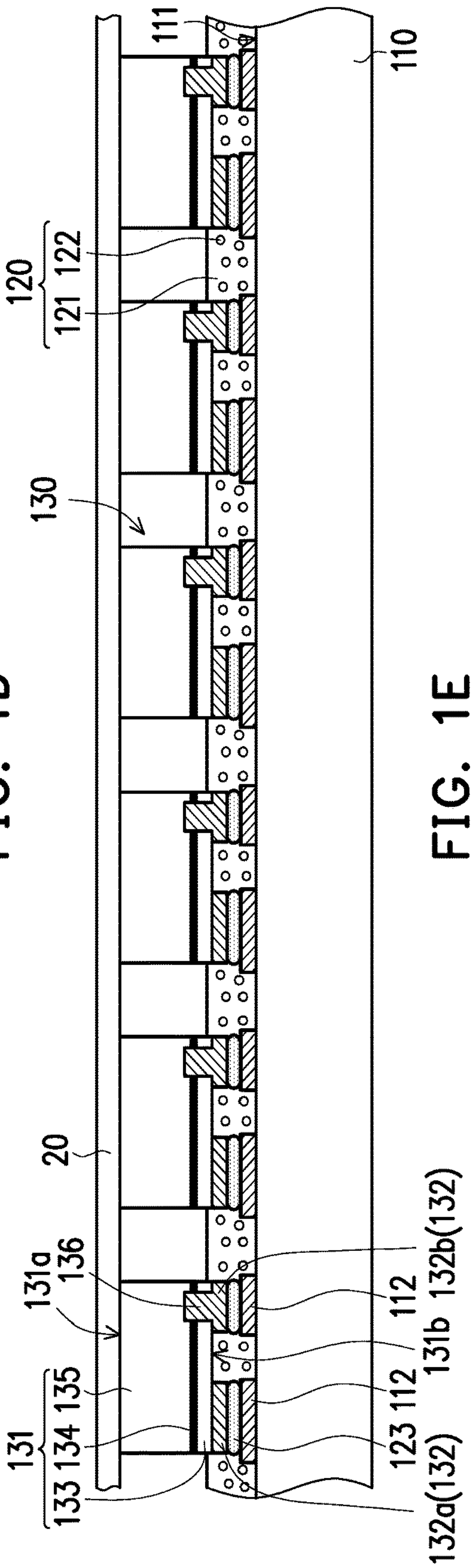

111
110
120
121
122
130
20
131a
136
131
133
134
135
131b
112
132b(132)
112
123
132a(132)

FIG. 1E

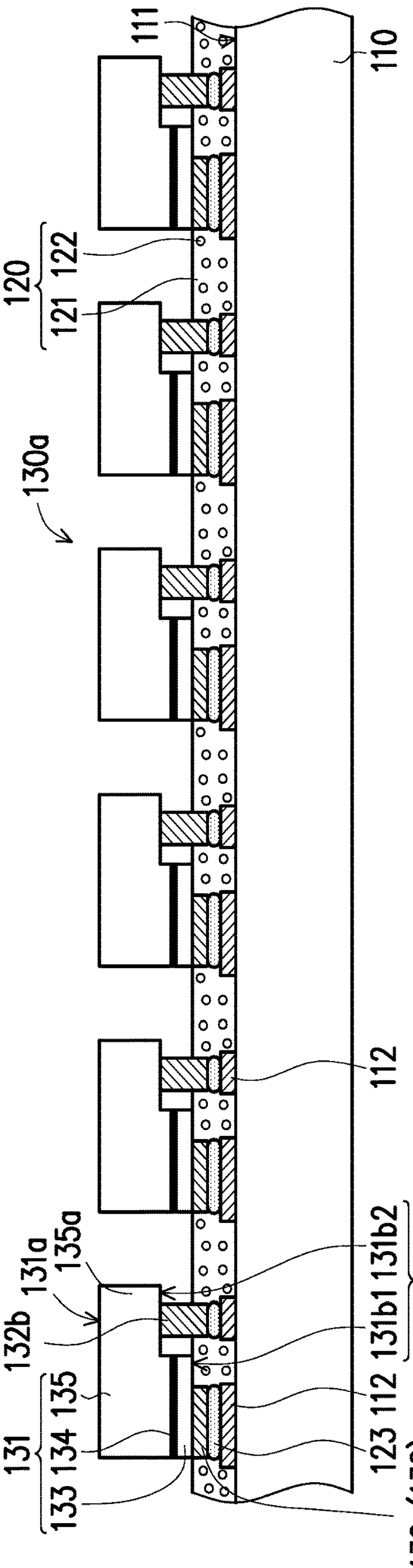

111
110
100A
120
121
122
130a
112
131
133
134
135
132b
131a
135a
123
112
131b1
131b2
131b
132a(132)

