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(54) **TRANSFERRING METHOD, MANUFACTURING METHOD, DEVICE AND ELECTRONIC APPARATUS OF MICRO-LED**

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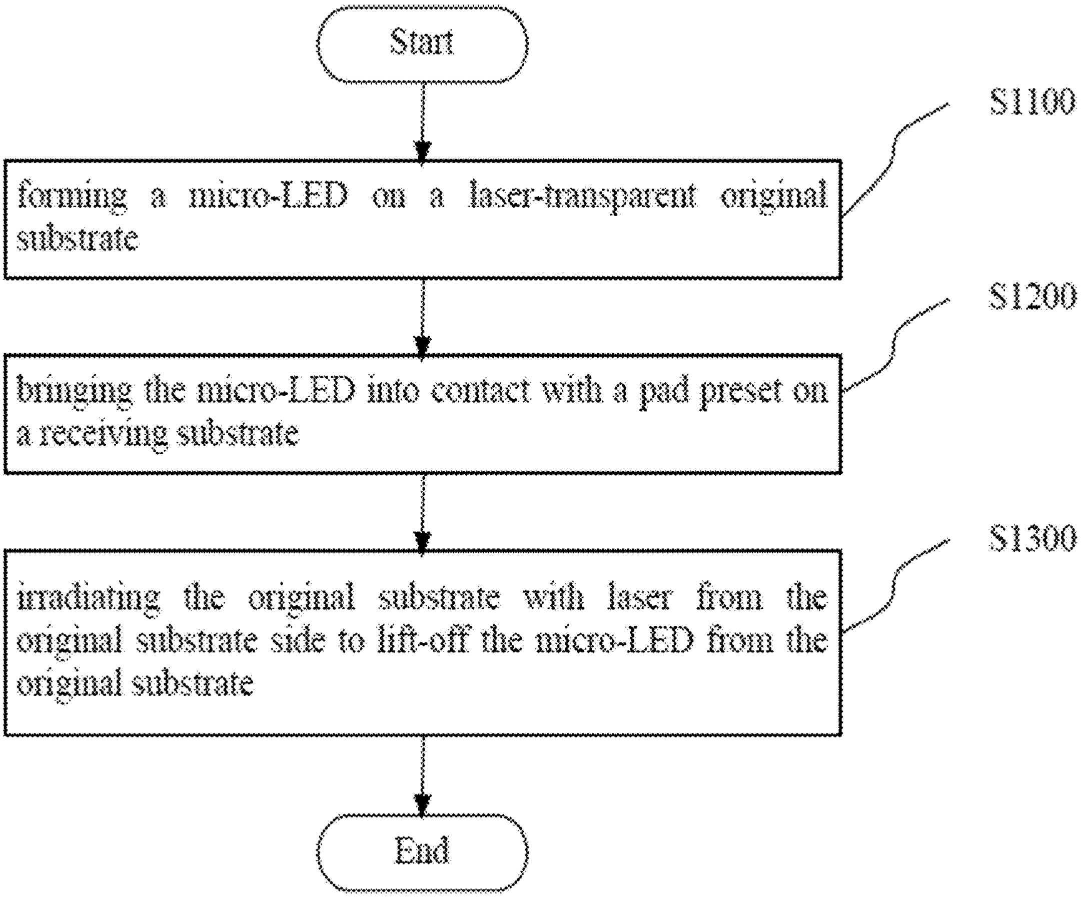
H01L 25/075	(2006.01)
H01L 33/20	(2006.01)
H01L 21/68	(2006.01)
H01L 21/786	(2006.01)

(52) **U.S. Cl.**

CPC ***H01L 33/0095*** (2013.01); ***H01L 27/15*** (2013.01); ***H01L 25/0753*** (2013.01); ***H01L 21/786*** (2013.01); ***H01L 33/20*** (2013.01); ***H01L 21/68*** (2013.01); ***H01L 33/0079*** (2013.01)

(57) **ABSTRACT**

The present invention discloses a transferring method, a manufacturing method, a device and an electronics apparatus of micro-LED. The method for transferring micro-LEDs comprises: forming a mask layer on the backside of a laser-transparent original substrate, wherein micro-LEDs are formed on the front-side of the original substrate; bringing the micro-LEDs on the original substrate in contact with preset pads on a receiving substrate; and irradiating the original substrate from the original substrate side with laser through the mask layer, to lift-off micro-LEDs from the original substrate.



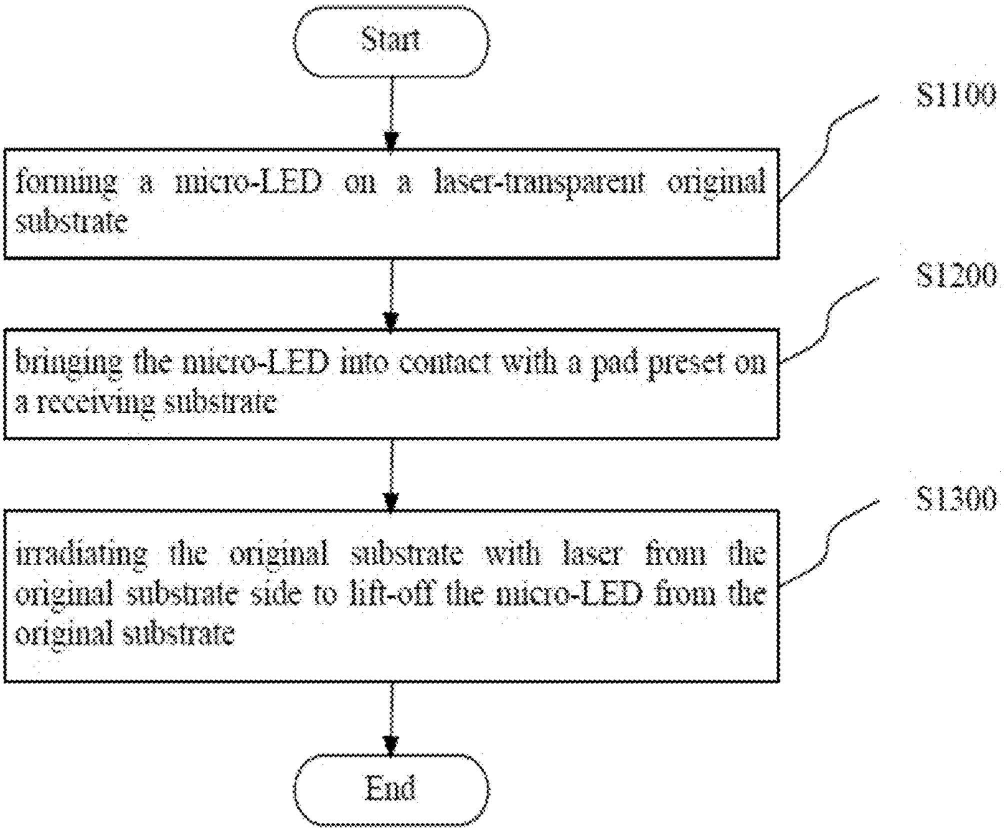

Start
forming a micro-LED on a laser-transparent original substrate
S1100
bringing the micro-LED into contact with a pad preset on a receiving substrate
S1200
irradiating the original substrate with laser from the original substrate side to lift-off the micro-LED from the original substrate
S1300
End

FIG. 1

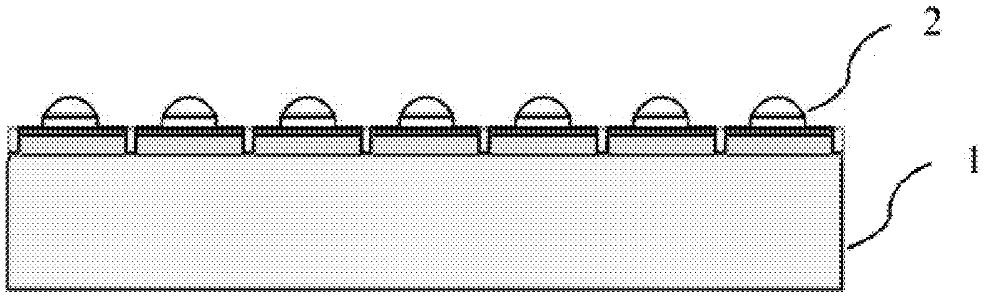

2
1

FIG. 2A

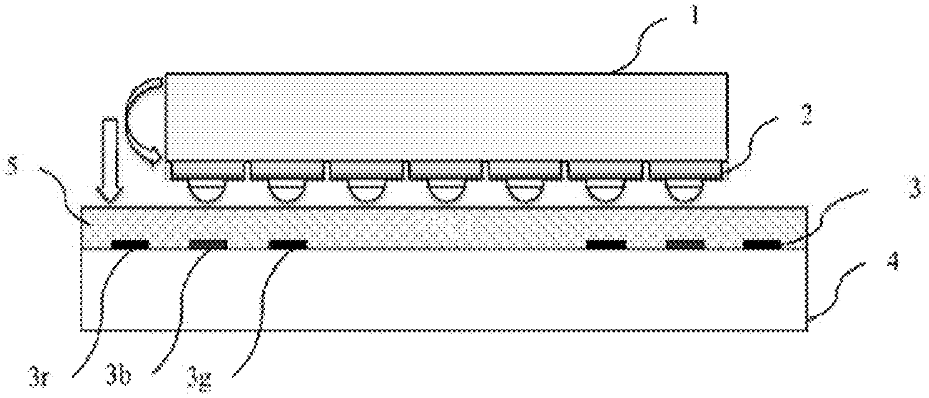


FIG. 2B

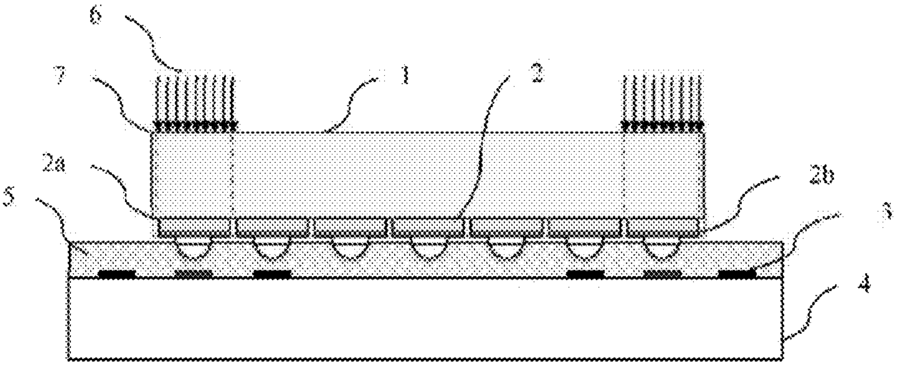


FIG. 2C

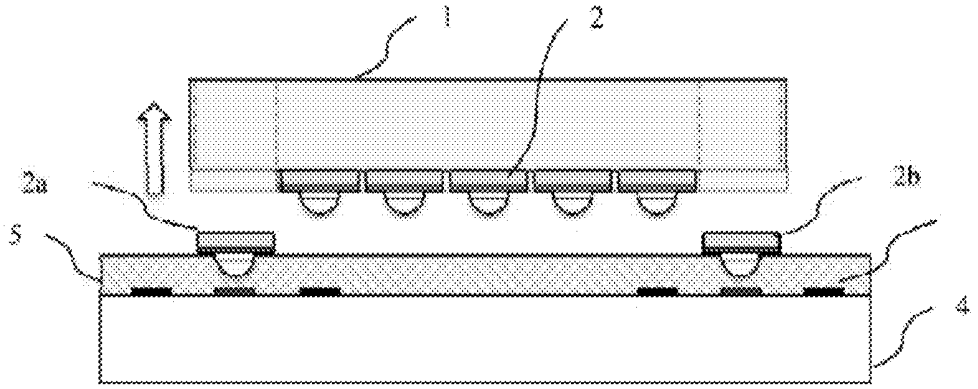


FIG. 2D

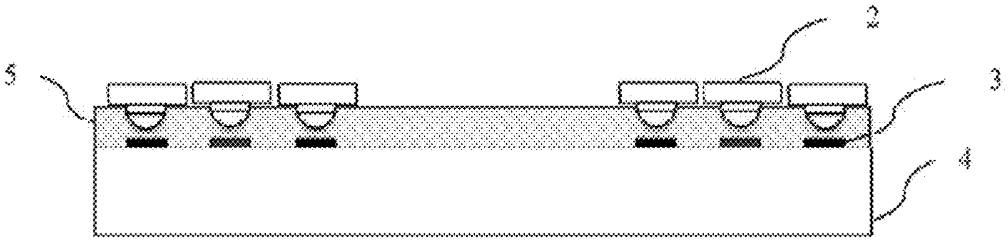


FIG. 2E

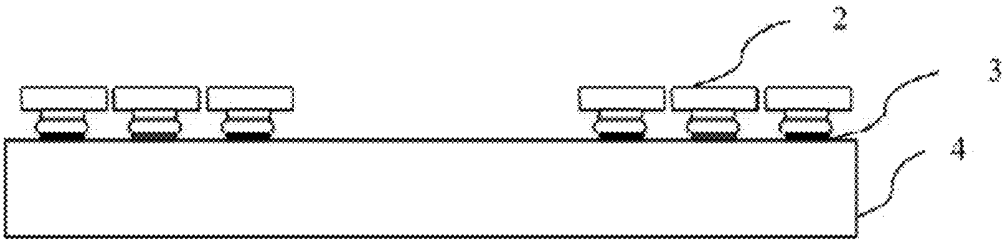


FIG. 2F

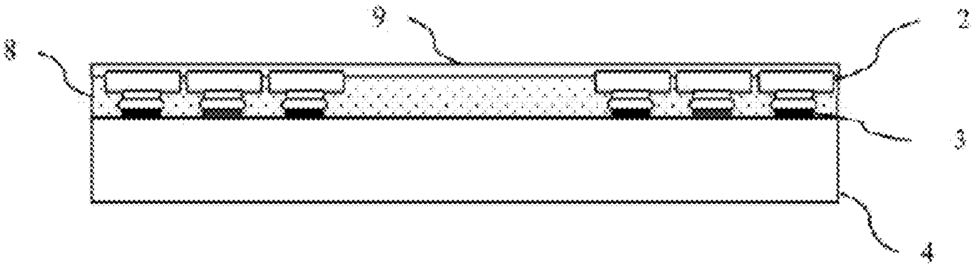

9
8
2
3
4

FIG. 2G

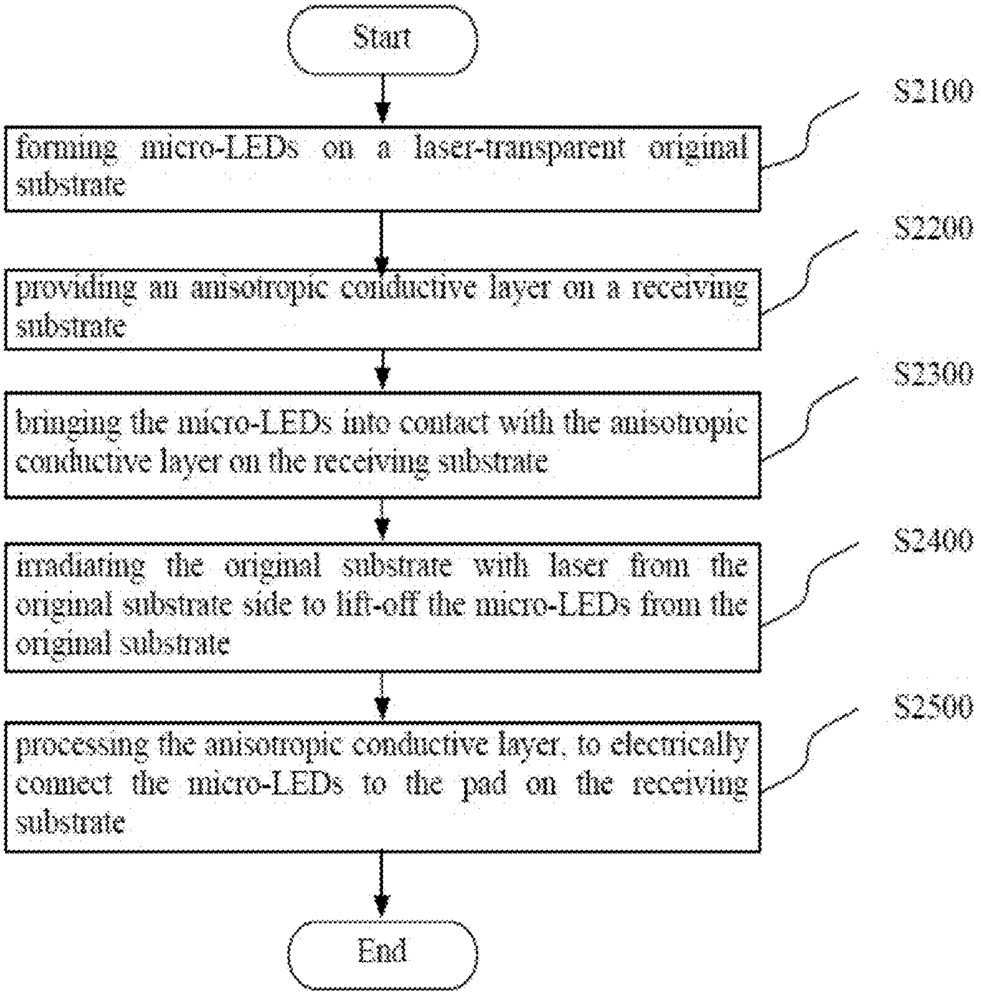

Start
S2100
forming micro-LEDs on a laser-transparent original substrate
S2200
providing an anisotropic conductive layer on a receiving substrate
S2300
bringing the micro-LEDs into contact with the anisotropic conductive layer on the receiving substrate
S2400
irradiating the original substrate with laser from the original substrate side to lift-off the micro-LEDs from the original substrate
S2500
processing the anisotropic conductive layer, to electrically connect the micro-LEDs to the pad on the receiving substrate
End

FIG. 3

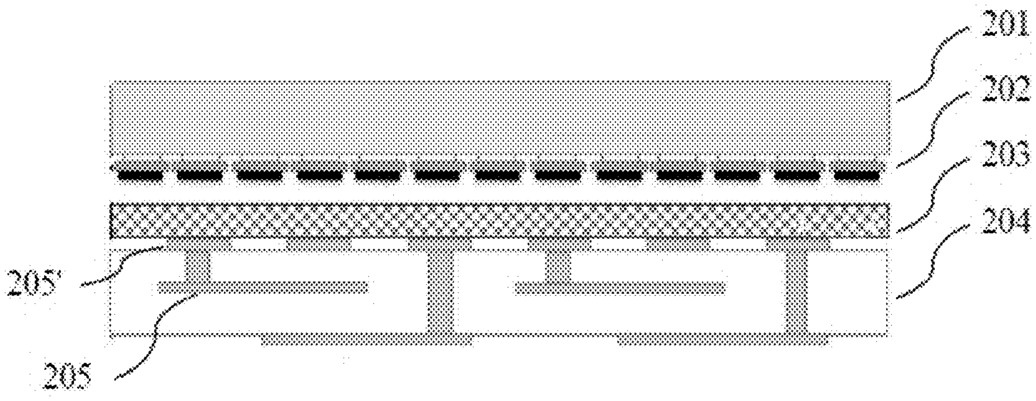


FIG. 4A

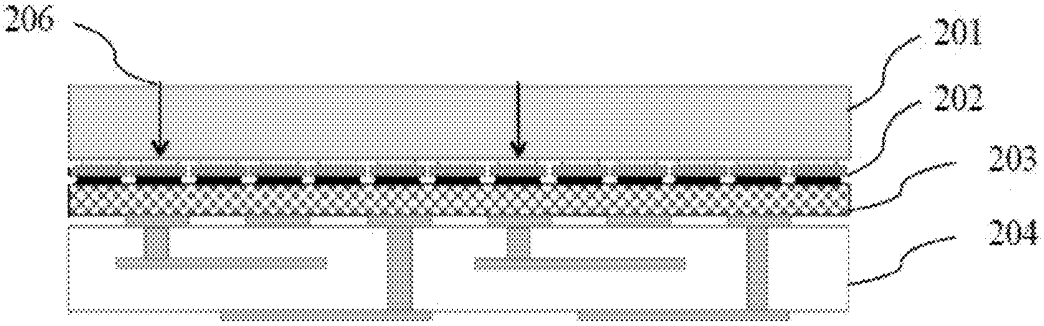


FIG. 4B

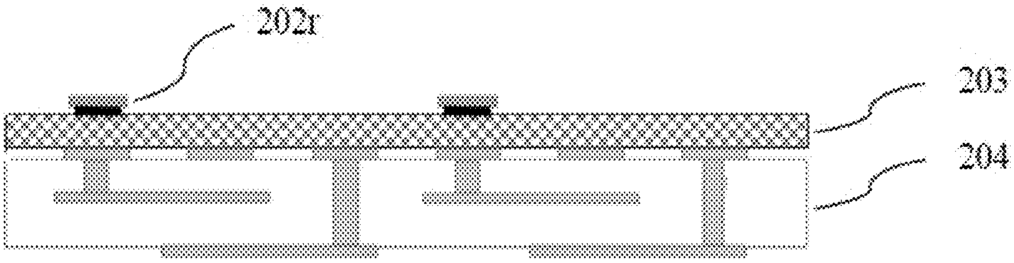


FIG. 4C

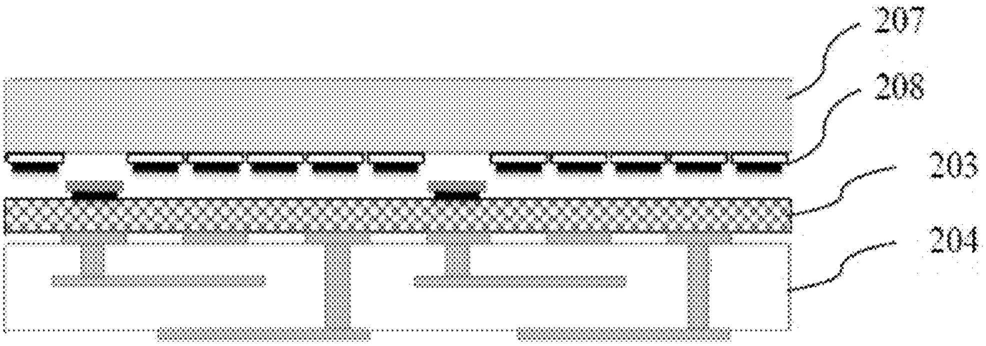


FIG. 4D

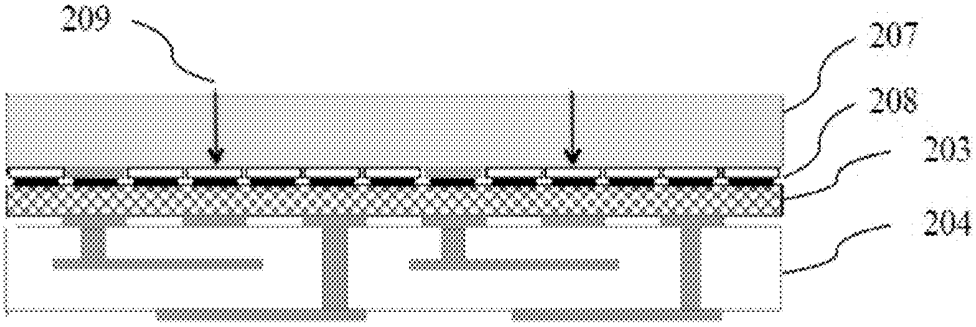


FIG. 4E

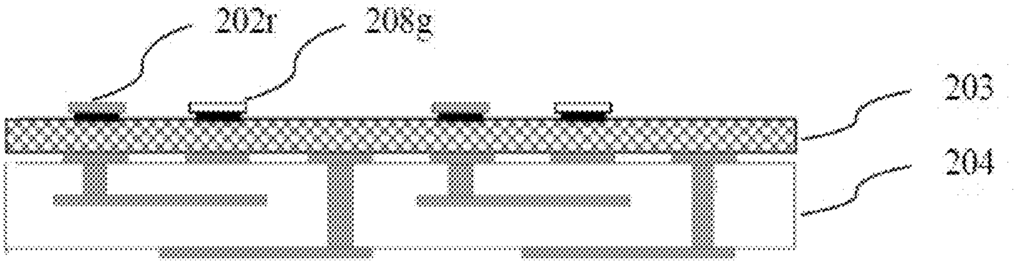


FIG. 4F

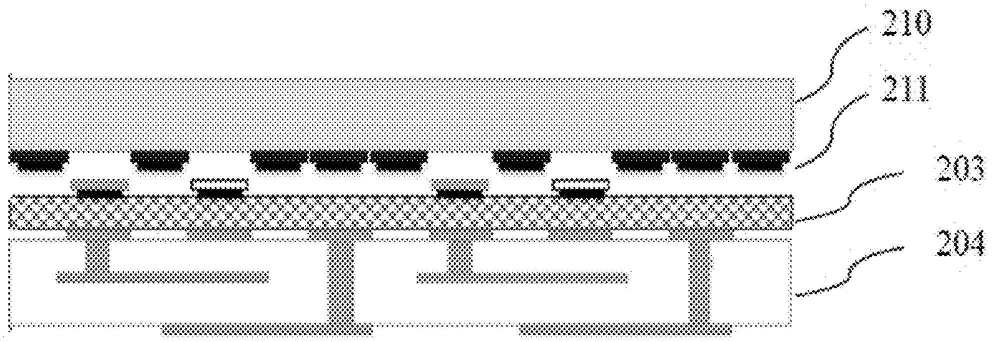


FIG. 4G

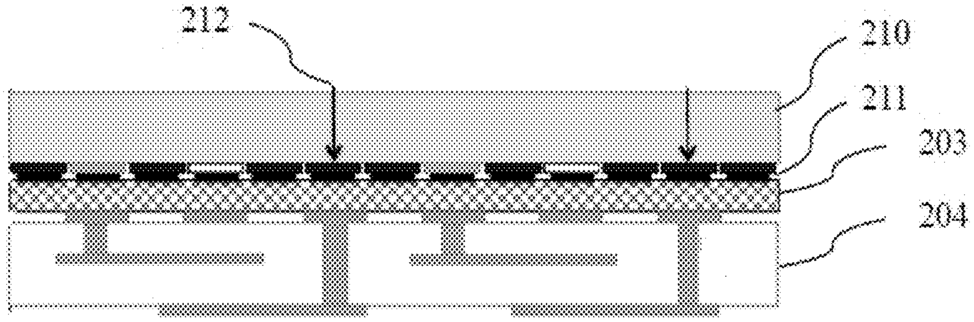


FIG. 4H

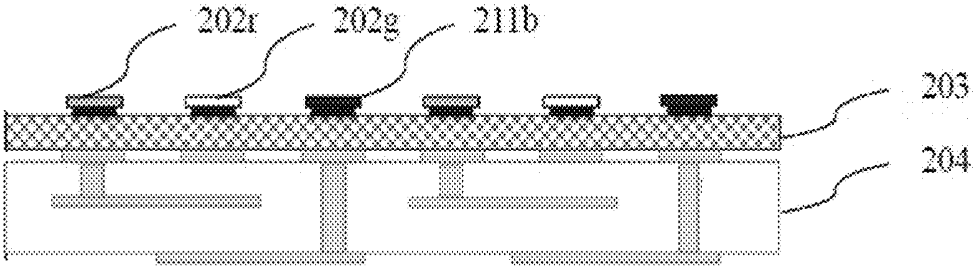


FIG. 4I

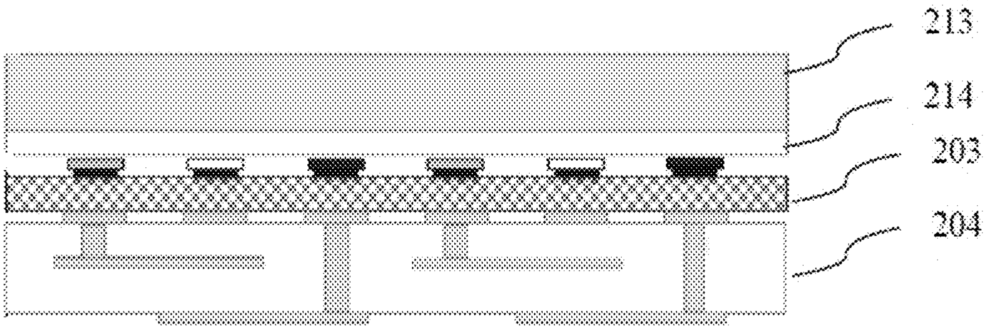


FIG. 4J

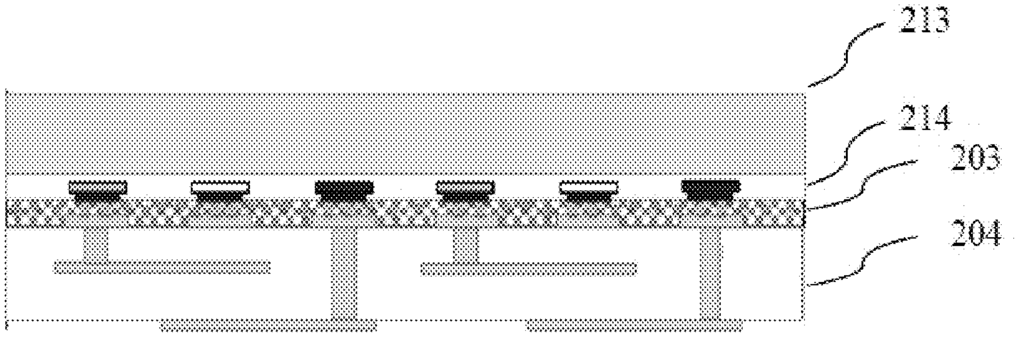


FIG. 4K

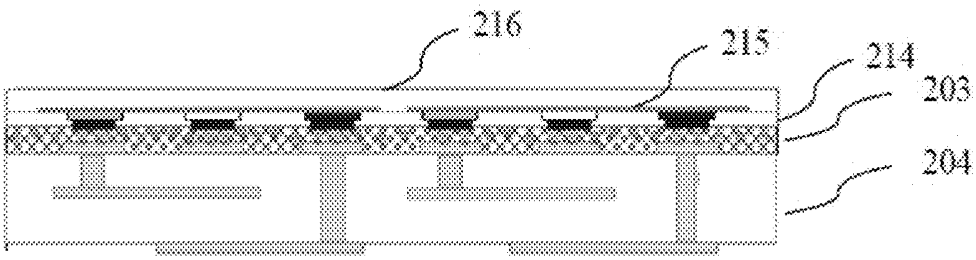


FIG. 4L

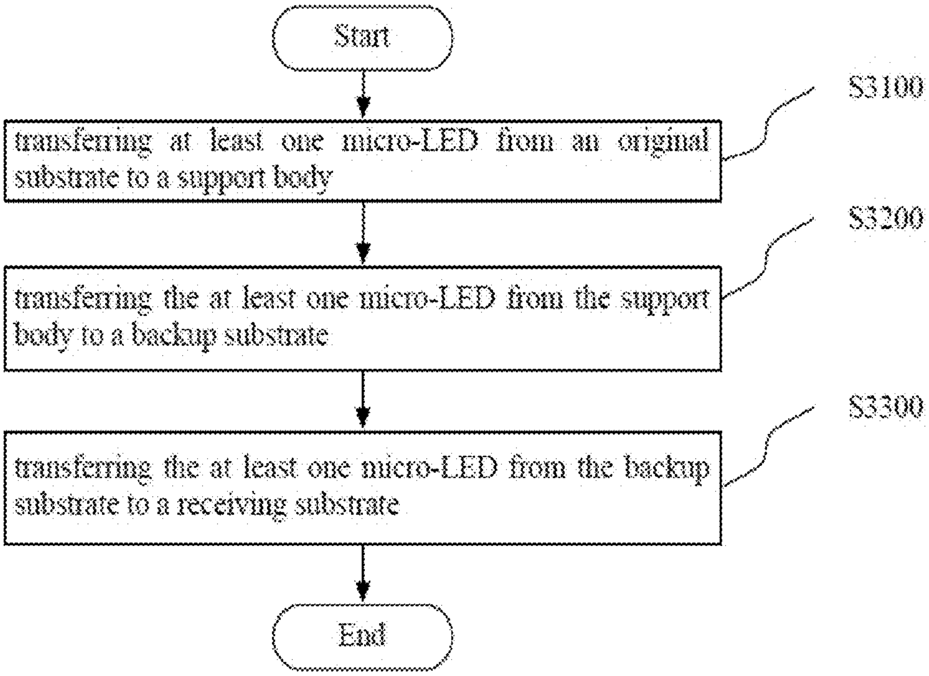


FIG. 5

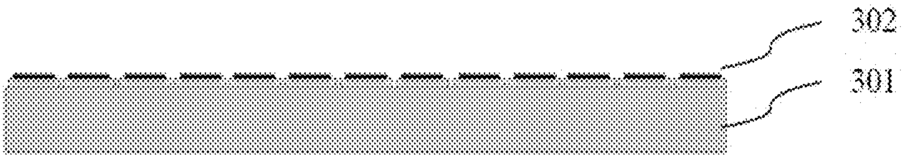


FIG. 6A

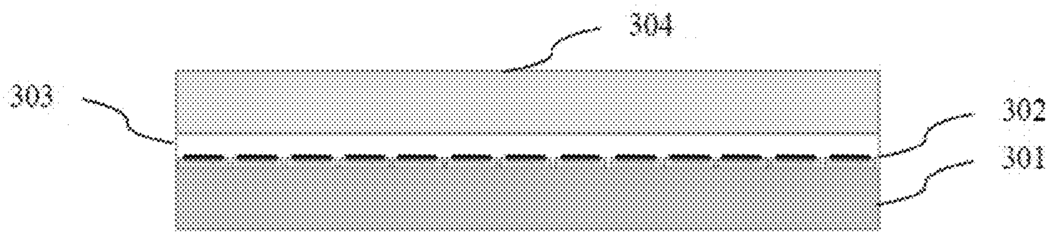


FIG. 6B

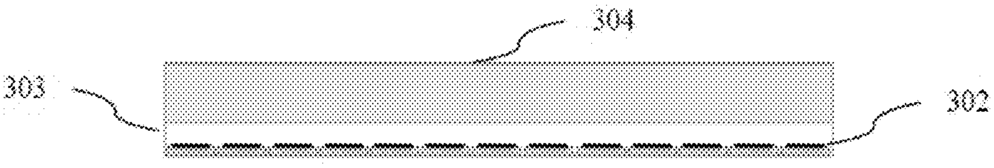


FIG. 6C

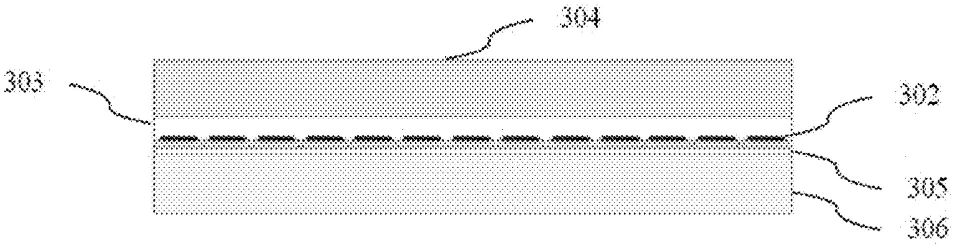


FIG. 6D

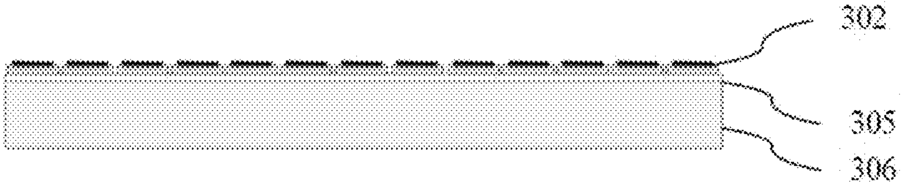


FIG. 6E

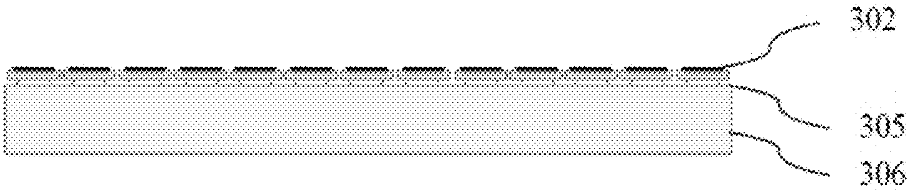


FIG. 6F

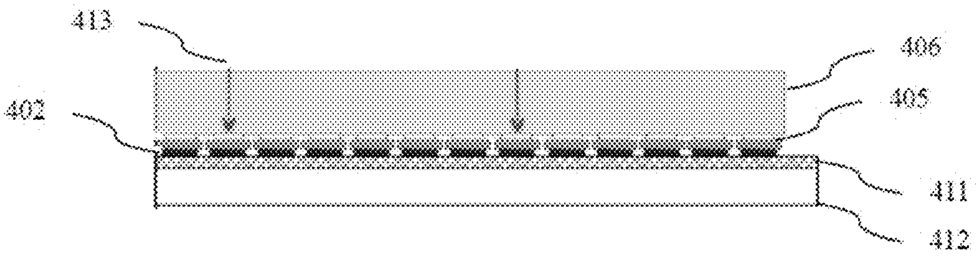


FIG. 7A

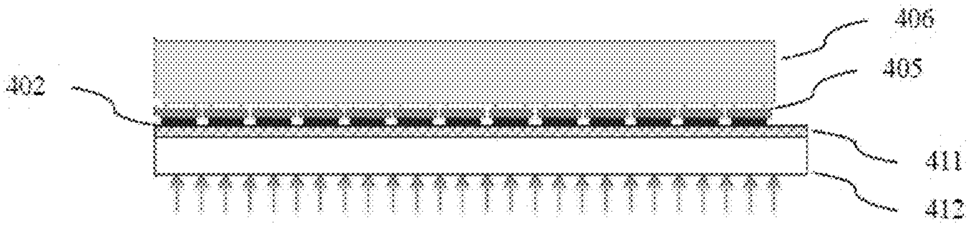


FIG. 7B