FIG. 2

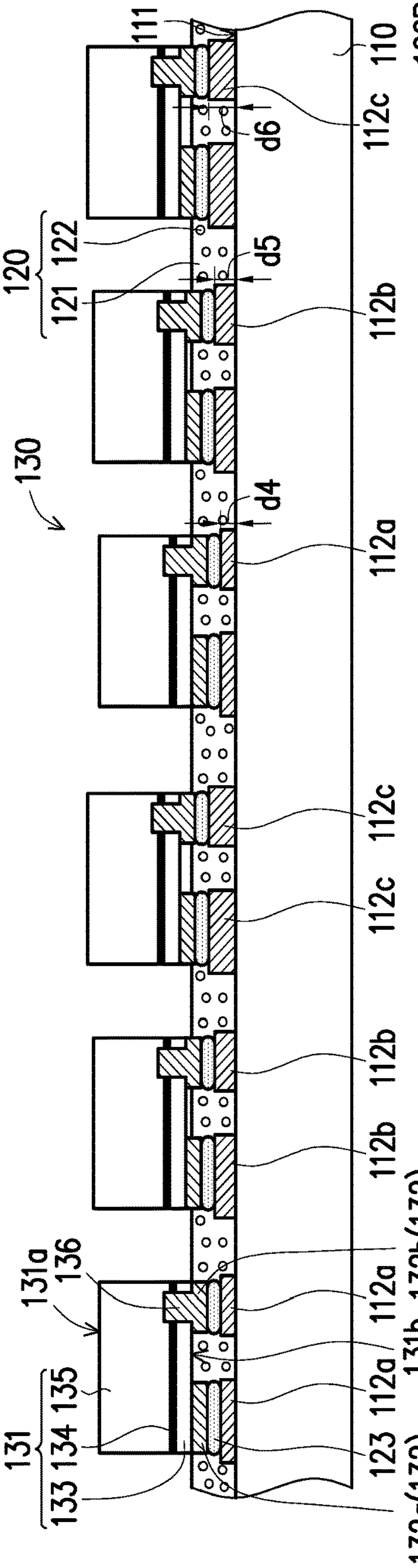
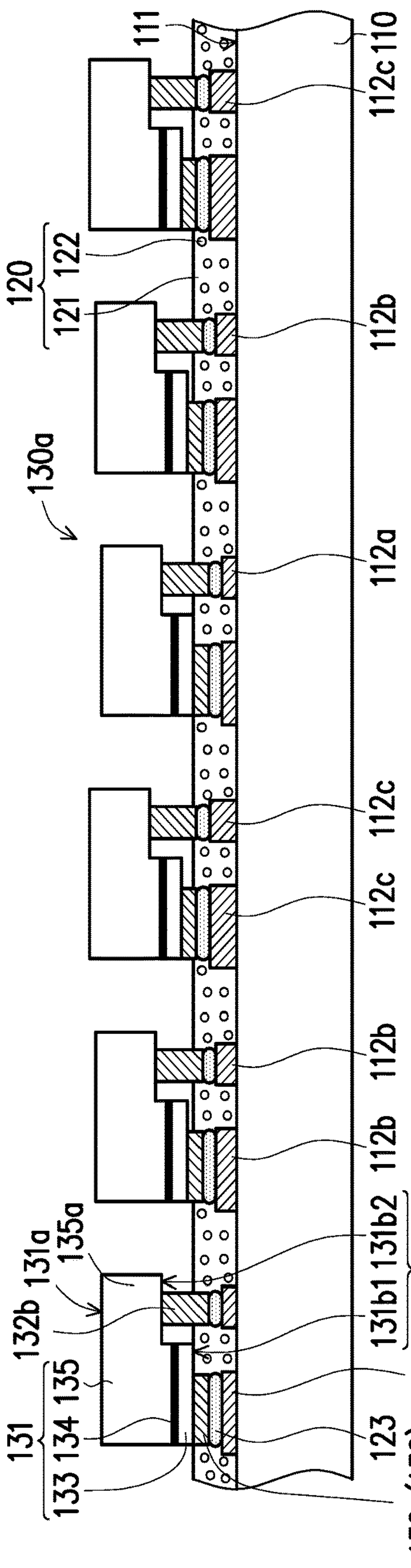
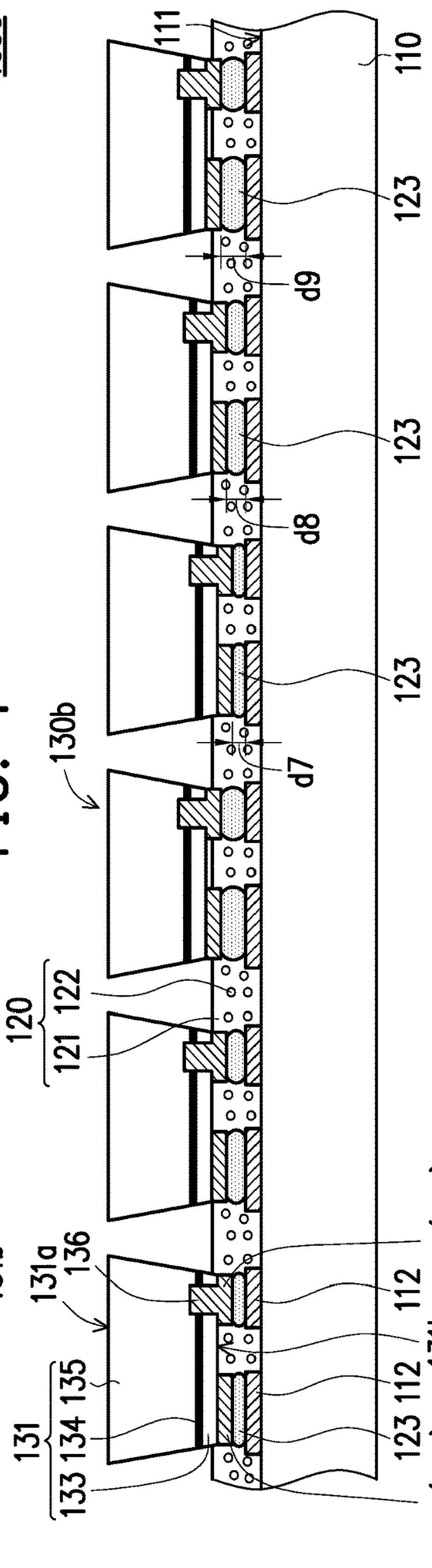

111
110
100B
112c
d6
120
121
122
d5
112b
130
d4
112a
112c
112c
112b
112b
131
133
134
135
131a
136
123
112a
131b
112a
132b(132)
132a(132)

FIG. 3



111
110
112c
100C
120
121
122
112b
130a
112a
112c
112c
112b
112b
131
133
134
135
132b
131a
135a
131b1
131b2
131b
112a
123
132a(132)

FIG. 4



111
110
100D
123
d9
123
d8
123
130b
d7
120
121
122
131
133
134
135
131a
136
112
132b(132)
131b
112
123
132a(132)

FIG. 5

MICRO-LED DISPLAY PANEL AND MANUFACTURING METHOD THEREOF

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the priority benefit of Taiwan application serial no. 106137561, filed on Oct. 31, 2017. The entirety of the above-mentioned patent application is hereby incorporated by reference herein and made a part of this specification.

BACKGROUND OF THE INVENTION

Field of the Invention

[0002] The invention relates to a display panel and a manufacturing method thereof, and more particularly relates to a micro-LED (light-emitting diode) display panel and a manufacturing method thereof.

Description of Related Art

[0003] Micro-LED displays have advantages not only in low power consumption, high brightness, high color saturation, fast response, and power saving, but also in material stability and image sticking. Therefore, the development of the display technology of micro-LED displays has drawn much attention.

[0004] In terms of the manufacturing process, in the process of transferring micro-LEDs from a growth substrate to a driving circuit substrate, it is required to apply heat and pressure to the micro-LEDs, so as to electrically bond the micro-LEDs to the driving circuit substrate. However, in the transfer process, the micro-LEDs may be damaged easily or even break, which impairs the reliability of the micro-LED display obtained in the subsequent processes.

SUMMARY OF THE INVENTION

[0005] The invention provides a micro-LED display panel having good reliability.

[0006] The invention provides a manufacturing method of a micro-LED display panel for improving product reliability.

[0007] A micro-LED display panel according to an embodiment of the invention includes a substrate, an anisotropic conductive film, and a plurality of micro-LEDs. The anisotropic conductive film is disposed on the substrate. The micro-LEDs and the anisotropic conductive film are disposed at the same side of the substrate, and the micro-LEDs are electrically connected to the substrate via the anisotropic conductive film, wherein each of the micro-LEDs includes an epitaxial layer and an electrode layer electrically connected to the epitaxial layer, and the electrode layer comprises a first electrode and a second electrode which are located between the substrate and the epitaxial layer, wherein a ratio of a thickness of each of the electrode layers to a thickness of the corresponding epitaxial layer is in a range of 0.1 to 0.5. A gap between the first electrode and the second electrode of each of the micro-LEDs is in a range of 1 μm to 30 μm.