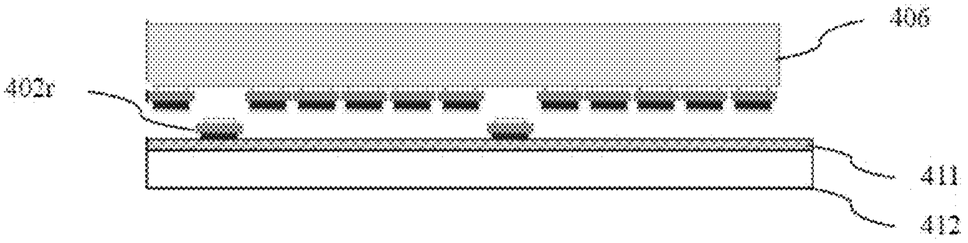


FIG. 7C

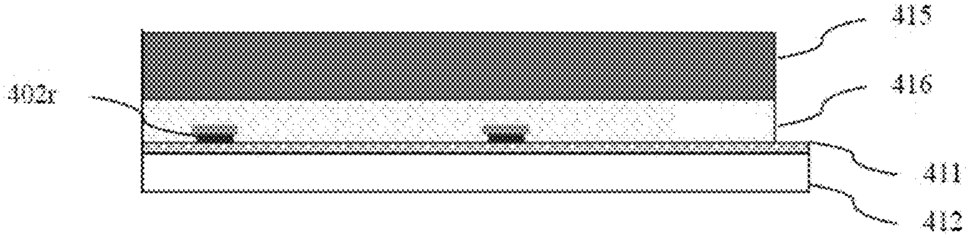


FIG. 7D

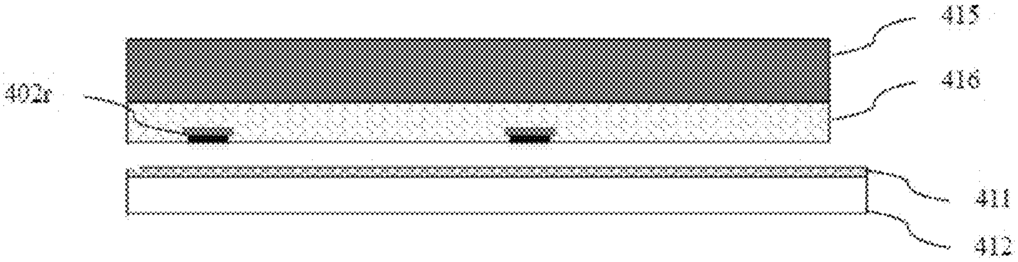


FIG. 7E

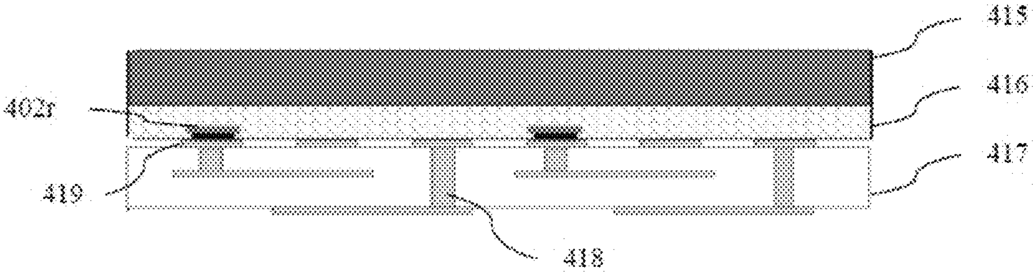


FIG. 7F

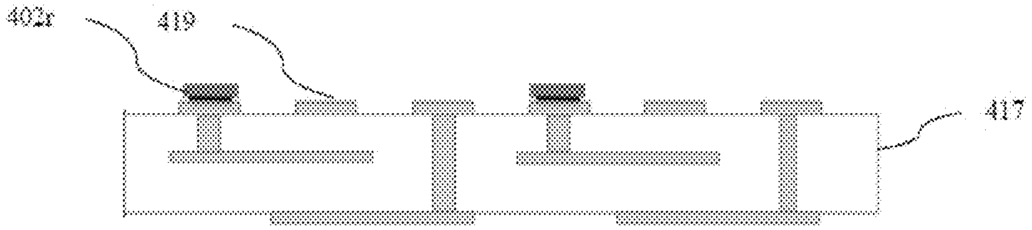


FIG. 7G

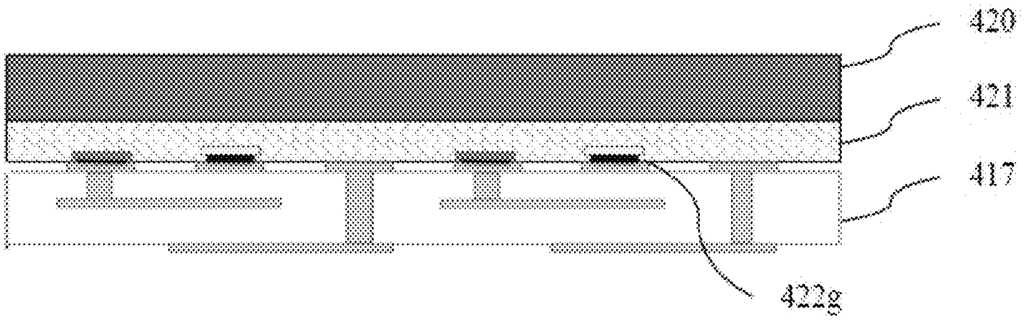


FIG. 7H

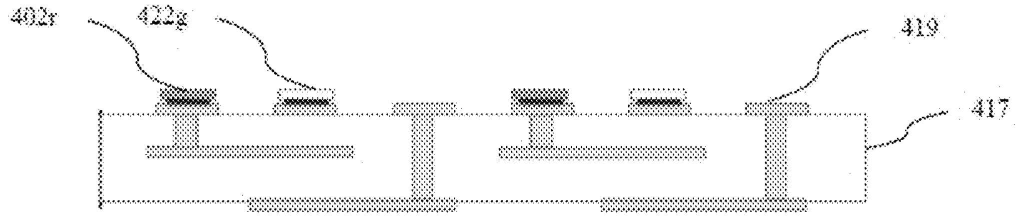


FIG. 7I

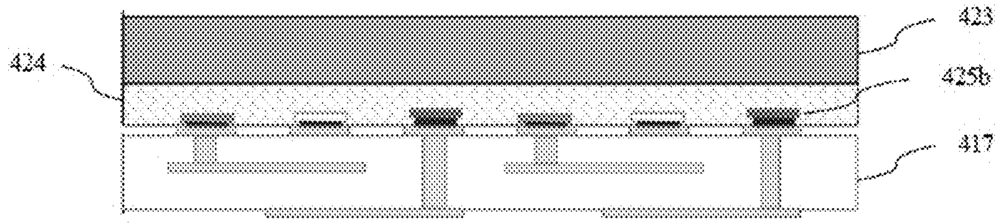


FIG. 7J

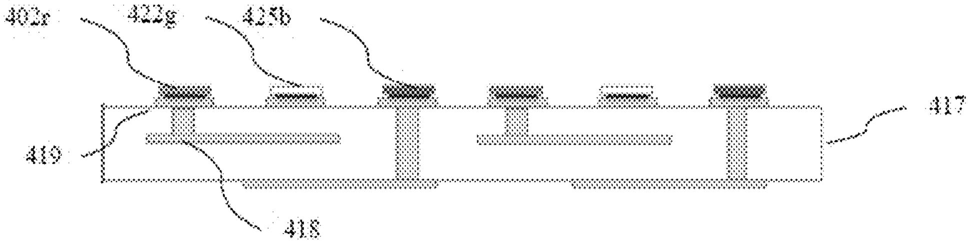


FIG. 7K

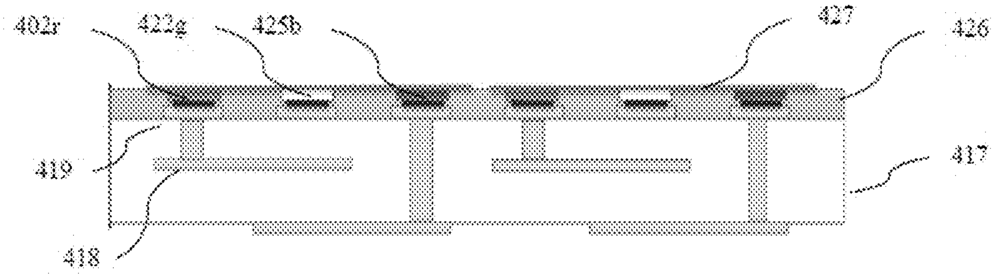
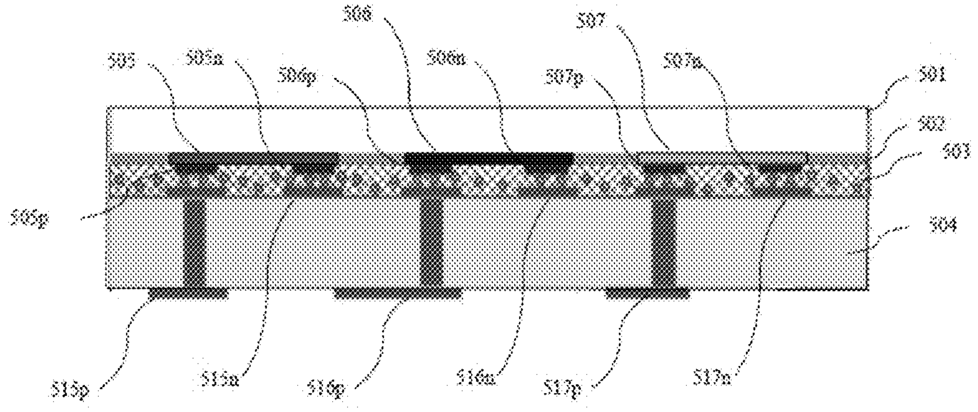


FIG. 7L


506
507
505
505n
506p
506n
507p
507n
501
502
503
505p
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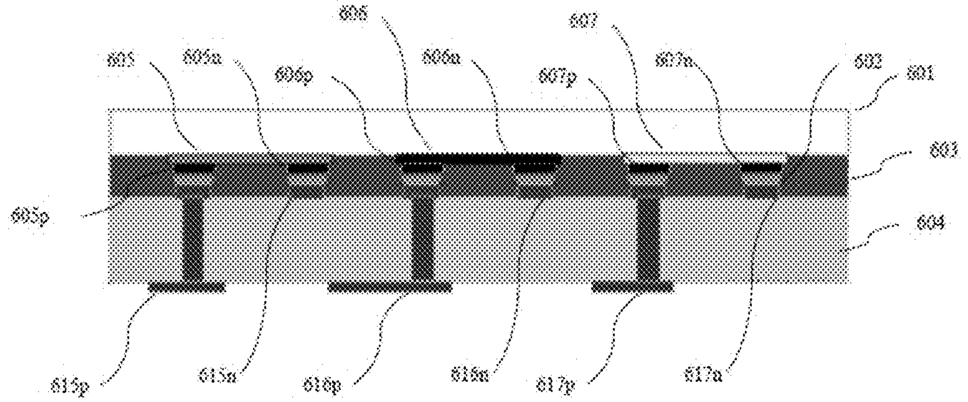
515p
515n
516p
516n
517p
517n

FIG. 8


606
607
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617n

FIG. 9

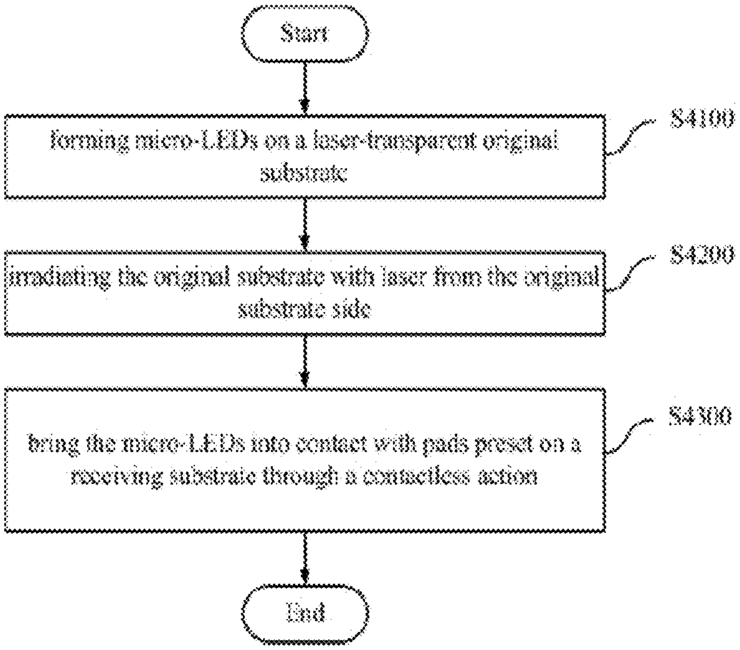
Start
forming micro-LEDs on a laser-transparent original substrate
S4100
irradiating the original substrate with laser from the original substrate side
S4200
bring the micro-LEDs into contact with pads preset on a receiving substrate through a contactless action
S4300
End