[0008] In an embodiment of the invention, each of the epitaxial layers has a first surface and a second surface opposite to each other, each of the first electrodes and each of the second electrodes are disposed on the corresponding second surface, and each of the second surfaces faces the anisotropic conductive film.

[0009] In an embodiment of the invention, a part of the second surface of each of the micro-LEDs is adjacent to the anisotropic conductive film.

[0010] In an embodiment of the invention, a part of the second surface of each of the micro-LEDs contacts the anisotropic conductive film.

[0011] In an embodiment of the invention, each of the epitaxial layers includes a first type semiconductor layer, a light emitting layer and a second type semiconductor layer, wherein the first type semiconductor layer and the second type semiconductor layer are located at two opposite sides of the light emitting layer, and the light emitting layer connects the first type semiconductor layer and the second type semiconductor layer, wherein each of the first type semiconductor layers has the second surface. Each of the first electrodes is electrically contacted with the corresponding second surface, and each of the second electrodes is electrically contacted with the corresponding second type semiconductor layer via a conductive hole and electrically isolated to the corresponding first type semiconductor layer.

[0012] In an embodiment of the invention, a ratio of a depth of one of the conductive holes to the thickness of the corresponding epitaxial layer is in a range of 0.15 to 0.35.

[0013] In an embodiment of the invention, a side length of each of the micro-LEDs is in a range of 3 μm to 100 μm.

[0014] In an embodiment of the invention, a ratio of the gap between the first electrode and the second electrode of each of the micro-LEDs to the side length of the micro-LED is in a range of 0.1 to 0.25.

[0015] In an embodiment of the invention, each of the epitaxial layers comprises a first type semiconductor layer, a second type semiconductor layer, and a light emitting layer connected to and disposed between the first type semiconductor layer and the second type semiconductor layer, wherein the second type semiconductor layer extends beyond the light emitting layer and the first type semiconductor layer in one of the micro-LEDs, the second surface has a first sub-surface and a second sub-surface separated from each other, the first type semiconductor layer has the first sub-surface, and an end of the second type semiconductor layer has the second sub-surface, wherein in one of the micro-LEDs, the first electrode is electrically contacted with the first sub-surface, and the second electrode is electrically contacted with the second sub-surface.

[0016] In an embodiment of the invention, the substrate includes a plurality of pads, and the anisotropic conductive film covers the pads, and the electrode layers are electrically bonded to the pads respectively.

[0017] In an embodiment of the invention, at least one of the pads has a first thickness and at least another one of the pads has a second thickness, and the second thickness is greater than the first thickness.

[0018] In an embodiment of the invention, the anisotropic conductive film comprises an insulation film and a plurality of conductive particles dispersed in the insulation film, wherein a particle size of each of the conductive particles is smaller than the gap between the first electrode and the second electrode of one of the micro-LEDs, and a plurality of bonding layers are formed between the electrode layers and the pads and electrically connect the electrode layers and the pads respectively.

[0019] In an embodiment of the invention, at least one of the bonding layers has a first transmittance and at least another one of the bonding layers has a second transmittance, and the second transmittance is greater than the first transmittance.

[0020] In an embodiment of the invention, at least one of the bonding layers has a first thickness and at least another one of the bonding layers has a second thickness, and the second thickness is greater than the first thickness.

[0021] In an embodiment of the invention, the anisotropic conductive film includes an insulation film and a plurality of conductive particles dispersed in the insulation film, and a ratio of a particle size of each of the conductive particles to a side length of each of the micro-LEDs is in a range of 0.1 to 0.2.

[0022] In an embodiment of the invention, the anisotropic conductive film comprises an insulation film and a plurality of conductive particles dispersed in the insulation film, and a particle size of each of the conductive particles is smaller than the gap between the first electrode and the second electrode of each of the micro-LEDs.

[0023] In an embodiment of the invention, a distance between one of the micro-LEDs and the substrate is different from a distance between another one of the micro-LEDs and the substrate.

[0024] A manufacturing method of a micro-LED display panel according to an embodiment of the invention includes the following: a step (A) of providing a substrate with an anisotropic conductive film; a step (B) of transferring a plurality of micro-LEDs to the substrate and disposing the micro-LEDs on the anisotropic conductive film; a step (C) of repeating the step (B) to dispose a required number of the micro-LEDs on the substrate; and a step (D) of processing by heating and pressuring to electrically bond the micro-LEDs to the substrate.

[0025] In an embodiment of the invention, in the step (B), the micro-LEDs are aligned with a plurality of pads of the substrate respectively.

[0026] In an embodiment of the invention, in the step (D), a bonding layer is formed between one of the micro-LEDs and one of the pads to electrically connect the one of the micro-LEDs and the substrate.

[0027] Based on the above, the micro-LEDs in the micro-LED display panel according to one or some embodiments of the invention are electrically connected to the substrate via the anisotropic conductive film. The anisotropic conductive film may serve as a buffer and therefore is capable of preventing damage or breakage of the micro-LEDs under heat and pressure, and thereby improving the reliability of the micro-LED display panel. In other words, the micro-LED display panel obtained by the manufacturing method of one or some embodiments of the invention has good reliability.

[0028] To make the aforementioned and other features and advantages of the invention more comprehensible, several embodiments accompanied with drawings are described in detail as follows.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029] The accompanying drawings are included to provide a further understanding of the invention, and are incorporated in and constitute a part of this specification. The drawings illustrate exemplary embodiments of the invention and, together with the description, serve to explain the principles of the invention.

[0030] FIG. **1**A is a partial cross-sectional diagram of a micro-LED display panel according to the first embodiment of the invention.

[0031] FIG. **1**B to FIG. **1**E are partial cross-sectional diagrams showing a manufacturing process of the micro-LED display panel according to the first embodiment of the invention.

[0032] FIG. **2** is a partial cross-sectional diagram of a micro-LED display panel according to the second embodiment of the invention.

[0033] FIG. **3** is a partial cross-sectional diagram of a micro-LED display panel according to the third embodiment of the invention.

[0034] FIG. **4** is a partial cross-sectional diagram of a micro-LED display panel according to the fourth embodiment of the invention.

[0035] FIG. **5** is a partial cross-sectional diagram of a micro-LED display panel according to the fifth embodiment of the invention.

DESCRIPTION OF THE EMBODIMENTS

[0036] FIG. **1**A is a partial cross-sectional diagram of a micro-LED display panel according to the first embodiment of the invention. Referring to FIG. **1**, in this embodiment, a micro-LED display panel **100** includes a substrate **110**, an anisotropic conductive film **120**, and a plurality of micro-LEDs **130**, wherein the substrate **110** may be a driving circuit substrate, and a driving circuit (not shown) and a plurality of pads **112** electrically connected to the driving circuit (not shown) are disposed on a surface **111** of the substrate **110**.

[0037] The anisotropic conductive film **120** is disposed at a side of the substrate **110**. That is, the anisotropic conductive film **120** is disposed on the surface **111** of the substrate **110** and covers the pads **112**. The anisotropic conductive film **120** includes an insulation film **121** and a plurality of conductive particles **122**, wherein the insulation film **120** may be formed of a resin, and the conductive particles **122** are dispersed in the insulation film **121**. The micro-LEDs **130** and the anisotropic conductive film **120** are disposed at the same side of the substrate **110**. That is, the micro-LEDs **130** and the anisotropic conductive film **120** are both disposed on the surface **111**. Based on the properties that the anisotropic conductive film **120** is electrically conductive in a direction perpendicular to the surface **111** and electrically insulative in a direction parallel to the surface **111**, the micro-LEDs **130** may be electrically connected to the substrate **110** via the anisotropic conductive film **120**, and the micro-LEDs **130** arranged side by side on the surface **111** of the substrate **110** are not electrically conducted with each other to cause a short circuit.

[0038] In this embodiment, each micro-LED **130** includes an epitaxial layer **131** and an electrode layer **132** electrically connected to the epitaxial layer **131**, and each electrode layer **132** is located between the substrate **110** and the corresponding epitaxial layer **131**. As shown in FIG. **1**A, each epitaxial layer **131** and the substrate **110** are located at two opposite sides of the anisotropic conductive film **120**, and the anisotropic conductive film **120** covers the electrode layer **132**. For example, the anisotropic conductive film **120** may completely cover the electrode layer **132** or partially cover the electrode layer **132**, and the invention is not intended to limit how the anisotropic conductive film **120** covers the electrode layer **132**.

[0039] Furthermore, each micro-LED 130 is correspondingly bonded to a pair of pads 112, and each epitaxial layer 131 is aligned with the corresponding pair of pads 112 via the corresponding electrode layer 132, such that the corresponding electrode layer 132 is embedded in the anisotropic conductive film 120. After the electrode layer 132 of each epitaxial layer 131 is electrically conducted with (or electrically bonded to) the corresponding pair of pads 112, each epitaxial layer 131 is electrically connected to the substrate 110. In addition, a ratio of a thickness d1 of each electrode layer 132 to a thickness d2 of the corresponding epitaxial layer 131 is in a range of 0.1 to 0.5. If the thickness d1 of each electrode layer 132 is overly large, the gap between each epitaxial layer 131 and the substrate 110 is increased, and the structural strength of each micro-LED 130 is reduced. On the other hand, if the thickness d1 of each electrode layer 132 is overly small, poor electrical conduction or uneven current distribution may occur.

[0040] In this embodiment, each electrode layer 132 includes a first electrode 132*a* and a second electrode 132*b*, and each epitaxial layer 131 has a first surface 131*a* and a second surface 131*b* opposite to each other. As shown in FIG. 1A, each first electrode 132*a* and each second electrode 132*b* (or referred to as the first electrode 132*a* and the second electrode 132*b* disposed in pair) are disposed on the corresponding second surface 131*b*. The first electrode 132*a* of the first electrode 132*a* and the second electrode 132*b* disposed in pair is connected to one pad 112 of the corresponding pair of pads 112, and the second electrode 132*b* of the first electrode 132*a* and the second electrode 132*b* disposed in pair is connected to the other pad 112 of the corresponding pair of pads 112. Each second surface 131*b* faces and contacts the anisotropic conductive film 120 (or faces the surface 111 of the substrate 110), such that each first electrode 132*a* and each second electrode 132*b* are embedded in the anisotropic conductive film 120. In other words, each first surface 131*a* faces away from the anisotropic conductive film 120 (or faces away from the surface 111 of the substrate 110).

[0041] In addition, each epitaxial layer 131 includes a first type semiconductor layer 133, a light emitting layer 134, and a second type semiconductor layer 135, wherein each first type semiconductor layer 133 and the corresponding second type semiconductor layer 135 are located at two opposite sides of the corresponding light emitting layer 134, and each light emitting layer 134 connects the corresponding first type semiconductor layer 133 and the corresponding second type semiconductor layer 135. Furthermore, each first type semiconductor layer 133 has the second surface 131*b*. Each first electrode 132*a* is electrically contacted with the corresponding second surface 131*b*, and each second electrode 132*b* is electrically contacted with the corresponding second type semiconductor layer 135 via a conductive hole 136 and electrically isolated to the corresponding first type semiconductor layer 133. For example, the anisotropic conductive film 120 may further cover a side surface of the first type semiconductor layer 133, but the invention is not limited thereto. In other embodiments, the anisotropic conductive film may completely cover the electrode layer, and a top surface of the anisotropic conductive film is flush with the second surface (i.e., the surface that faces the substrate) of each first type semiconductor layer, for example, or the top surface of the anisotropic conductive film is separated from the second surface (i.e., the surface that faces the substrate) of each first type semiconductor layer by a distance and partially covers the electrode layer.

[0042] In this embodiment, a ratio of a depth d3 of each conductive hole 136 to the thickness d2 of the corresponding epitaxial layer 131 is in a range of 0.15 to 0.35, wherein the depth d3 of each conductive hole 136 is calculated from the second surface 131*b* of the corresponding first type semiconductor layer 133 to an end of each conductive hole 136 that penetrates the corresponding second type semiconductor layer 135. If the depth d3 of each conductive hole 136 is overly small, the current distribution becomes uneven and the current does not flow from the second electrode 132*b* to the second type semiconductor layer 135 easily. On the other hand, if the depth d3 of each conductive hole 136 is overly large, the epitaxial layer 131 may break easily under pressure.

[0043] In this embodiment, a side length L of each micro-LED 130 is in a range of 3 μm to 100 μm, and a gap G between the first electrode 132*a* and the second electrode 132*b* of each micro-LED 130 is in a range of 1 μm to 30 μm. Furthermore, a ratio of the gap G between the first electrode 132*a* and the second electrode 132*b* of each micro-LED 130 to the side length L of the corresponding micro-LED 130 is in a range of 0.1 to 0.25. If the gap G is overly small, a short circuit may occur between the first electrode 132*a* and the second electrode 132*b* of each micro-LED 130 due to bonding of the conductive particles 122. If the gap G is overly large, the area of the first electrode 132*a* and the area of the second electrode 132*b* of each micro-LED 130 are reduced, which makes it difficult to align the first electrode 132*a* and the second electrode 132*b* of each micro-LED 130 with the corresponding pair of pads 112 and results in drop of the bonding yield between the first electrode 132*a* and the second electrode 132*b* of each micro-LED and the corresponding pair of pads 112.

[0044] Furthermore, a particle size P of each conductive particle 122 is smaller than the gap G between the first electrode 132*a* and the second electrode 132*b* of each micro-LED 130, and when the anisotropic conductive film 120 is under pressure, a portion of the conductive particles 122 in the insulation film 121 between each electrode layer 132 and the corresponding pair of pads 112 form a bonding layer 123, wherein each bonding layer 123 is configured to electrically connect the corresponding electrode layer 132 and one pair of pads 112. In addition, a ratio of the particle size P of each conductive particle 122 to the side length L of each micro-LED 130 is in a range of 0.1 to 0.2.