FIG. 10

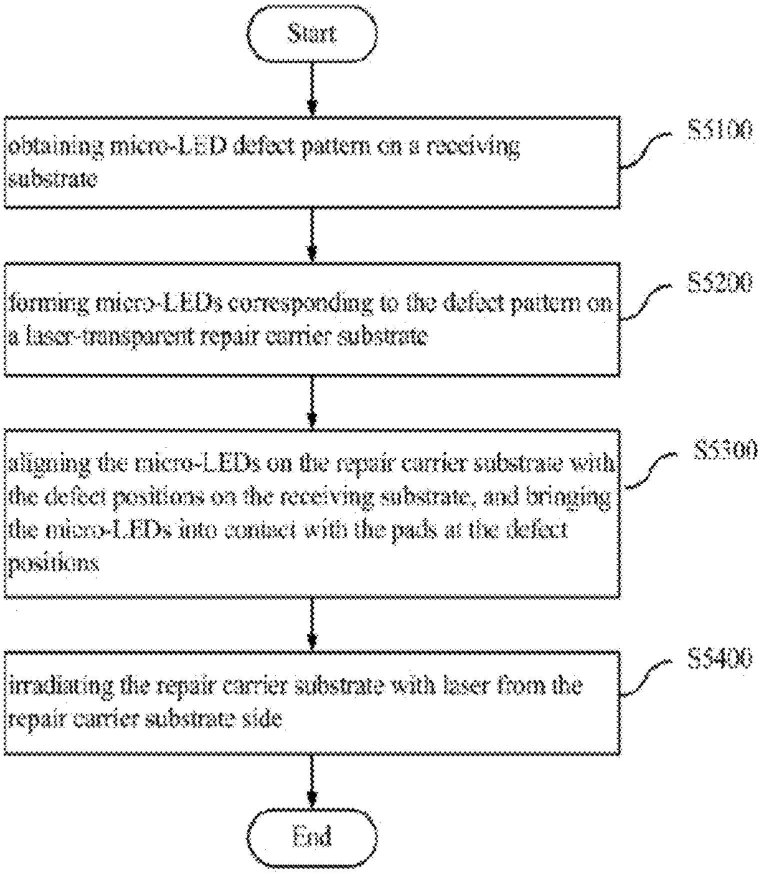
Start
obtaining micro-LED defect pattern on a receiving substrate
S5100
forming micro-LEDs corresponding to the defect pattern on a laser-transparent repair carrier substrate
S5200
aligning the micro-LEDs on the repair carrier substrate with the defect positions on the receiving substrate, and bringing the micro-LEDs into contact with the pads at the defect positions
S5300
irradiating the repair carrier substrate with laser from the repair carrier substrate side
S5400
End