[0045] Under the circumstances that the particle size P of each conductive particle 122 is smaller than the gap G between the first electrode 132*a* and the second electrode 132*b* of each micro-LED 130, and the ratio of the particle size P of each conductive particle 122 to the side length L of each micro-LED 130 is in a range of 0.1 to 0.2, electrical conduction between each electrode layer 132 and the corresponding pair of pads 112 in the direction perpendicular to the surface 111 may be ensured, and a short circuit between the first electrode 132*a* and the second electrode 132*b* of each micro-LED 130 due to bonding of the conductive particles 122 may be prevented (that is, the conductive particles 122 located between the first electrode 132*a* and the second electrode 132*b* of each micro-LED 130 do not cause electrical conduction between the first electrode 132*a* and the second electrode 132*b* in the direction parallel to the surface 111).

[0046] Referring to FIG. 1A again, in this embodiment, the micro-LEDs **130** may include red light micro-LEDs, green light micro-LEDs, and blue light micro-LEDs, wherein the red light micro-LEDs, the green light micro-LEDs, and the blue light micro-LEDs may be arranged repeatedly in this order along the direction parallel to the surface **111** of the substrate **110**. However, the order of the red light micro-LEDs, the green light micro-LEDs, and the blue light micro-LEDs is not limited to the above and may be adjusted according to the requirements of the design.

[0047] In the process of transferring the red light micro-LEDs, the green light micro-LEDs, and the blue light micro-LEDs in batches to the substrate **110**, and applying heat and pressure to the red light micro-LEDs, the green light micro-LEDs, and the blue light micro-LEDs transferred to the substrate **110** and the anisotropic conductive film **120** on the substrate **110**, the insulation film **121** is cured by the heat, so as to fix the red light micro-LEDs, the green light micro-LEDs, and the blue light micro-LEDs to the substrate **110**, and the pressure causes a portion of the conductive particles **122** in the insulation film **121** to form the bonding layer **123**, so as to electrically connect the red light micro-LEDs, the green light micro-LEDs, and the blue light micro-LEDs to the substrate **110**.

[0048] In the process of applying the heat and pressure to the red light micro-LEDs, the green light micro-LEDs, and the blue light micro-LEDs, the anisotropic conductive film **120** may serve as a buffer and therefore is capable of preventing damage or breakage of the red light micro-LEDs, the green light micro-LEDs, and the blue light micro-LEDs, and thereby improving the reliability of the micro-LED display panel **100**. Since the red light micro-LEDs, the green light micro-LEDs, and the blue light micro-LEDs are transferred to the substrate **110** in batches, the micro-LEDs **130** that are transferred to the substrate **110** first are pressed most and the bonding layer **123** under the micro-LEDs **130** that are pressed most has the lowest transmittance. That is, the conductive particles **122** under the micro-LEDs **130** that are pressed most are pressed most closely.

[0049] For example, the bonding layer **123** for electrically bonding the red light micro-LEDs and the substrate **110** has a first transmittance, the bonding layer **123** for electrically bonding the green light micro-LEDs and the substrate **110** has a second transmittance, and the bonding layer **123** for electrically bonding the blue light micro-LEDs and the substrate **110** has a third transmittance. If the red light micro-LEDs are pressed most, the green light micro-LEDs are pressed second most, and the blue light micro-LEDs are pressed least, the third transmittance is greater than the second transmittance, and the second transmittance is greater than the first transmittance. On the other hand, the electrical conductivity of the bonding layer **123** having the greater transmittance is lower than the electrical conductivity of the bonding layer **123** having the smaller transmittance.

[0050] Several processes for transferring the micro-LEDs **130** to the substrate **110** and electrically connecting the micro-LEDs **130** to the substrate **110** are described hereinafter as examples.

[0051] FIG. 1B to FIG. 1E are partial cross-sectional diagrams showing a manufacturing process of the micro-LED display panel according to the first embodiment of the invention. Take the first manufacturing process as an example, referring to FIG. 1B, first, Step (A) is performed to provide the substrate **110** with the anisotropic conductive film **120** disposed thereon, wherein the anisotropic conductive film **120** covers the surface **111** of the substrate **110** and the pads **112** located on the surface **111**. Next, referring to FIG. 1C, Step (B) is performed to transfer the micro-LEDs **130** on one growth substrate (not shown, referred to as first growth substrate hereinafter) to the substrate **110** via a transfer component **10** and dispose the micro-LEDs **130** on the anisotropic conductive film **120**. At this time, the electrode layers **132** of the micro-LEDs **130** are disposed to be aligned with the pads **112** on the substrate **110**, and the micro-LEDs **130** are embedded in the anisotropic conductive film **120** to be pre-fixed to the substrate **110** by adhesion, and then the transfer component **10** is removed. In another embodiment, the micro-LEDs **130** may not be embedded in the anisotropic conductive film **120** and may be attached to a surface of the anisotropic conductive film **120**. Then, Step (C) is performed, referring to FIG. 1D. That is, Step (B) is repeated to transfer the micro-LEDs **130** on another growth substrate (not shown) to the substrate **110**, or transfer other micro-LEDs **130** on the first growth substrate (not shown), which have not been transferred, to the substrate **110**, so as to dispose a required number of micro-LEDs **130** on the substrate **110**.

[0052] After transferring all the micro-LEDs **130** required for the substrate **110**, Step (D) is performed, referring to FIG. 1E, to apply heat and pressure to the micro-LEDs **130** on the anisotropic conductive film **120** via a heating and pressurizing component **20**, such that the anisotropic conductive film **120** between each electrode layer and the corresponding pair of pads **112** forms the bonding layer **123**, so as to electrically connect each electrode layer and the corresponding pair of pads **112**. For example, in Step (D), the value of the pressure applied is about 5 MPa to 40 MPa, the value of the temperature applied is about 100° C. to 200° C., and the time of applying the heat and pressure is about 0.5 seconds to 2 seconds. The heat and pressure may break the conductive particles **122** in the anisotropic conductive film **120** to form the vertically conductive bonding layer **123**. At last, the micro-LED display panel **100** as shown in FIG. 1A is obtained. Since the micro-LEDs **130** and the substrate **110** are electrically connected, the micro-LEDs **130** may be controlled by the substrate **110** to emit light, so as to display images. It should be noted that the heating and pressurizing component **20** and the transfer component **10** may be the same device, but in this embodiment, the heating and pressurizing component **20** and the transfer component **10** are different machines.

[0053] In addition, the second bonding process is provided as an example. First, the substrate **110** with the anisotropic conductive film **120** disposed thereon is provided, and then the micro-LEDs **130** on one growth substrate (not shown, referred to as first growth substrate hereinafter) are transferred to the substrate **110** with the anisotropic conductive film **120** disposed thereon via the transfer component (not shown). Specifically, the electrode layers **132** of the micro-LEDs **130** on the transfer component (not shown) are disposed to be aligned with the pads **112** on the substrate **110**, and heat and pressure are applied to the micro-LEDs **130** transferred to the substrate **110** and the anisotropic conductive film **120** disposed on the substrate **110**, so as to electrically connect the micro-LEDs **130** and the substrate **110**. Thereafter, the steps described above are repeated to transfer the micro-LEDs **130** on another growth substrate (not shown) to the substrate **110** with the anisotropic conductive film **120** disposed thereon, or transfer other micro-LEDs **130** on the first growth substrate (not shown), which have not been transferred, to the substrate **110** with the anisotropic conductive film **120** disposed thereon, and then the step of applying heat and pressure is performed to electrically connect the micro-LEDs **130** and the substrate **110**.

[0054] Take the third manufacturing process as an example, the micro-LEDs **130** on one growth substrate (not shown, referred to as first growth substrate hereinafter) are transferred to a temporary carrier (not shown) via the transfer component (not shown). Then, the steps described above are repeated to transfer the micro-LEDs **130** on another growth substrate (not shown) to the temporary carrier (not shown) or transfer other micro-LEDs **130** on the first growth substrate (not shown), which have not been transferred, to the temporary carrier (not shown). After completing the step of transferring the micro-LEDs **130** on multiple growth substrates (not shown) to the temporary carrier (not shown), the micro-LEDs **130** on the temporary carrier (not shown) are transferred to the substrate **110** with the anisotropic conductive film **120** disposed thereon. After aligning the electrode layers **132** of the micro-LEDs **130** with the pads **112** on the substrate **110**, the step of applying heat and pressure is performed to electrically connect the micro-LEDs **130** and the substrate **110**.

[0055] Provided below are some other exemplary embodiments. It should be noted that reference numerals and some descriptions provided in the previous embodiment also apply to the following embodiment. The same reference numerals are presented to denote identical or similar components in the embodiments, and repetitive descriptions are omitted. The omitted descriptions may be found in the previous exemplary embodiment, and thus will not be repeated hereinafter.

[0056] FIG. **2** is a partial cross-sectional diagram of a micro-LED display panel according to the second embodiment of the invention. Referring to FIG. **2**, a micro-LED display panel **100**A of this embodiment is similar to the micro-LED display panel **100** of the first embodiment, and a main difference lies in that: an end **135***a* of the second type semiconductor layer **135** of each micro-LED **130***a* extends beyond the corresponding light emitting layer **134** and the corresponding first type semiconductor layer **133**, wherein the second surface **131***b* of each epitaxial layer **131** has a first sub-surface **131***b* **1** and a second sub-surface **131***b***2** separated from each other, and a height difference exists between each first sub-surface **131***b***1** and the corresponding second sub-surface **131***b***2**. Furthermore, the first sub-surface **131***b***1** and the second sub-surface **131***b***2** both face the surface **111** of the substrate **110**.

[0057] As shown in FIG. **2**, each first sub-surface **131***b***1** is closer to the surface **111** of the substrate **110** than the corresponding second sub-surface **131***b***2**. Furthermore, each first type semiconductor layer **133** has the first sub-surface **131***b***1**, and the end **135***a* of each second type semiconductor layer **135** has the second sub-surface **131***b***2**, wherein each first electrode **132***a* is electrically contacted with the corresponding first sub-surface **131***b***1**, and each second electrode **132***b* is electrically contacted with the corresponding second sub-surface **131***b***2**. In this embodiment, each second electrode **132***b* may be a columnar conductive pattern (e.g., a conductive pillar), wherein each second electrode **132***b* is partially embedded in the anisotropic conductive film **120**, and a gap is formed between each second sub-surface **131***b***2** and the anisotropic conductive film **120**. That is, the second sub-surface **131***b***2** is not contacted with the anisotropic conductive film **120**.

[0058] FIG. **3** is a partial cross-sectional diagram of a micro-LED display panel according to the third embodiment of the invention. Referring to FIG. **3**, a difference between a micro-LED display panel **100**B of this embodiment and the micro-LED display panel **100** of the first embodiment lies in that: in this embodiment, a pair of pads **112***a* having a first thickness d**4**, a pair of pads **112***b* having a second thickness d**5**, and a pair of pads **112***c* having a third thickness d**6** are arranged repeatedly in this order on the surface **111** of the substrate **110**, wherein the first thickness d**4** is smaller than the second thickness d**5**, and the second thickness d**5** is smaller than the third thickness d**6**. Based on the thickness design of the pairs of pads **112***a* to **112***c*, the micro-LEDs **130** that are transferred to the substrate **110** first are bonded to one pair of pads having the smaller thickness, and when other micro-LEDs **130** are transferred to the substrate **110** in the subsequent processes, the other micro-LEDs **130** are bonded to one pair of pads having the larger thickness, so as to prevent the micro-LEDs **130** that have been transferred to the substrate **110** from being pressed repeatedly.

[0059] As shown in FIG. **3**, the first surface **131***a* of the micro-LED **130** electrically bonded to the substrate **110** via the pad **112***a* is lower than the first surface **131***a* of the micro-LED **130** electrically bonded to the substrate **110** via the pad **112***b*, and the first surface **131***a* of the micro-LED **130** electrically bonded to the substrate **110** via the pad **112***b* is lower than the first surface **131***a* of the micro-LED **130** electrically bonded to the substrate **110** via the pad **112***c*. In other words, a distance between the second surface **131***b* of the micro-LED **130** electrically bonded to the substrate **110** via the pad **112***a* and the surface **111** of the substrate **110** is smaller than a distance between the second surface **131***b* of the micro-LED **130** electrically bonded to the substrate **110** via the pad **112***b* and the surface **111** of the substrate **110**, and a distance between the second surface **131***b* of the micro-LED **130** electrically bonded to the substrate **110** via the pad **112***b* and the surface **111** of the substrate **110** is smaller than a distance between the second surface **131***b* of the micro-LED **130** electrically bonded to the substrate **110** via the pad **112***c* and the surface **111** of the substrate **110**. Besides, a part of the second surface **131***b* of each of the micro-LEDs **130** is adjacent to anisotropic conductive film **120**.

[0060] FIG. **4** is a partial cross-sectional diagram of a micro-LED display panel according to the fourth embodiment of the invention. Referring to FIG. **4**, a difference between a micro-LED display panel **100**C of this embodiment and the micro-LED display panel **100**A of the second embodiment lies in that: in this embodiment, a pair of pads **112***a* having a first thickness d**4**, a pair of pads **112***b* having a second thickness d**5**, and a pair of pads **112***c* having a third thickness d**6** are arranged repeatedly in this order on the surface **111** of the substrate **110**, wherein the first thickness d**4** is smaller than the second thickness d**5**, and the second thickness d**5** is smaller than the third thickness d**6**. Based on the thickness design of the pairs of pads **112***a* to **112***c*, the micro-LEDs **130** that are transferred to the substrate **110** first are bonded to one pair of pads having the smaller thickness, and when other micro-LEDs **130** are transferred to the substrate **110** in the subsequent processes, the other micro-

LEDs **130** are bonded to one pair of pads having the larger thickness, so as to prevent the micro-LEDs **130** that have been transferred to the substrate **110** from being pressed repeatedly.