FIG. 11

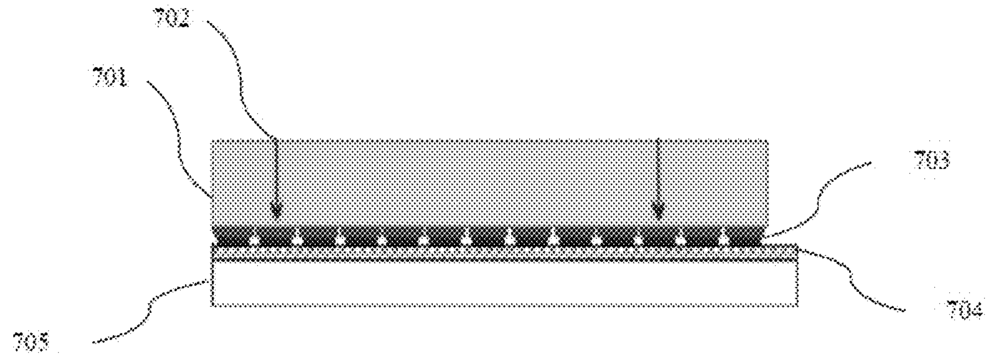

FIG. 12A

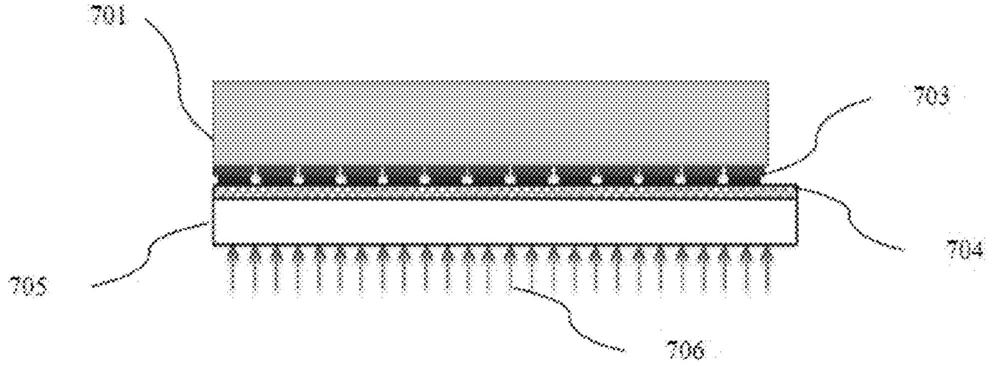

FIG. 12B

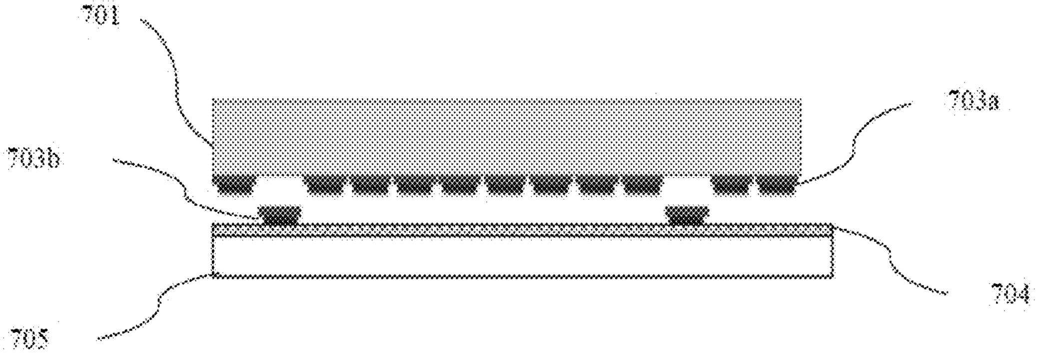

FIG. 12C

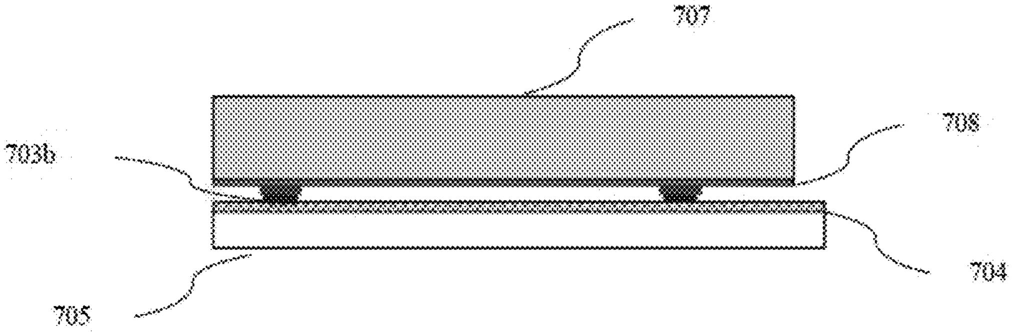

FIG. 12D

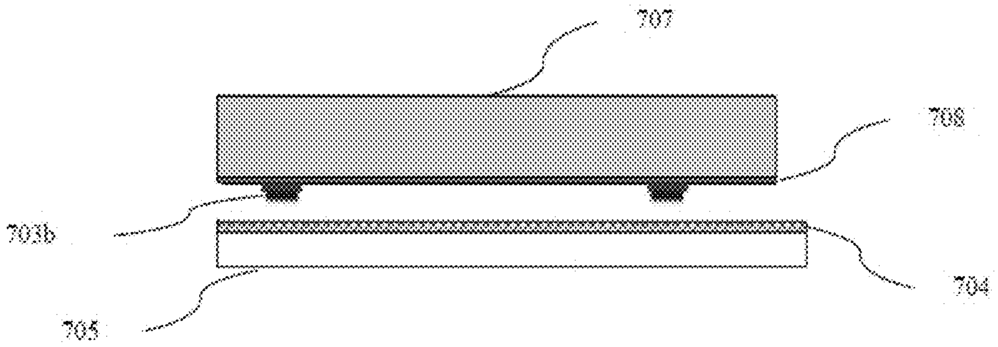

FIG. 12E

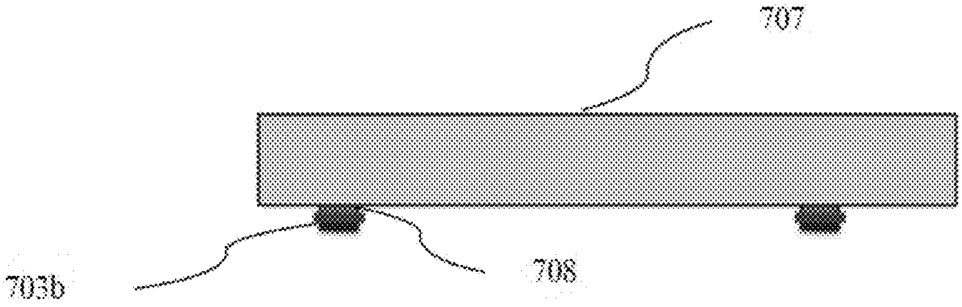

FIG. 12F

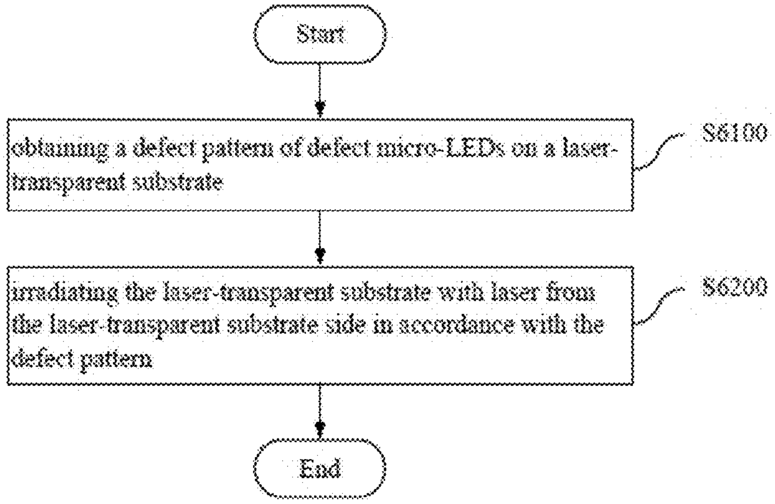

FIG. 13

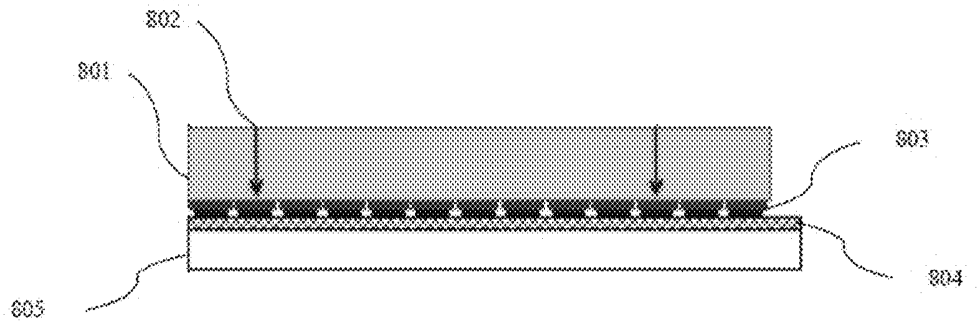

FIG. 14A

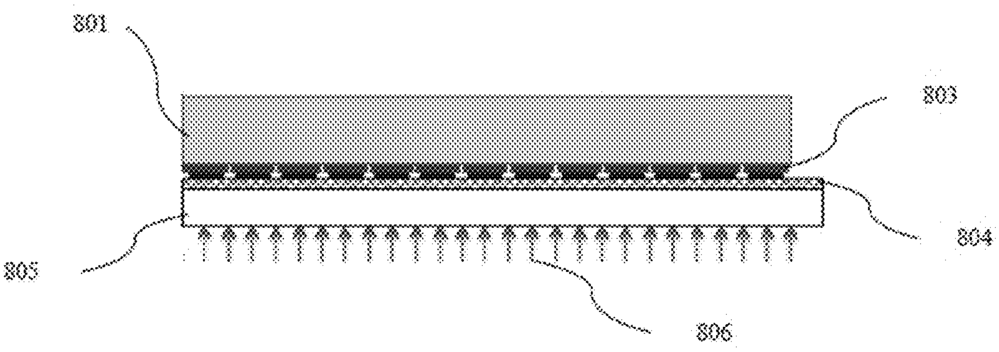

FIG. 14B

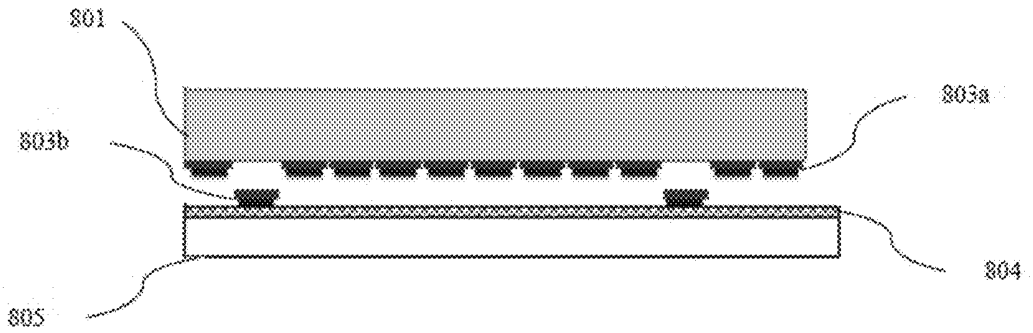

FIG. 14C

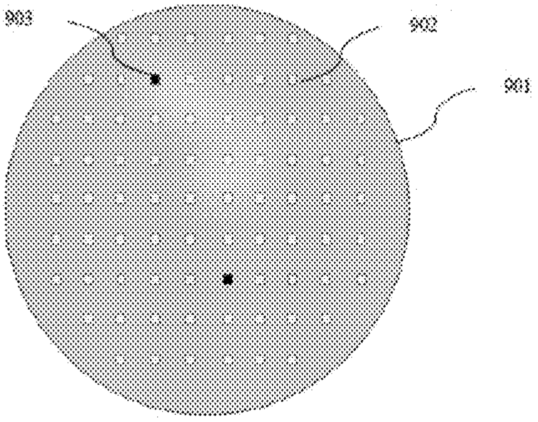

FIG. 15A

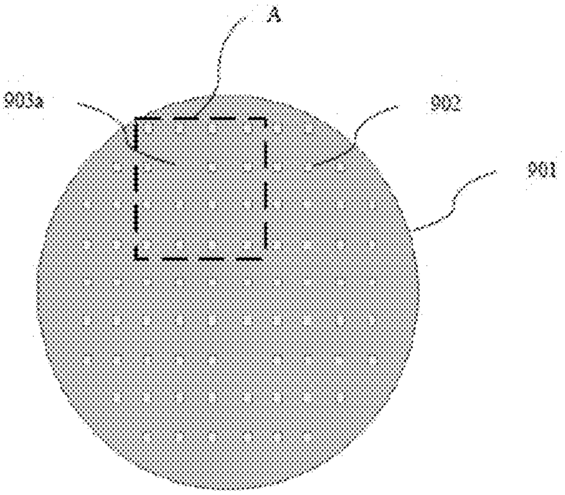

FIG. 15B

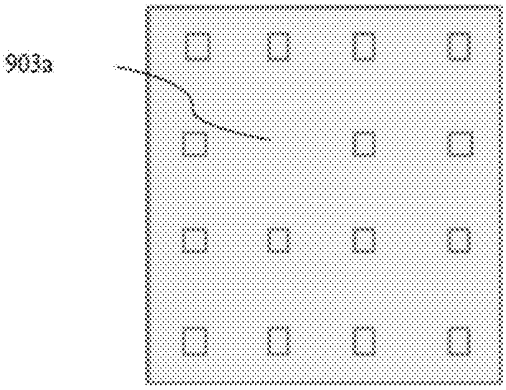

FIG. 16A

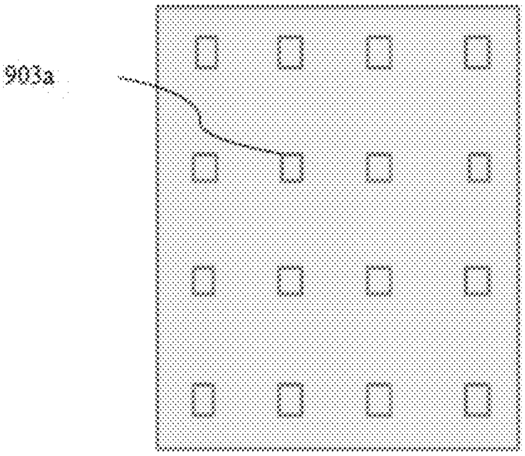

FIG. 16B

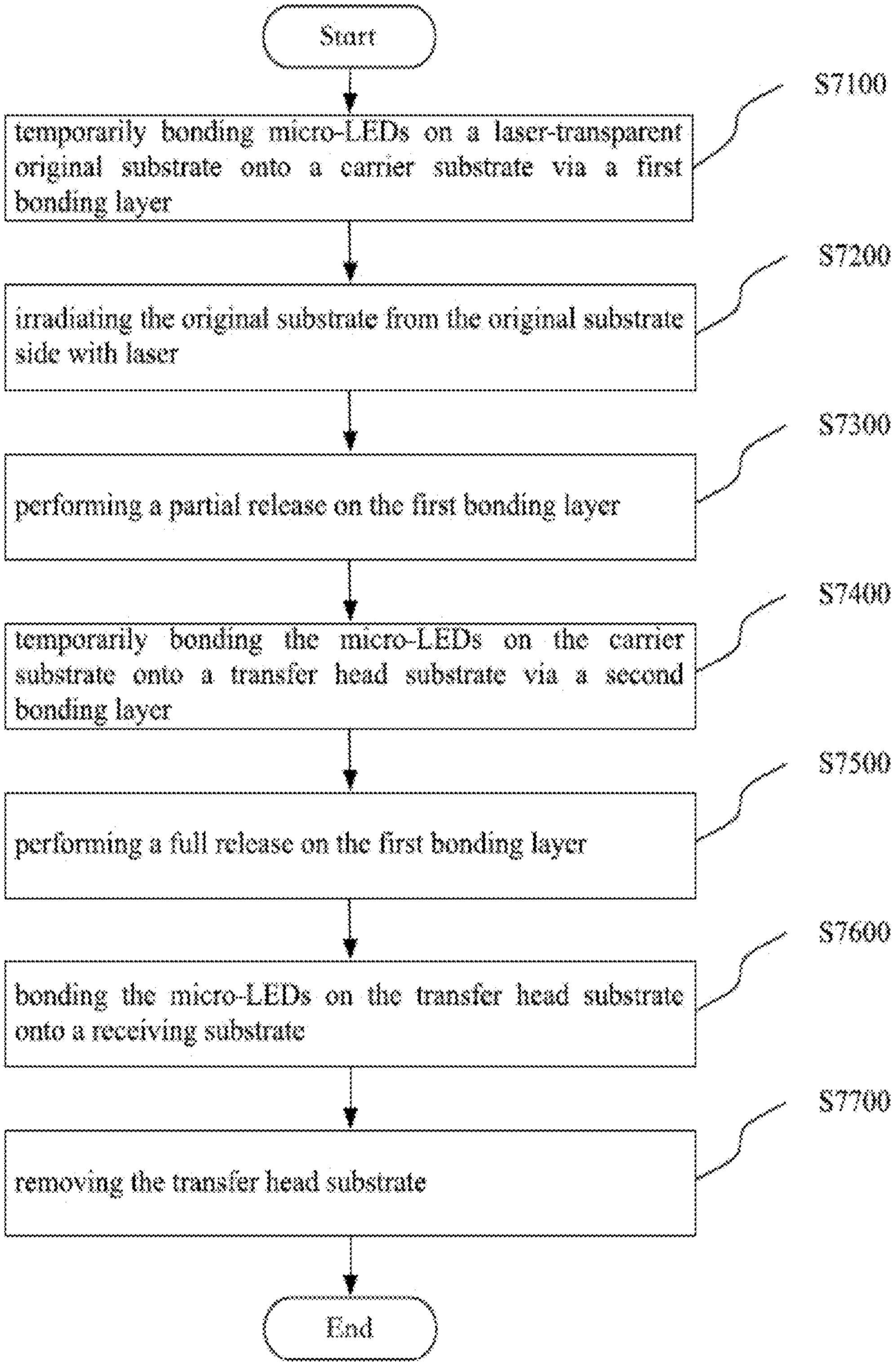
Start
S7100
temporarily bonding micro-LEDs on a laser-transparent original substrate onto a carrier substrate via a first bonding layer
S7200
irradiating the original substrate from the original substrate side with laser
S7300
performing a partial release on the first bonding layer
S7400
temporarily bonding the micro-LEDs on the carrier substrate onto a transfer head substrate via a second bonding layer
S7500
performing a full release on the first bonding layer
S7600
bonding the micro-LEDs on the transfer head substrate onto a receiving substrate
S7700
removing the transfer head substrate
End