[0061] As shown in FIG. **4**, the first surface **131***a* of the micro-LED **130***a* electrically bonded to the substrate **110** via the pad **112***a* is lower than the first surface **131***a* of the micro-LED **130***a* electrically bonded to the substrate **110** via the pad **112***b*, and the first surface **131***a* of the micro-LED **130***a* electrically bonded to the substrate **110** via the pad **112***b* is lower than the first surface **131***a* of the micro-LED **130***a* electrically bonded to the substrate **110** via the pad **112***c*. In other words, a distance between the second surface **131***b* of the micro-LED **130***a* electrically bonded to the substrate **110** via the pad **112***a* and the surface **111** of the substrate **110** is smaller than a distance between the second surface **131***b* of the micro-LED **130***a* electrically bonded to the substrate **110** via the pad **112***b* and the surface **111** of the substrate **110**, and a distance between the second surface **131***b* of the micro-LED **130***a* electrically bonded to the substrate **110** via the pad **112***b* and the surface **111** of the substrate **110** is smaller than a distance between the second surface **131***b* of the micro-LED **130***a* electrically bonded to the substrate **110** via the pad **112***c* and the surface **111** of the substrate **110**.

[0062] FIG. **5** is a partial cross-sectional diagram of a micro-LED display panel according to the fifth embodiment of the invention. Referring to FIG. **5**, a difference between a micro-LED display panel **100**D of this embodiment and the micro-LED display panels **100**A to **100**C of the embodiments described above lies in that: in this embodiment, the bonding layer **132** has at least two different thicknesses, and for example, a cross-sectional shape of the micro-LED **130***b* is an inverted trapezoidal shape, and the micro-LEDs **130***b* may include red light micro-LEDs, green light micro-LEDs, and blue light micro-LEDs, wherein a thickness of the red light micro-LED is greater than a thickness of the green light micro-LED, and the thickness of the green light micro-LED is greater than a thickness of the blue light micro-LED, for example. Nevertheless, the invention is not intended to limit the red light micro-LED, the green light micro-LED, and the blue light micro-LED to certain cross-sectional shapes, nor limit the thickness ratio of the red light micro-LED, the green light micro-LED, and the blue light micro-LED.

[0063] Moreover, the bonding layer **123** for electrically bonding the red light micro-LED and the substrate **110** has a thickness d**7**, the bonding layer **123** for electrically bonding the green light micro-LED and the substrate **110** has a thickness d**8**, and the bonding layer **123** for electrically bonding the blue light micro-LED and the substrate **110** has a thickness d**9**, wherein the thickness d**9** is greater than the thickness d**8**, and the thickness d**8** is greater than the thickness d**7**. Therefore, a distance between the second surface **131***b* of the red light micro-LED that faces the surface **111** of the substrate **110** and the surface **111** of the substrate **110** is smaller than a distance between the second surface **131***b* of the green light micro-LED that faces the surface **111** of the substrate **110** and the surface **111** of the substrate **110**, and a distance between the second surface **131***b* of the green light micro-LED that faces the surface **111** of the substrate **110** and the surface **111** of the substrate **110** is smaller than a distance between the second surface **131***b* of the blue light micro-LED that faces the surface **111** of the substrate **110** and the surface **111** of the substrate **110**. Moreover, the first surface **131***a* of the red light micro-LED that faces away from the surface **111** of the substrate **110**, the first surface **131***a* of the green light micro-LED that faces away from the surface **111** of the substrate **110**, and the first surface **131***a* of the blue light micro-LED that faces away from the surface **111** of the substrate **110** are flush with one another.

[0064] In other words, the height difference between the surface of the micro-LED, which faces away from the substrate, and the substrate may be controlled by adjusting the thickness of the micro-LED, the thickness of the bonding layer, or the thickness of the pad on the substrate, and the distance between the surface of the micro-LED, which faces the substrate, and the substrate may be controlled by adjusting the thickness of the bonding layer or the thickness of the pad on the substrate.

[0065] To sum up, the micro-LEDs in the micro-LED display panel according to one or some embodiments of the invention are electrically connected to the substrate via the anisotropic conductive film. The anisotropic conductive film may serve as a buffer and therefore is capable of preventing damage or breakage of the micro-LEDs under heat and pressure, and thereby improving the reliability of the micro-LED display panel. In other words, the micro-LED display panel obtained by the manufacturing method of one or some embodiments of the invention has good reliability. Furthermore, the insulation film in the anisotropic conductive film is cured under heat so as to fix the micro-LEDs to the substrate and keep the micro-LEDs from coming off the substrate. Moreover, a portion of the conductive particles in the insulation film are pressed to form the bonding layer so as to electrically connect the micro-LEDs to the substrate. Based on the properties that the anisotropic conductive film is electrically conductive in the direction perpendicular to the surface (i.e., the surface of the substrate with the anisotropic conductive film disposed thereon) and electrically insulative in the direction parallel to the surface (i.e., the surface of the substrate with the anisotropic conductive film disposed thereon), the micro-LEDs may be electrically connected to the substrate via the anisotropic conductive film, while the micro-LEDs arranged side by side on the surface (i.e., the surface of the substrate with the anisotropic conductive film disposed thereon) are not electrically conducted with each other to cause a short circuit.

[0066] It will be apparent to those skilled in the art that various modifications and variations can be made to the disclosed embodiments without departing from the scope or spirit of the invention. In view of the foregoing, it is intended that the invention covers modifications and variations provided that they fall within the scope of the following claims and their equivalents.

What is claimed is:

1. A micro-LED display panel, comprising:

a substrate;

an anisotropic conductive film, disposed on the substrate; and

a plurality of micro-LEDs, wherein the micro-LEDs and the anisotropic conductive film are disposed at the same side of the substrate, and the micro-LEDs are electrically connected to the substrate via the anisotropic conductive film, wherein each of the micro-LEDs comprises an epitaxial layer and an electrode layer electrically connected to the epitaxial layer, and the electrode layer comprises a first electrode and a second electrode which are located between the substrate and the epitaxial layer, wherein a ratio of a thickness of each of the electrode layers to a thickness of the corresponding epitaxial layer is in a range of 0.1 to 0.5, and a gap between the first electrode and the second electrode of each of the micro-LEDs is in a range of 1 μm to 30 μm.