FIG. 17

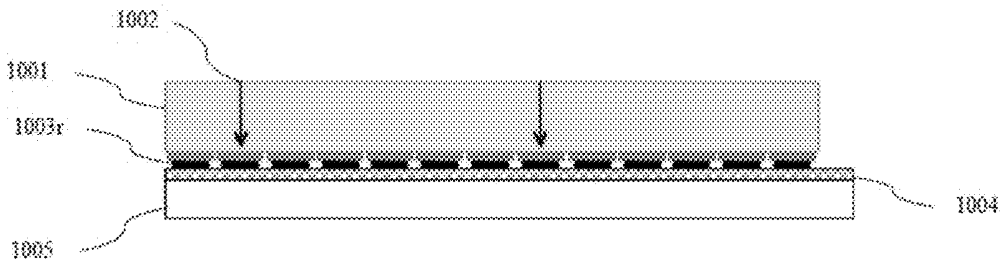

FIG. 18A

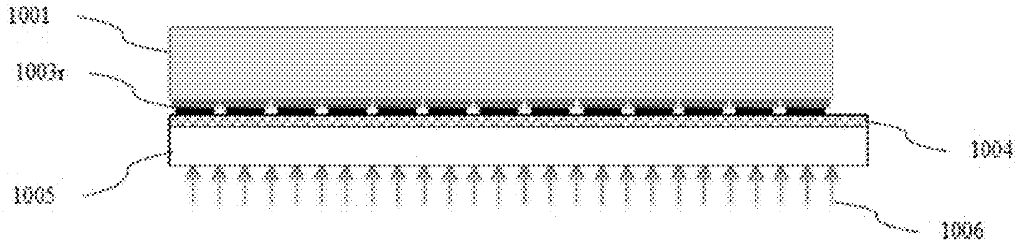

FIG. 18B

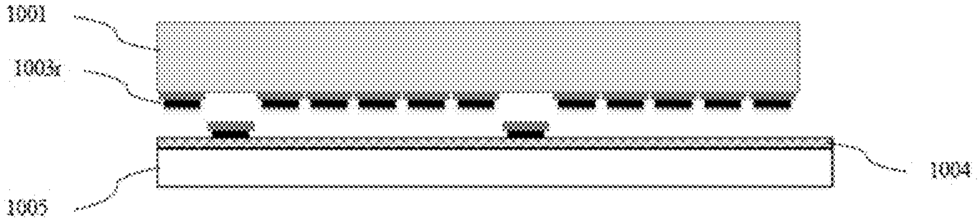

FIG. 18C

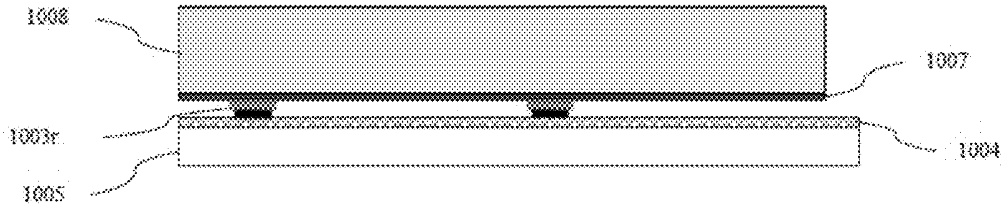

FIG. 18D

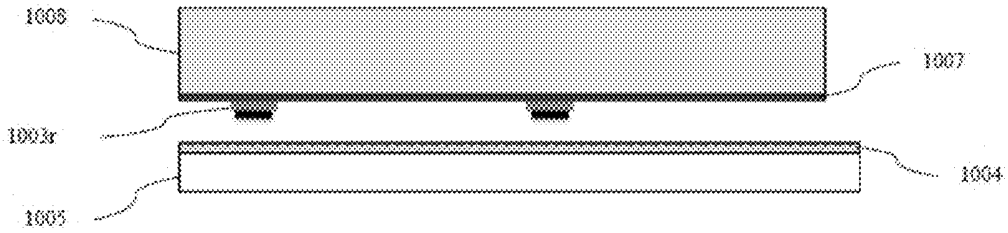

FIG. 18E

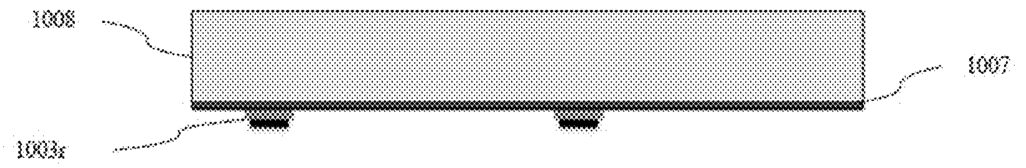

FIG. 18F

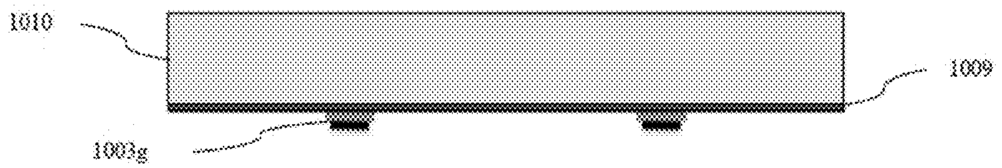

FIG. 18G

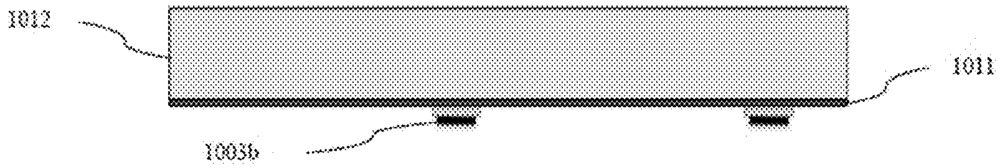

FIG. 18H

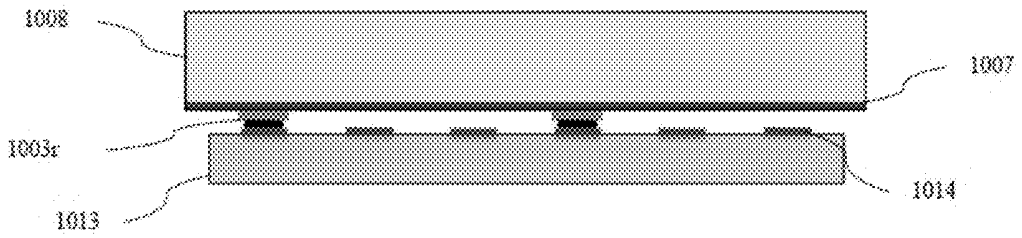

FIG. 18I

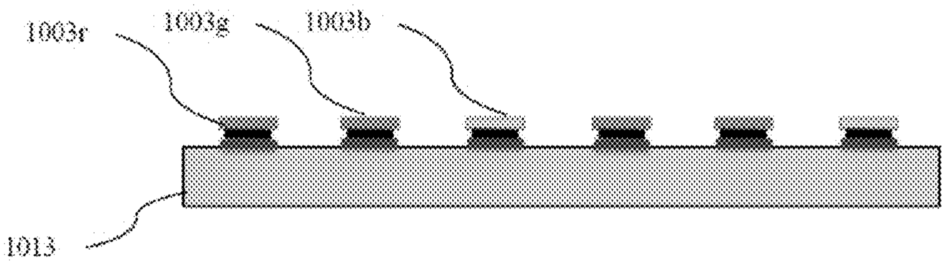

FIG. 18J

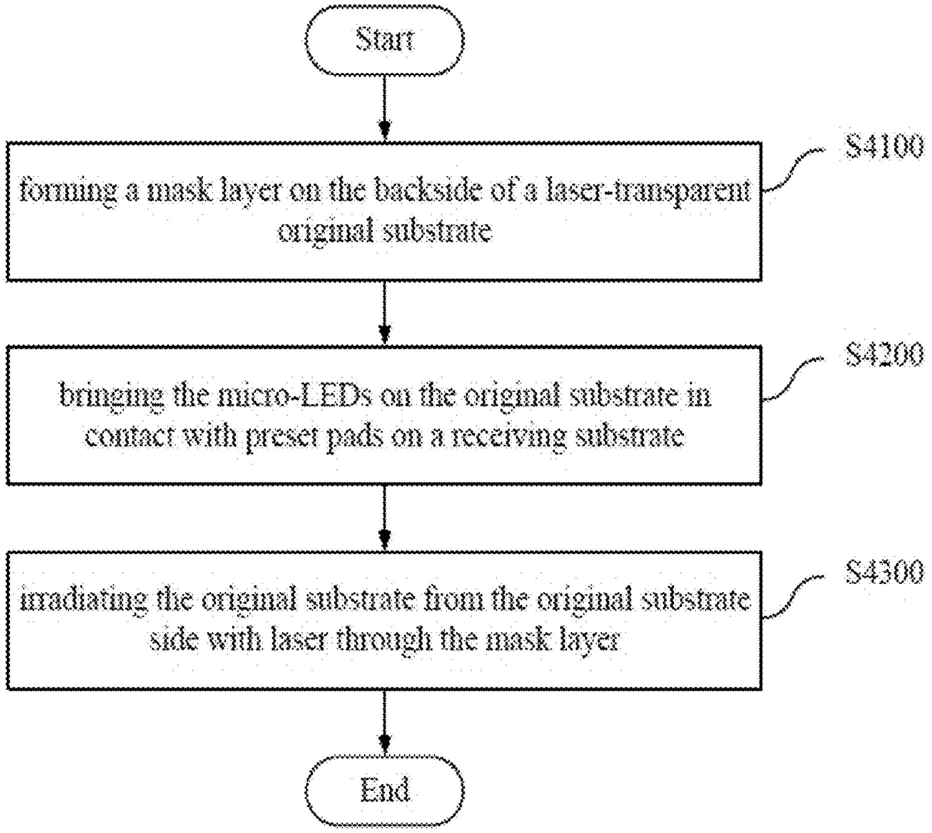

FIG. 19

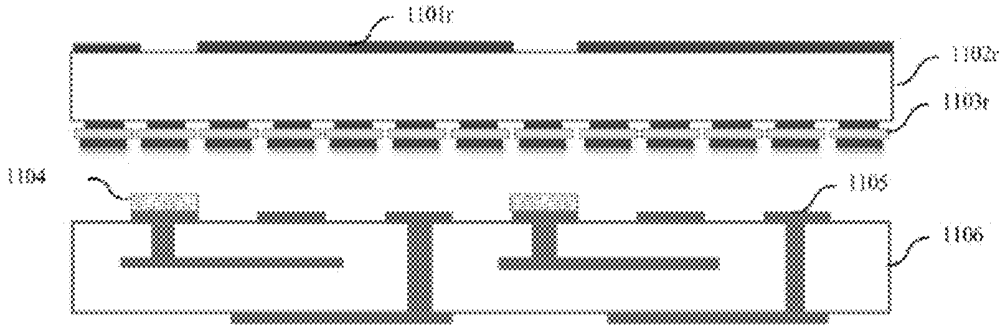

FIG. 20A

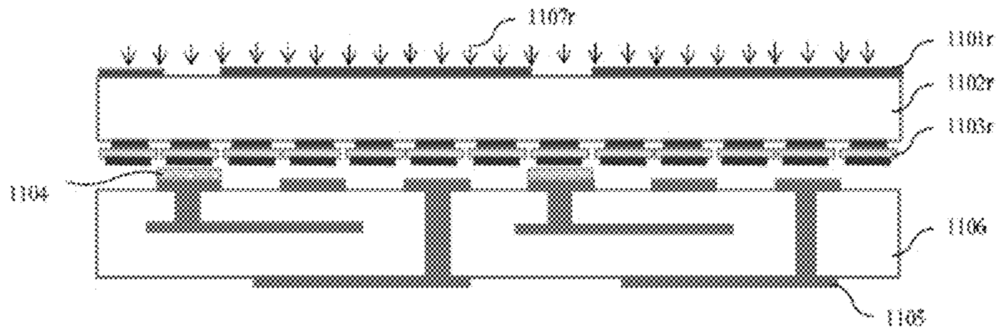

FIG. 20B

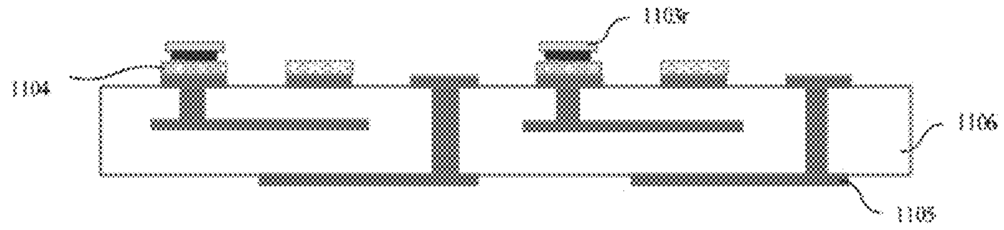

FIG. 20C

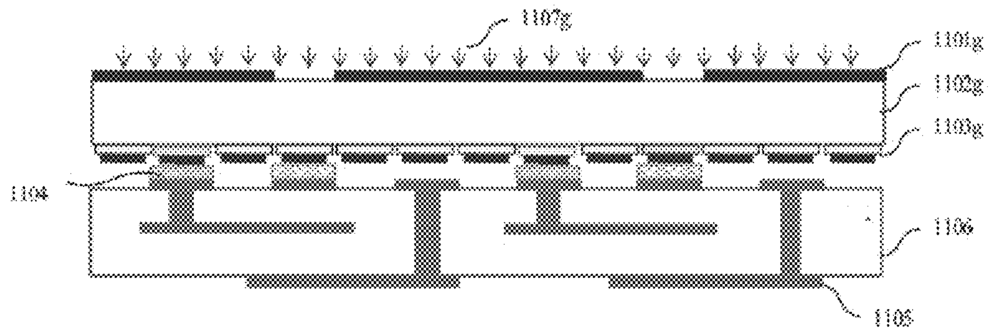

FIG. 20D

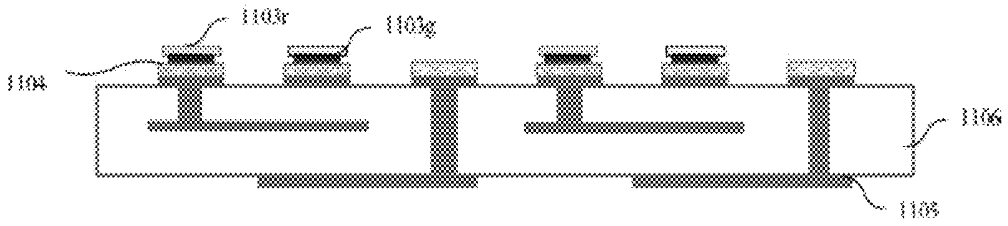

FIG. 20E

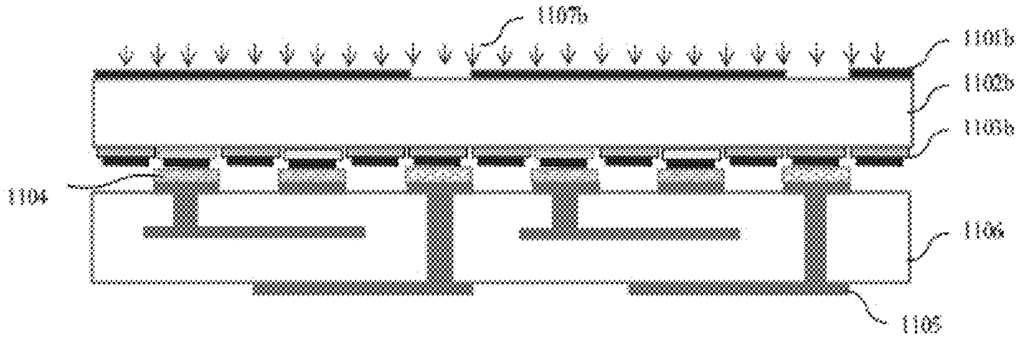

FIG. 20F

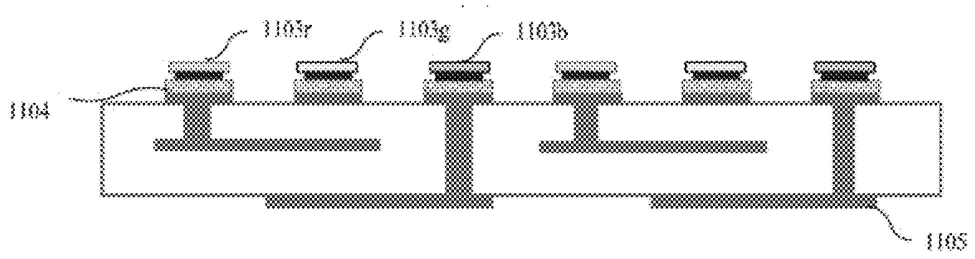

FIG. 20G

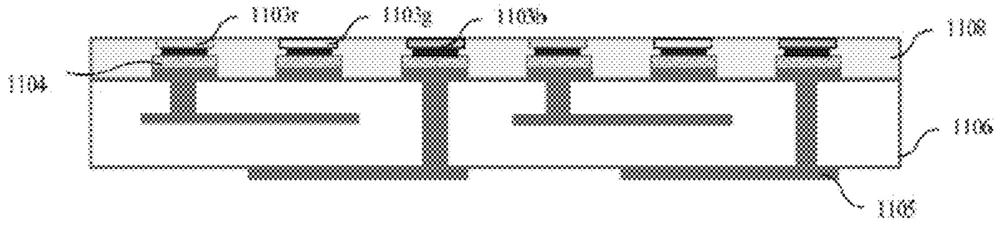

FIG. 20H

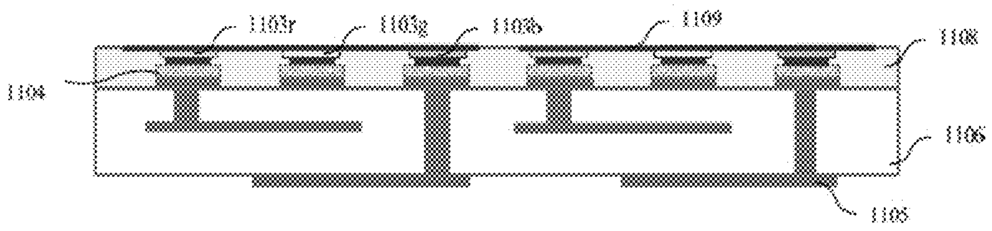

FIG. 20I

TRANSFERRING METHOD, MANUFACTURING METHOD, DEVICE AND ELECTRONIC APPARATUS OF MICRO-LED

[0001] This application is national stage application, filed under 35 U.S.C. § 371, of International Application No. PCT/CN2015/093787, filed on Nov. 4, 2015, which is hereby incorporated by reference in its entirety.

FIELD OF THE INVENTION

[0002] The present invention relates to Micro-Light Emitting Diode (micro-LED) array for display, and in particular, to a method for transferring micro-LED, a method for manufacturing a micro-LED device, a micro-LED device and an electronic apparatus containing a micro-LED device.

BACKGROUND OF THE INVENTION

[0003] The micro-LED technology refers to the LED array of small size integrated on a substrate with high density. Currently, the micro-LED technology is starting development, and it is expected in the industry that a high-quality micro-LED product comes into the market. High-quality micro-LED will have a deep affection on the conventional display products such as LCD/OLED that have already been put into the market.

[0004] In the process of manufacturing micro-LEDs, micro-LEDs are first formed on a donor wafer, and then the micro-LEDs are transferred to a receiving substrate. The receiving substrate is a display screen, for example.

[0005] One difficulty during manufacturing a micro-LED lies in how to transfer a micro-LED from a donor wafer to a receiving substrate. In the prior art, the transfer is generally performed by means of electrostatic pick-up. A transfer head array will be needed during the electrostatic pick-up. The structure of the transfer head array is relatively complicated, and the stability thereof shall be considered. An extra cost shall be paid for manufacturing a transfer head array. A phase change shall be made before pick-up with the transfer head array. In addition, during manufacturing with a transfer head array, limitations apply to the thermo budget of a micro-LED for phase change, which is generally lower than 350° C., or more specifically, lower than 200° C.; otherwise, the performance of the micro-LED will be degraded. It generally requires two transfers during the manufacturing with transfer head array, i.e., the transfer from a donor wafer to a carrier wafer and the transfer from the carrier wafer to a receiving substrate.

[0006] U.S. Pat. No. 8,333,860B1 discloses an array of transfer heads for transferring micro devices, in which a voltage is applied to the electrode in the transfer head to pick-up a micro device. This patent is fully incorporated hereby as reference herein.

[0007] U.S. Pat. No. 8,426,227B1 discloses a method of forming a micro light emitting diode array, in which a micro-LED array is transferred to a receiving substrate by using a transfer head array. This patent is fully incorporated hereby as reference herein.

SUMMARY OF THE INVENTION

[0008] One object of this invention is to provide a new technical solution for transferring micro-LEDs.

[0009] According to an embodiment of the present invention, there is provided method for transferring micro-LEDs, comprising: forming a mask layer on the backside of a laser-transparent original substrate, wherein micro-LEDs are formed on the front-side of the original substrate; bringing the micro-LEDs on the original substrate in contact with preset pads on a receiving substrate; and irradiating the original substrate from the original substrate side with laser through the mask layer, to lift-off micro-LEDs from the original substrate.

[0010] Preferably, the original substrate is a sapphire substrate, and the thickness range of the original substrate is 20-1000 μm, or 50-500 μm, or 100-300 μm.

[0011] Preferably, the spatial resolution range of the mask layer is 1-50 μm.

[0012] Preferably, the material of the mask layer is selected from photoresist, polymer, metal/metal compound, metal/metal alloy, metal/metal composite, silicon and silicide.

[0013] Preferably, the micro-LEDs are in contact with the pad through micro-bump bonding.

[0014] Preferably, during the micro-LEDs is lifted-off from the original substrate, a contactless action is applied onto the micro-LEDs.

[0015] Preferably, the contactless action is at least one of gravity, electrostatic force and electromagnetic force.

[0016] Preferably, the laser beam size of the laser is 50-5000 μm.

[0017] Preferably, the micro-LEDs are arranged on the receiving substrate in a redundant manner.

[0018] According to another embodiment of the present invention, there is provided a method for manufacturing a micro-LED device, comprising transferring micro-LEDs onto a receiving substrate of the micro-LED device by using the method according to the present invention.

[0019] According to another embodiment of the present invention, there is provided a micro-LED device, which is manufactured by using the method according to the present invention.

[0020] According to another embodiment of the present invention, there is provided an electronic apparatus, containing a micro-LED device according to the present invention.

[0021] In addition, it should be understood by a person skilled in the art that, although a lot of problems exist in the prior art, the solution of each embodiment or each claim could just improve in one or several aspects, and it is not necessary for it to solve all the technical problems listed in the Background of the Invention or in the prior art. It should be understood by a person skilled in the art that content which is not mentioned in a claim should not be regarded as a limitation to said claim.

[0022] Further features of the present invention and advantages thereof will become apparent from the following detailed description of exemplary embodiments according to the present invention with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate embodiments of the invention and, together with the description thereof, serve to explain the principles of the invention.

[0024] FIG. **1** shows a flow chart of an illustrative embodiment of the method according to the present invention.

[0025] FIG. **2**A to **2**G shows an example for transferring a micro-LED according to the present invention.

[0026] FIG. **3** shows a flow chart of another illustrative embodiment of the method according to the present invention.

[0027] FIGS. **4**A to **4**L show another example for transferring a micro-LED according to the present invention.

[0028] FIG. **5** shows a flow chart of still another illustrative embodiment of the method according to the present invention.

[0029] FIGS. **6**A to **6**F show an example for transferring red micro-LEDs according to the present invention.

[0030] FIGS. **7**A to **7**L show still another example for transferring a micro-LED according to the present invention.

[0031] FIG. **8** shows still an example for transferring a lateral micro-LED according to the present invention.

[0032] FIG. **9** shows still another example for transferring a lateral micro-LED according to the present invention.

[0033] FIG. **10** shows a flow chart of still another illustrative embodiment of the method according to the present invention.

[0034] FIG. **11** shows a flow chart of still another illustrative embodiment of the method according to the present invention.

[0035] FIGS. **12**A to **12**F show an example for repairing micro-LED defects according to the present invention.

[0036] FIG. **13** shows a flow chart of still another illustrative embodiment of the method according to the present invention.

[0037] FIGS. **14**A to **14**C show an example for pre-screening defect micro-LEDs according to the present invention.

[0038] FIGS. **15**A to **15**B show another example for pre-screening defect micro-LEDs according to the present invention.

[0039] FIGS. **16**A to **16**B is an enlarged view of the area "A" of FIG. **15**B.

[0040] FIG. **17** shows a flow chart of still another illustrative embodiment of the method according to the present invention.

[0041] FIGS. **18**A to **18**J show an example for transferring micro-LEDs at wafer level according to the present invention.

[0042] FIG. **19** shows a flow chart of still another illustrative embodiment of the method according to the present invention.

[0043] FIGS. **20**A to **20**I show another example for transferring micro-LEDs according to the present invention.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0044] Various exemplary embodiments of the present invention will now be described in detail with reference to the drawings. It should be noted that the relative arrangement of the components and steps, the numerical expressions, and numerical values set forth in these embodiments do not limit the scope of the present invention unless it is specifically stated otherwise.

[0045] The following description of at least one exemplary embodiment is merely illustrative in nature and is in no way intended to limit the invention, its application, or uses.

[0046] Techniques, methods and apparatus as known by one of ordinary skill in the relevant art may not be discussed in detail but are intended to be part of the specification where appropriate.

[0047] In all of the examples illustrated and discussed herein, any specific values should be interpreted to be illustrative only and non-limiting. Thus, other examples of the exemplary embodiments could have different values.

[0048] Notice that similar reference numerals and letters refer to similar items in the following figures, and thus once an item is defined in one figure, it is possible that it need not be further discussed for following figures.

[0049] Embodiments and examples of the present invention will be described below with reference to the drawings.

[0050] FIG. **1** shows a flow chart of an illustrative embodiment of the method for transfer micro-LED according to the present invention.

[0051] As shown in FIG. **1**, at step S**1100**, a micro-LED is formed on a laser-transparent original substrate.

[0052] The laser-transparent original substrate can be a sapphire substrate, SiC substrate and so on, for example. The micro-LED can be used for being mounted on a display screen panel.

[0053] It should be understood by a person skilled in the art that one micro-LED could be formed on the original substrate, or a plurality of micro-LED could be formed on the original substrate. For example, a plurality of micro-LEDs can be formed on the laser-transparent original substrate. The plurality of micro-LEDs can form an array.

[0054] In an example, in a case where a plurality of micro-LEDs are formed on the laser-transparent original substrate, the original substrate can be singulated or divided into multiple pieces for more flexible transferring.

[0055] At step S**1200**, the micro-LED is brought into contact with a pad preset on a receiving substrate.

[0056] For example, the receiving substrate is a display screen panel.

[0057] For example, the pad can be set for red pixel array, yellow pixel array or blue pixel array.

[0058] In an example, in a case where a plurality of micro-LED are formed, at least one micro-LED of the plurality of micro-LEDs can be brought into contact with at least one pad preset on the receiving substrate. The at least one micro-LED could be one, several or all of the plurality of micro-LEDs. It should be understood by a person skilled in the art that, although it is just described here that at least one micro-LED, which is expected to be lifted-off, is in contact with a pad, a remaining micro-LED of the plurality of micro-LEDs can also be in contact with a pad.

[0059] For example, in the step of contact (S**1200**), the micro-LED can be brought into contact with the pad preset on the receiving substrate via a liquid thin film. For example, the liquid thin film can include flux. Herein, the lift-off of a micro-LED will be easy through the surface tension force of the liquid thin film (flux), and the successful rate is high.

[0060] At step S**1300**, the original substrate is irradiated with laser from the original substrate side to lift-off the micro-LED from the original substrate.

[0061] In an example, in a case where at least one micro-LED is in contact with pad, at least one area on the original substrate can be irradiated with laser from the original substrate side to lift-off the at least one micro-LED from the original substrate. For example, a technician can select the at least one area. For example, the at least one area corresponds to the at least micro-LED, respectively. The at least one area can be just partial area on the original substrate, or can be the whole area.

[0062] In another example, the original substrate can be offset for transferring additional micro-LEDs.

[0063] In another example, after the transferring using the original substrate, an additional laser-transparent backup substrate can be used to cope with a situation in which micro-LEDs are missing at some points on the display screen panel. For example, a micro-LED can be formed on an additional laser-transparent backup substrate; the micro-LED on the backup substrate is brought into contact with a pad preset on a receiving substrate; and the backup substrate is irradiated with laser from the backup substrate side to lift-off the micro-LED from the backup substrate. In such a way, the quality of a display screen can further be improved.

[0064] An array of micro-LEDs can be formed on the receiving substrate after the transferring of micro-LEDs to the receiving substrate.

[0065] After the transferring of micro-LEDs to the receiving substrate, the present invention can further include subsequent steps.

[0066] For example, the lifted-off micro-LEDs can be reflow-soldered on the receiving substrate. A negative electrode can be deposited on the micro-LEDs. The reflow-soldering can be performed after micro-LEDs of each color are transferred. Alternatively, the reflow-soldering can be performed after micro-LEDs of all colors are transferred.

[0067] In addition, the soldered micro-LED can be filled with polymer. For example, a confocal dielectric deposition can be used instead of polymer filling.

[0068] In another embodiment, the present invention further includes a method for manufacturing a micro-LED device. The manufacturing method comprises transferring a micro-LED to a receiving substrate by using the method for transferring a micro-LED according to the present invention.

[0069] In another embodiment, the present invention further includes a micro-LED device, such as a display screen device. The micro-LED device can be manufactured by using the method for manufacturing a micro-LED device according to the present invention.

[0070] In comparison with the prior art, under the similar conditions, the micro-LED manufactured by using the solution of the present invention is relatively simple and reliable while maintaining a high quality, and the through put thereof is relatively high with low cost.

[0071] In another embodiment, the present invention further includes an electronic apparatus. The electronic apparatus contains a micro-LED device according to the present invention. For example, the electronic apparatus can be a mobile phone, a pad computer and so on.

[0072] In the solution of the present invention, a micro-LED is formed directly on the original substrate and it is transferred to a receiving substrate by means of laser lift-off. The solution of this invention have not been conceived by the prior art.

[0073] In addition, the micro-LED can be selectively transferred through the present invention.