2. The micro-LED display panel according to claim **1**, wherein each of the epitaxial layers has a first surface and a second surface opposite to each other, each of the first electrodes and each of the second electrodes are disposed on the corresponding second surface, and each of the second surfaces faces the anisotropic conductive film.

3. The micro-LED display panel according to claim **2**, wherein a part of the second surface of each of the micro-LEDs is adjacent to the anisotropic conductive film.

4. The micro-LED display panel according to claim **2**, wherein a part of the second surface of each of the micro-LEDs contacts the anisotropic conductive film.

5. The micro-LED display panel according to claim **2**, wherein each of the epitaxial layers comprises a first type semiconductor layer, a light emitting layer and a second type semiconductor layer, the first type semiconductor layer and the second type semiconductor layer are located at two opposite sides of the light emitting layer, and the light emitting layer connects the first type semiconductor layer and the second type semiconductor layer, wherein each of the first type semiconductor layers has the second surface, each of the first electrodes is electrically contacted with the corresponding second surface, and each of the second electrodes is electrically contacted with the corresponding second type semiconductor layer via a conductive hole and electrically isolated to the corresponding first type semiconductor layer.

6. The micro-LED display panel according to claim **5**, wherein a ratio of a depth of one of the conductive holes to the thickness of the corresponding epitaxial layer is in a range of 0.15 to 0.35.

7. The micro-LED display panel according to claim **2**, wherein a side length of each of the micro-LEDs is in a range of 3 μm to 100 μm.

8. The micro-LED display panel according to claim **2**, wherein a ratio of the gap between the first electrode and the second electrode of each of the micro-LEDs to the side length of the micro-LED is in a range of 0.1 to 0.25.

9. The micro-LED display panel according to claim **2**, wherein each of the epitaxial layers comprises a first type semiconductor layer, a second type semiconductor layer, and a light emitting layer connected to and disposed between the first type semiconductor layer and the second type semiconductor layer, wherein the second type semiconductor layer extends beyond the light emitting layer and the first type semiconductor layer in one of the micro-LEDs, the second surface has a first sub-surface and a second sub-surface separated from each other, the first type semiconductor layer has the first sub-surface, and an end of the second type semiconductor layer has the second sub-surface, wherein in one of the micro-LEDs, the first electrode is electrically contacted with the first sub-surface, and the second electrode is electrically contacted with the second sub-surface.

10. The micro-LED display panel according to claim **1**, wherein the substrate comprises a plurality of pads, and the anisotropic conductive film covers the pads, and the electrode layers are electrically bonded to the pads respectively.

11. The micro-LED display panel according to claim **10**, wherein at least one of the pads has a first thickness and at least another one of the pads has a second thickness, and the second thickness is greater than the first thickness.

12. The micro-LED display panel according to claim **10**, wherein the anisotropic conductive film comprises an insulation film and a plurality of conductive particles dispersed in the insulation film, wherein a particle size of each of the conductive particles is smaller than the gap between the first electrode and the second electrode of one of the micro-LEDs, and a plurality of bonding layers are formed between the electrode layers and the pads and electrically connect the electrode layers and the pads respectively.

13. The micro-LED display panel according to claim **12**, wherein at least one of the bonding layers has a first transmittance and at least another one of the bonding layers has a second transmittance, and the second transmittance is greater than the first transmittance.

14. The micro-LED display panel according to claim **12**, wherein at least one of the bonding layers has a first thickness and at least another one of the bonding layers has a second thickness, and the second thickness is greater than the first thickness.

15. The micro-LED display panel according to claim **1**, wherein the anisotropic conductive film comprises an insulation film and a plurality of conductive particles dispersed in the insulation film, and a ratio of a particle size of each of the conductive particles to a side length of each of the micro-LEDs is in a range of 0.1 to 0.2.

16. The micro-LED display panel according to claim **1**, wherein the anisotropic conductive film comprises an insulation film and a plurality of conductive particles dispersed in the insulation film, and a particle size of each of the conductive particles is smaller than the gap between the first electrode and the second electrode of each of the micro-LEDs.

17. The micro-LED display panel according to claim **1**, wherein a distance between one of the micro-LEDs and the substrate is different from a distance between another one of the micro-LEDs and the substrate.

18. A manufacturing method of a micro-LED display panel, comprising:

(A) providing a substrate with an anisotropic conductive film;

(B) transferring a plurality of micro-LEDs to the substrate and disposing the micro-LEDs on the anisotropic conductive film;

(C) repeating the step (B) to dispose a required number of the micro-LEDs on the substrate; and

(D) processing by heating and pressuring to electrically bond the micro-LEDs to the substrate.

19. The manufacturing method of the micro-LED display panel according to claim **18**, wherein in the step (B), the micro-LEDs are aligned with a plurality of pads of the substrate respectively.

20. The manufacturing method of the micro-LED display panel according to claim **18**, wherein in the step (D), a bonding layer is formed between one of the micro-LEDs and one of the pads to electrically connect the one of the micro-LEDs and the substrate.

* * * * *

专利名称(译)	微型led显示面板及其制造方法		
公开(公告)号	US20190131282A1	公开(公告)日	2019-05-02
申请号	US16/164816	申请日	2018-10-19
[标]申请(专利权)人(译)	錼创科技股份有限公司		
申请(专利权)人(译)	PLAYNITRIDE INC.		
当前申请(专利权)人(译)	PLAYNITRIDE INC.		
[标]发明人	LIU YING TSANG LI YU CHU CHEN PEI HSIN CHEN YI CHING		
发明人	LIU, YING-TSANG LI, YU-CHU CHEN, PEI-HSIN CHEN, YI-CHING		
IPC分类号	H01L25/075 H01L33/62 H01L33/38 H01L23/00 H01L25/16		
CPC分类号	H01L25/0753 H01L33/62 H01L33/38 H01L24/32 H01L24/83 H01L25/167 H01L2933/0066 H01L2224/83203 H01L2224/32145 H01L2924/12041 H01L2224/83005 H01L33/0079 H01L24/14 H01L24/16 H01L24/29 H01L24/73 H01L24/81 H01L24/95 H01L2224/1403 H01L2224/2929 H01L2224/29298 H01L2224/73204 H01L2224/81903 H01L2224/83192 H01L2224/83851 H01L2224/95001 H01L2924/00014 H01L2924/10156 H01L2924/00012 H01L2224/13099 H01L2224/32225 H01L2224/16225 H01L33/0093		
优先权	106137561 2017-10-31 TW		
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摘要(译)

提供一种微LED显示面板，包括基板，各向异性导电膜和多个微LED。各向异性导电膜设置在基板上。微LED和各向异性导电膜设置在基板的同一侧，并且微LED通过各向异性导电膜电连接到基板。每个微LED包括外延层和电连接到外延层的电极层，并且电极层包括位于基板和相应的外延层之间的第一电极和第二电极。每个电极层的厚度与相应的外延层的厚度的比率在0.1至0.5的范围内，并且每个微LED的第一电极和第二电极之间的间隙在1μm的范围内。至30微米。