[0074] In addition, in the solution of the present invention, the transfer can be performed only once while two transfers are needed in the prior art.

[0075] In addition, in comparison with the prior art, the solution of the present invention is relatively efficient, the cost is relatively low and product performance degrade due to an extra thermal budget will not occur.

[0076] In addition, in comparison with the prior art using a pick-up head, the present invention does not need a complicated pick-up system, and thus the cost of product manufactured using the present invention will relatively low and reliable.

[0077] In addition, since it does not need the temporary bonding in the prior art between the micro-LED and the intermediate carrier substrate, the cost can be further decreased by this invention.

[0078] Since it is not necessary to consider the phase change of bonding layer considered in the prior art using pick-up head, the manufacturing method of the present invention can have a relatively high through put and the extra thermal load limitation will be less. Consequently, under the similar conditions, the manufactured micro-LED will have a higher performance.

[0079] An example for transferring a micro-LED according to the present invention will be described below with reference to FIGS. **2**A to **2**G.

[0080] As shown in FIG. **2**A, micro-LEDs **2** are formed on a laser-transparent original substrate **1** such as sapphire substrate. The micro-LEDs **2** have a vertical micro-LED structure, for example. The micro-LEDs **2** contains, for example, a n-doped GaN layer, a multiple quantum well structure, a p-doped GaN layer, a p metal electrode, a bump, and so on.

[0081] As shown in FIG. **2**A, the plurality of micro-LEDs **2** can be singulated.

[0082] As shown in FIG. **2**B, the original substrate **1** is flipped over, and is aligned with a receiving substrate **4** with liquid thin film (for example, containing flux) **5**. The micro bumps on the micro-LEDs are in contact with the flux. Pads **3** are preset on the receiving substrate **4**. For example, the pads **3** include pad **3***r* for receiving red micro-LED, pad **3***b* for receiving blue micro-LED and pad **3***g* for receiving green micro-LED.

[0083] As shown in FIG. **2**C, partial areas **7** on the original substrate are selectively irradiated with laser **7**, to lift off the selected micro-LEDs **2***a*, **2***b* of the plurality of formed micro-LEDs from the original substrate.

[0084] As shown in FIG. **2**D, the original substrate **1** is lifted up. Because of the function of the surface tension force of the liquid thin film, the selected micro-LEDs **2***a*, **2***b* are lifted-off easily, while the other micro-LEDs are remained on the original substrate **1**.

[0085] Then, the original substrate is moved and the operations of FIGS. **2**C to **2**D are repeated, so that a plurality of micro-LEDs are transferred to the receiving substrate.

[0086] As shown in FIG. **2**E, the plurality of micro-LEDs are transferred to the receiving substrate **4**.

[0087] As shown in FIG. **2**F, for example, the plurality of micro-LEDs are soldered onto the receiving substrate through reflow soldering. Then, the flux is cleaned.

[0088] As shown in FIG. **2**G, the receiving substrate is filled with polymer **8** and is sealed. Then, n-metal electrode **9** is deposited, for example, using ITO material.

[0089] FIG. **3** shows a flow chart of another illustrative embodiment of the method for transferring a micro-LED according to the present invention.

[0090] As shown in FIG. **3**, at step **S2100**, micro-LEDs are formed on a laser-transparent original substrate.

[0091] At step S**2200**, an anisotropic conductive layer is provided on a receiving substrate.

[0092] For example, the anisotropic conductive layer is at least one of an anisotropic conductive film (ACF), an anisotropic conductive paste (ACP) and an anisotropic conductive tape (ACT).

[0093] At step S**2300**, the micro-LEDs are brought into contact with the anisotropic conductive layer on the receiving substrate. For example, the micro-LEDs are adhered to the anisotropic conductive layer on the receiving substrate. At this step, the micro-LEDs can be aligned with the receiving substrate in advance, for example.

[0094] At step S**2400**, the original substrate is irradiated with laser from the original substrate side to lift-off the micro-LEDs from the original substrate.

[0095] For example, the above steps can be performed with respect to red micro-LEDs, green micro-LEDs and blue micro-LEDs, respectively. Since the transfer with respect to the three micro-LEDs can be regarded as a simple repeat of the above steps, they are not repeated here. As long as each of the above steps are performed in a solution, the solution will be covered by this invention.

[0096] At step S**2500**, the anisotropic conductive layer is processed to electrically connect the micro-LEDs (its electrodes) with the pads on the receiving substrate.

[0097] In an example, pressure can be applied on the anisotropic conductive layer from the micro-LED side by using an auxiliary substrate. For example, the temperature of processing the anisotropic conductive layer can be between 150° C. and 200° C. For example, the applied pressure is between 1 MPa and 4 MPa. For example, the time period of applying pressure is between 10 second and 30 second.

[0098] In an example, the auxiliary substrate can be a flat rigid substrate. The inventors of the present application have found that the possible displacement of the micro-LEDs can be reduced by using a rigid substrate. This point has not noticed by a person skilled in the art.

[0099] For example, the surface of the auxiliary substrate can be coated with temporary bonding polymer. In this situation, the step S**2500** can further comprises: bonding the auxiliary substrate with the anisotropic conductive layer via the temporary bonding polymer; and after applying pressure, de-bonding the auxiliary substrate via the temporary bonding polymer, to remove the auxiliary substrate. The advantage of temporarily bonding the auxiliary substrate with the anisotropic conductive layer lies in that, the positions of the micro-LEDs can be relatively fixed, and the displacement of micro-LEDs during processing the anisotropic conductive layer is reduced.

[0100] After the above processes, normal subsequent processes can be done on the micro-LEDs. For example, the subsequent processes include: etching the temporary bonding polymer, to expose the epitaxial layers of the micro-LEDs; forming N-metal electrodes on the epitaxial layers of the micro-LEDs; and performing encapsulation on the N-metal electrodes.

[0101] For example, the receiving substrate can be a display substrate. Leads and pads can be set on the receiving substrate in advance, to be electronically connect with the micro-LEDs.

[0102] In this embodiment, the micro-LEDs and the receiving substrate are connected through a anisotropic conductive layer. This approach of processing is relatively simple and is more suitable for production in large bulk.

[0103] In another embodiment, the present invention further provides a method for manufacturing a micro-LED device. The manufacturing method comprises transferring micro-LEDs to a receiving substrate by using the method according to the present invention. For example, the receiving substrate is a display screen or display substrate. The micro-LED device is a display device, for example.

[0104] In another embodiment, the present invention further provides a micro-LED device, such as a display device. The micro-LED device can be manufactured by using the method for manufacturing a micro-LED device according to the present invention. In the micro-LED device according to the embodiment, the micro-LEDs come into electronic contact with the pads on the receiving substrate via the anisotropic conductive layer, which is different from the micro-LED device in the prior art.

[0105] In another embodiment, the present invention further provides an electronic apparatus. The electronic apparatus contains a micro-LED device according to the embodiment. For example, the electronic apparatus can be a mobile phone, a pad and so on.

[0106] FIG. **4**A to **4**L shows another example for transferring a micro-LED according to the present invention.

[0107] As shown in FIG. **4**A, an original substrate **201** such as a sapphire substrate has red micro-LEDs **202** thereon. The receiving substrate **204** such as display substrate has an anisotropic conductive film (ACF) **203** thereon. The receiving substrate **204** has signal leads **205** and pads **205'** for connecting micro-LEDs.

[0108] As shown in FIG. **4**B, the original substrate **201** (red micro-LED **202**) is brought into contact with the anisotropic conductive film **203** with a light force. For example, the red micro-LEDs **202** to be transferred can be aligned with the pads on the receiving substrate **204**. The original substrate **201** is irradiated with laser **206**, to selectively lift-off red micro-LEDs.

[0109] FIG. **4**C shows lifted-off red micro-LEDs **202***r*.

[0110] FIG. **4**D shows an original substrate **207** and the green micro-LEDs **208** thereof. The green micro-LEDs to be lifted-off are aligned with the pads on the receiving substrate **204**.

[0111] FIG. **4**E shows the situation in which the green micro-LEDs **208** are in contact with the anisotropic conductive film **203** with a light force. At least one green micro-LED is selectively lifted-off by using laser **209**.

[0112] FIG. **4**F shows lifted-off red micro-LEDs **202***r* and green micro-LEDs **208***g*.

[0113] FIG. **4**G shows an original substrate **210** and the blue micro-LEDs **211** thereof. The blue micro-LEDs to be lifted-off are aligned with the pads on the receiving substrate **204**.

[0114] FIG. **4**H shows the situation in which the blue micro-LEDs **211** are in contact with the anisotropic conductive film **203** with a light force. At least one blue micro-LED is selectively lifted-off by using laser **212**.

[0115] FIG. **4**F shows lifted-off red micro-LEDs **202***r*, green micro-LEDs **208***g* and blue micro-LEDs **211***b*.

[0116] After the transfer of micro-LEDs in the three colors, an inspection and repair can be performed with respect to any defect.

[0117] FIG. **4**J shows an auxiliary substrate **213**. The auxiliary substrate **213** is a flat rigid substrate, such a glass substrate. Polymer **214** such as 3M LC5200/5320 is coated on the auxiliary substrate **213**. The polymer can be cured through UV and can be de-bonded through red laser.

[0118] In FIG. **4**K, the ACF **203** is processed through the auxiliary substrate **213**. For example, the processing condition is that the temperature is be between 150° C. and 200° C., the applied pressure is between 1 MPa and 4 MPa, the time period of applying pressure is between 10 second and 30 second. Through these processes, the ACF **203** interconnects the micro-LEDs with corresponding pad in the vertical direction.

[0119] Then, the auxiliary substrate **213** is de-bonded (through the polymer **214**).

[0120] In FIG. **4**L, the normal subsequent processes are performed: etching the polymer **214**, to expose the epitaxial layers of the micro-LEDs; forming N-metal electrodes **215** (for example, ITO electrodes) on the epitaxial layers of the micro-LEDs; and performing encapsulation **216** on the N-metal electrodes (for example, PET lamination).

[0121] FIG. **5** shows a flow chart of still another illustrative embodiment of the method for transferring a micro-LED according to the present invention.

[0122] As shown in FIG. **5**, at step S**3100**, at least one micro-LED is transferred from an original substrate to a support body. For example, the original substrate is laser-transparent.

[0123] In an example, this step can comprises: mounting the original substrate onto the support body, wherein the micro-LEDs are formed on the original substrate, the support body has light-release adhesive on its surface, and the micro-LEDs are adhered to the support body via the light-release adhesive; irradiating the original substrate with laser from the original substrate side, for lifting-off the at least one micro-LED from the original substrate, and irradiating light from the support body side, to release un-lifted-off micro-LEDs. In this example, the support body is transparent.

[0124] For example, the light-release adhesive can be a UV tape. For example, the support body is stiff. The displacement of micro-LEDs during transfer will have affect on the quality of the final product. The inventors of this application have found that this displacement can be reduced by using a stiff support body. This point has not been noticed by a person skilled in the art. For example, the material of the support body can be PET.

[0125] Generally, it is difficult to form red micro-LEDs on a laser-transparent substrate such as a sapphire substrate. Accordingly, in an example, the red micro-LEDs are formed in advance and then are transferred to an original substrate, for being finally transferred to a receiving substrate. For example, in this embodiment, red micro-LEDs can be formed on a growth substrate. Then, the red micro-LEDs are transferred to an intermediate substrate. After that, the red micro-LEDs are transferred from the intermediate substrate to the original substrate.

[0126] At step S**3200**, the at least one micro-LED are transferred from the support body to a backup substrate.

[0127] For example, the backup substrate has elastomer or polymer on its surface. For example, the at least one micro-LED are bonded to the backup substrate through the elastomer or polymer.

[0128] In an example, this step can further comprises: bonding the support body with the at least one micro-LED to the backup substrate, and irradiating light from the support body side, to release the at least one micro-LED.

[0129] At step S**3300**, the at least one micro-LED are transferred from the backup substrate to a receiving substrate.

[0130] In an example, the step can further comprise: aligning the at least one micro-LED with the pads on the receiving substrate; and lifting-off the at least one micro-LED via the elastomer or polymer.

[0131] For example, the above transfer steps can be performed with respect to red micro-LEDs, blue micro-LEDs and greed micro-LEDs, respectively. They will not be repeatedly described here.

[0132] After the above processes, normal subsequent processes can be done on the micro-LEDs. For example, the subsequent processes include: coating polymer on the receiving substrate with micro-LEDs; curing the polymer; etching the polymer, to expose the epitaxial layers of the micro-LEDs; forming N-metal electrodes on the epitaxial layers of the micro-LEDs; and performing encapsulation on the N-metal electrodes.

[0133] The inventors of this invention have found that during the transfer of micro-LEDs, usually, only part of the micro-LEDs on the original substrate are transferred. If the micro-LEDs are directly transferred to a receiving substrate, the remaining micro-LEDs on the original substrate are often contaminated. In this embodiment, this contamination can be reduced through the transfer via an intermediate support body.

[0134] In another embodiment, the present invention further provides a method for manufacturing a micro-LED device. The manufacturing method comprises transferring micro-LEDs to a receiving substrate by using the method for transferring micro-LEDs according to this embodiment. For example, the receiving substrate is a display screen or display substrate. The micro-LED device is a display device, for example.

[0135] In another embodiment, the present invention further provides a micro-LED device, such as a display device. The micro-LED device can be manufactured by using the method for manufacturing a micro-LED device according to said embodiment.

[0136] In another embodiment, the present invention further provides an electronic apparatus. The electronic apparatus contains a micro-LED device according to the embodiment. For example, the electronic apparatus can be a mobile phone, a pad and so on.

[0137] Generally, red micro-LEDs cannot be directly formed on a laser-transparent original substrate such as sapphire substrate. Thus, it is required that red micro-LEDs are formed on an additional substrate in advance, and then are transferred to a sapphire substrate. FIG. **6**A to **6**F shows an example for transferring red micro-LEDs according to the present invention.

[0138] As shown in FIG. **6**A, red micro-LEDs **302** are formed on a growth substrate **301** such as GaAs substrate.

[0139] As shown in FIG. **6**B, the red micro-LEDs **302** are bonded with intermediate substrate **304** such as silicon substrate, through temporary bonding polymer **303**. The polymer **303** is a thermal release tape (TRT), for example.

[0140] As shown in FIG. **6**C, the growth substrate **301** is removed by a wet etching method, for example.

[0141] As shown in FIG. **6**D, a light resist **305** is coated on an original substrate **306** such as sapphire substrate. The original substrate **306** and the red micro-LEDs **302** are bonded through the resist **305**. The resist **305** can endure the temperature above 200° C.; generally above 250° C.

[0142] As shown in FIG. **6**E, the polymer **303** is processed under a temperature less than 200° C., to remove the intermediate substrate **304**.

[0143] As shown in FIG. **6**F, a O2 plasma etching is performed on the resist **305**, to isolate the respective red micro-LEDs **302**.

[0144] FIG. **7**A to **7**L shows still another example for transferring a micro-LED according to the present invention.

[0145] As shown in FIG. **7**A, the original substrate **406** has resist **405** and red micro-LEDs **402** thereon. The red micro-LEDs **402** are mounted onto a UV tape **411**. The UV tape **411** is located on a stiff PET support body **402**. The red micro-LEDs are selectively lifted-off through laser **413**.

[0146] As shown in FIG. **7**B, a ultraviolet is irradiated from the support body **412** side, to release un-lifted-off red micro-LEDs.

[0147] The lifted-off red micro-LEDs **402***r* are easily separated from the original substrate **406**. As shown in FIG. **7**C, the lifted-off red micro-LEDs **402***r* are adhered on the UV tape **411**, while other red micro-LEDs remain on the original substrate **406**.

[0148] As shown in FIG. **7**D, the backup substrate **415** such as glass substrate has elastomer/polymer **416** thereon. For example, the elastomer/polymer **416** is coated on the backup substrate **415** through spin coating. For example, the elastomer/polymer **416** is PDMS or 3M LC 5320, and can be cured through ultraviolet, for example.

[0149] As shown in FIG. **7**E, the support body is fully irradiated with ultraviolet, to release the red micro-LEDs and elastomer/polymer **416**.

[0150] After that, for example, if the micro-LEDs do not have bumps thereon, the micro-LEDs on the backup substrate **415** can be screen-printed using silver paste.

[0151] As shown in **7**F, the red micro-LEDs on the backup substrate **415** are aligned with the pads **419** on the receiving substrate **417**. For example, the receiving substrate is a display substrate, and includes signal leads **418**. For example, the red micro-LEDs are bonded to the pads **419** through reflow. The temperature of reflow can be more than 260° C. Then, the backup substrate **415** is separated from the receiving substrate **417** through laser lift-off.

[0152] FIG. **7**G shows separated receiving substrate **417**. The receiving substrate **417** has pads **419** and red micro-LEDs **402***r* thereon.

[0153] FIG. **7**H shows a schematic diagram of transferring red micro-LEDs **422***g* from a backup substrate **420** to the receiving substrate **417**. The backup substrate **420** has elastomer/polymer **421**.

[0154] FIG. **7**I shows the separated receiving substrate **417**. The receiving substrate **417** has pads **419**, red micro-LEDs **402***r* and green micro-LEDs **402***r* thereon.

[0155] FIG. **7**J shows a schematic diagram of transferring blue micro-LEDs **425***b* from a backup substrate **423** to the receiving substrate **417**. The backup substrate **423** has elastomer/polymer **424**.

[0156] FIG. **7**K shows the separated receiving substrate **417**. The receiving substrate **417** has pads **419**, red micro-LEDs **402***r,* green micro-LEDs **402***r* and blue micro-LEDs **425***b* thereon

[0157] In FIG. **7**L, the normal subsequent processes are performed on the transferred micro-LEDs: coating polymer **426** on the receiving substrate with micro-LEDs; curing the polymer **426**; etching the polymer, to expose the epitaxial layers of the micro-LEDs; forming N-metal electrodes **427** on the epitaxial layers of the micro-LEDs; and performing encapsulation (not shown) on the N-metal electrodes.

[0158] The solution of the present invention can use both vertical micro-LEDs and lateral micro-LEDs (flip-chip micro-LEDs). The micro-LEDs of vertical structure shown in the previous figures are illustrative and do not limit the scope of the present invention. FIG. **8** shows an example of lateral micro-LEDs.

[0159] In the example of FIG. **8**, the micro-LEDs are lateral micro-LEDs. In the lateral micro-LEDs, the P electrodes and the N electrodes thereof are located on the same side. FIG. **8** shows a red lateral micro-LED **505**, a green lateral micro-LED **506** and a blue lateral micro-LED **507**. The red lateral micro-LED **505** contains a P electrode **505***p* (positive electrode) and an N electrode **505***n* (negative electrode). The green lateral micro-LED **506** contains a P electrode **506***p* and an N electrode **506***n***6**. The blue lateral micro-LED **507** contains a P electrode **507***p* and an N electrode **507***n.*

[0160] Lead structures (including pads) **515***p,* **515***n,* **516***p,* **516***n,* **517***p,* **517***n* are provided in the substrate **504**. The lead structures **515***p,* **516***p,* **517***p* are for connection with positive electrodes. The lead structures **515***n,* **516***n,* **517***n* are for connection with negative electrodes.

[0161] In the example of FIG. **8**, the electrodes **505***p,* **505***n,* **506***p,* **506***n,* **507***p,* **507***n* are connected to the lead structures **515***p,* **515***n,* **516***p,* **516***n,* **517***p,* **517***n* via an anisotropic conductive layer **503**.

[0162] Polymer **502** can be coated between the lateral micro-LEDs. A transparent cover **501** can be provided over the lateral micro-LEDs.

[0163] FIG. **9** shows another example of lateral micro-LEDs. The difference between the example of FIG. **9** and that of FIG. **8** lies in that in FIG. **9**, the lateral micro-LEDs are connected to the substrate via solder rather than an anisotropic conductive layer.

[0164] FIG. **9** shows a red lateral micro-LED **605**, a green lateral micro-LED **606** and a blue lateral micro-LED **607**. The red lateral micro-LED **605** contains a P electrode **605***p* and an N electrode **605***n.* The green lateral micro-LED **606** contains a P electrode **606***p* and an N electrode **606***n.* The blue lateral micro-LED **607** contains a P electrode **60'7***p* and an N electrode **607***n.*

[0165] Lead structures (including pads) **615***p,* **615***n,* **616***p,* **616***n,* **61'7***p,* **617***n* are provided in the substrate **604**. The lead structures **615***p,* **616***p,* **61'7***p* are for connection with positive electrodes. The lead structures **615***n,* **616***n,* **617***n* are for connection with negative electrodes.

[0166] In the example of FIG. **9**, the electrodes **605***p,* **605***n,* **606***p,* **606***n,* **60'7***p,* **607***n* include solder bumps **602**, for example. The solder bumps **602** are coated with flux, for example. The electrodes **605***p,* **605***n,* **606***p,* **606***n,* **60'7***p,* **607***n* are bonded to the lead structures **615***p,* **615***n,* **616***p,* **616***n,* **61'7***p,* **617***n,* for example, through reflow-soldering, respectively.

[0167] For example, polymer **603** can filled between the lateral micro-LEDs and the substrate **604**. A transparent cover **601** can be provided over the lateral micro-LEDs. These processes are well-known in the art and thus are not described in detail here.

[0168] Therefore, for example, the present invention can further include the specific application of lateral micro-

LEDs. More specifically, the present invention further provides a method for transferring micro-LED. The method comprises: forming micro-LEDs on a laser-transparent original substrate, wherein the micro-LEDs are lateral micro-LEDs whose P electrodes and N electrodes are located on one side; bringing the P electrodes and N electrodes of the lateral micro-LEDs into contact with pads preset on a receiving substrate; and irradiating the original substrate with laser from the original substrate side to lift-off the lateral micro-LEDs from the original substrate.

[0169] A technical effect of using lateral micro-LEDs lies in that the processing for N metal electrode after the micro-LED transfer can be omitted. Furthermore, the wafer-level color-binning/testing can be simplified because the P electrodes and N electrodes already exist when a test at wafer-level is performed.

[0170] Furthermore, for example, in this method, an anisotropic conductive layer can be provided on a receiving substrate so as to bring the P electrodes and N electrodes of the lateral micro-LEDs into contact with the pads through the anisotropic conductive layer. Then, after lifting-off the lateral micro-LEDs from the original substrate, the anisotropic conductive layer is processed to electrically connect the P electrodes and N electrodes of the lateral micro-LEDs with the pads on the receiving substrate.

[0171] For example, the anisotropic conductive layer can be at least one of an anisotropic conductive film, an anisotropic conductive paste and an anisotropic conductive tape.

[0172] In addition to bringing the P electrodes and N electrodes of the lateral micro-LEDs into contact with pads preset on a receiving substrate by the stickiness of an anisotropic conductive layer or by the surface tension of liquid (such as flux), the present invention can further realize the contact by actions of gravity, electrostatic force and/or electromagnetic force.

[0173] For example, when the original substrate is irradiated with laser from the original substrate side, the lateral micro-LEDs are separated from the original substrate and the lateral micro-LEDs are dropped off onto the receiving substrate because of gravity.

[0174] For example, electrostatic force can be applied by applying voltage to the pads, so that the lateral micro-LEDs are dropped off onto the receiving substrate after being lifted-off from the original substrate because of the electrostatic force.

[0175] For example, in case that the lateral micro-LEDs contains magnetic substance such as Ni, a magnetic field can be provided, so that the lateral micro-LEDs are dropped off onto the receiving substrate after being lifted-off from the original substrate because of the electromagnetic force.

[0176] Similarly, the transfer method in the example of using lateral micro-LEDs can be applied to a method for manufacturing a micro-LED device for transferring the lateral micro-LEDs onto a receiving substrate. For example, the receiving substrate is a display screen or display substrate. The micro-LED device is a display device, for example.

[0177] For example, a micro-LED device, such as a display device, can be manufactured by using the manufacturing method. The micro-LED device adopts lateral micro-LEDs.

[0178] For example, the present invention further provides an electronic apparatus. The electronic apparatus contains the micro-LED device. For example, the electronic apparatus can be a mobile phone, a pad and so on.

[0179] FIG. **10** shows a flow chart of a method for transferring micro-LEDs by means of a contactless action according to the present invention.

[0180] As shown in FIG. **10**, in the method for transferring micro-LEDs, at step **S4100**, micro-LEDs are formed on a laser-transparent original substrate.

[0181] The micro-LEDs can be lateral micro-LEDs or can be micro-LEDs of vertical structure. In a lateral micro-LED, the P electrodes and N electrodes thereof are located on one same side. In a micro-LED of vertical structure, the P electrodes and N electrodes thereof are located on opposite sides.

[0182] At step **S4200**, the original substrate is irradiated with laser from the original substrate side to lift-off the micro-LEDs from the original substrate.

[0183] At step **S4300**, the micro-LEDs are brought into contact with pads preset on a receiving substrate through a contactless action.

[0184] The contactless action means that the action per se can be applied without the direct contact of objects. For example, the contactless action can be applied by means of a field. This is different from the action applied through the stickiness of an anisotropic conductive layer or by the surface tension of liquid (such as flux). It should be understand that although the contactless action per se can be applied without the direct contact of objects, the direct contact of objects can be kept through the contactless action. For example, several example of the contactless action are given as below.

[0185] For example, the contactless action is gravity. The micro-LEDs are placed over the receiving substrate. When the lift-off is performed, the micro-LEDs are dropped off on the receiving substrate and is left on the receiving substrate.

[0186] For example, the contactless action is electrostatic force. The electrostatic force can be applied by applying voltage to the pads.

[0187] For example, the contactless action is electromagnetic force. In case that the micro-LEDs contains magnetic substance, a magnetic field can be provided by means of a magnet such as permanent magnet, so that the micro-LEDs are dropped off and are left onto the receiving substrate after being lifted-off from the original substrate because of the electromagnetic force, thereby contacting with the pads directly or indirectly.

[0188] In this embodiment, the micro-LEDs are attached onto the receiving substrate via a contactless manner, which is not conceived by a person skilled in the art.

[0189] For example, the electrodes of the micro-LEDs include solder bumps. The solder bumps are bonded with the pads, for example, through reflow-soldering and so on.

[0190] The order of steps in FIG. **10** will not constitute any limitation o the present invention. For example, although the step **S4200** are shown in front of the step **S4030**, the action of gravity, the action of electrostatic force or the action of electromagnetic force can be applied before the step **S4200** or at the time when performing the step **S4200**. In another word, for example, the step **S4300** can be performed before the step **S4200** or simultaneously with the step **S4200**.

[0191] Similarly, the transfer method can be applied to a method for manufacturing a micro-LED device for transferring the micro-LEDs onto a receiving substrate. For example, the receiving substrate is a display screen or display substrate. The micro-LED device is a display device, for example.

[0192] For example, a micro-LED device, such as a display device, can be manufactured by using the manufacturing method.

[0193] For example, the present invention further provides an electronic apparatus. The electronic apparatus contains the micro-LED device. For example, the electronic apparatus can be a mobile phone, a pad and so on.

[0194] FIG. **11** shows a flow chart of still another illustrative embodiment of the method according to the present invention.

[0195] As shown in FIG. **11**, at step S**5100**, a micro-LED defect pattern on a receiving substrate is obtained.

[0196] For example, the defect pattern can be obtained through an automatic visual inspection (AVI), a photoluminescence (PL), an electro-optical test, or an electric-performance test, etc. These detection approaches are not the improvement of this invention and can be the prior art, and thus they are not described here in details.

[0197] At step S**5200**, micro-LEDs corresponding to the defect pattern are formed on a laser-transparent repair carrier substrate.

[0198] In an example, the micro-LEDs can first be mounted onto a temporary substrate in the defect pattern.

[0199] For example, the temporary substrate is rigid, such as a PET plate. For example, an adhesive, such as an UV tape, is coated on the temporary substrate. The micro-LEDs on a laser-transparent original substrate can be brought into contact with the adhesive. Then, the original substrate is irradiated with laser in the defect pattern, to lift-off the micro-LEDs from the original substrate. The lifted-off micro-LEDs in the defect pattern are kept on the temporary substrate while the un-lifted-off micro-LEDs are released through a partial adhesive releasing. After the partial adhesive releasing, the un-lifted-off micro-LEDs remain on the original substrate. The partial adhesive releasing means that after the releasing, the residual stiction of the adhesive is sufficient to separate the lifted-off micro-LEDs from the original substrate while it cannot separate the un-lifted-off micro-LEDs from the original substrate.

[0200] Next, the micro-LEDs on the temporary substrate are transferred to the repair carrier substrate.

[0201] For example, the micro-LEDs on the temporary substrate can first be bonded onto the repair carrier substrate. The micro-LEDs on the temporary substrate can be bonded onto the repair carrier substrate through a polymer thin film, for example. Then, the micro-LEDs is lifted-off from the temporary substrate through a complete adhesive releasing. For example, after the micro-LEDs is lifted-off from the temporary substrate, at least one part of the polymer thin film is removed, such as the polymer thin film portion between micro-LEDs.

[0202] For example, the partial adhesive releasing and the complete adhesive releasing can be performed through UV exposure.

[0203] Generally, the exposure time or energy used in the partial adhesive releasing is less than the standard exposure time or energy, i.e. the exposure time in the partial releasing is less than the standard time and/or the energy in the partial releasing is less than the standard energy. The exposure time or energy used in the complete adhesive releasing is higher than or equal to the standard exposure time or energy, i.e. the exposure time in the complete releasing is larger than or equal to the standard time and/or the energy in the complete releasing is larger than or equal to the standard energy. The standard exposure time or energy can be the exposure time or energy just releasing the adhesive completely, or can be the nominal exposure time or energy.

[0204] At step S**5300**, the micro-LEDs on the repair carrier substrate are aligned with the defect positions on the receiving substrate, and the micro-LEDs are brought into contact with the pads at the defect positions.

[0205] At step S**5400**, the repair carrier substrate is irradiated with laser from the repair carrier substrate side, to lift-off the micro-LEDs from the repair carrier substrate.

[0206] For example, the repair carrier substrate is a sapphire substrate. As described above, in the present invention, the substrate adopted is laser-transparent. That is, compared with the device such as a micro-LED to be lifted off, the substrate is transparent with respect to the laser to be irradiated, i.e. the substrate has a higher transmittance. Accordingly, the energy in the laser will be mainly absorbed by the device (such as a micro-LED) behind it when it is irradiated, to achieve the lift-off. Of course, the larger the transmittance difference between the laser-transparent substrate and the device is, the better the lift-off effect is.

[0207] In another embodiment, the present invention further provides a method for manufacturing a micro-LED device. The manufacturing method comprises repairing micro-LED defects on a receiving substrate by using the method for repairing micro-LED defects according to this embodiment. For example, the receiving substrate is a display screen or display substrate. The micro-LED device is a display device, for example.

[0208] In another embodiment, the present invention further provides a micro-LED device, such as a display device. The micro-LED device can be manufactured by using the method for manufacturing a micro-LED device according to said embodiment.

[0209] In another embodiment, the present invention further provides an electronic apparatus. The electronic apparatus contains a micro-LED device according to the embodiment. For example, the electronic apparatus can be a mobile phone, a pad and so on.

[0210] After micro-LEDs of large scale are transferred to a receiving substrate, a yield loss to a certain degree will arise. Thus, a repair is necessary at most cases to guarantee the product quality. In the prior art, a pick-up head is used to perform the repair. The repair approach of the prior is relatively complicated and the efficiency thereof is relatively low. The repair approach of this invention is relatively simple and/or has a relatively high efficiency.

[0211] FIGS. **12**A to **12**F show an example for repairing micro-LED defects according to the present invention.

[0212] As shown in FIG. **12**A, micro-LEDs **703** are formed on an original substrate **701**. The micro-LEDs **703** include defect micro-LEDs and good micro-LEDs. The micro-LEDs are mounted onto a temporary substrate **705** through an adhesive layer **704**. The adhesive layer **704** is an UV tape for example. The temporary substrate **705** is a PET plate, for example. The original substrate **701** is irradiated with laser **702** in a defect pattern, to lift off the defect micro-LEDs from the original substrate.

[0213] As shown in FIG. **12**B, the adhesive layer (the UV tape) **704** is partially exposed with an ultra violet radiation **706** from the side of the temporary substrate **705**.

[0214] As shown in FIG. **12**C, after the partial exposure, the adhesive layer **704** still remain a certain residual stiction sufficient to separate the laser-lifted-off micro-LEDs **703***b* from the original substrate, while leaving the un-laser-lifted-off micro LEDs **703***a* on the original substrate. Since the micro-LEDs are lifted off with laser in the defect pattern, the adhesive layer **704** (or the temporary substrate **705**) has good micro-LEDs arranged in the defect pattern thereon.

[0215] As shown in FIG. **12**D, the micro-LEDs **703***b* on the adhesive layer **704** are temporarily bonded onto a repair carrier substrate **707** through a polymer thin film **708**. Then, the adhesive layer **704** is completely exposed. As shown in FIG. **12**E, the adhesive layer **704** is separated from the micro-LEDs **703***b*. FIG. **12**F shows the repair carrier substrate **707** and the micro-LEDs **703***b* in the defect pattern thereon for repairing. As shown in FIG. **12**F, the bonding polymer thin film **708** between the micro-LEDs **703***b* can be removed, leaving the thin film portions between the micro-LEDs **703***b* and the substrate **707**.

[0216] Next, the repair carrier substrate **707** can be used for repairing the defects on a receiving substrate by means of laser lifting-off.

[0217] FIG. **13** shows a flow chart of the method for pre-screening defect micro-LEDs of still another illustrative embodiment according to the present invention.

[0218] As shown in FIG. **13**, at step S**6100**, a defect pattern of defect micro-LEDs on a laser-transparent substrate is obtained.

[0219] For example, the defect pattern can be obtained through an automatic visual inspection, a photoluminescence, an electro-optical test, or an electric-performance test.

[0220] At step S**6200**, the laser-transparent substrate is irradiated with laser from the laser-transparent substrate side in accordance with the defect pattern, to lift-off the defect micro-LEDs from the laser-transparent substrate.

[0221] In an example, an action is applied through a contact manner to separate the lifted-off micro-LEDs from the laser-transparent substrate. For example, the micro-LEDs on the laser-transparent substrate can be mounted onto an UV tape. For example, the UV tape is attached on a rigid support body. The defect micro-LEDs are lifted-off through laser to the UV tape and the non-defect micro-LEDs are kept on the laser-transparent substrate though an UV exposure.

[0222] In another example, the defect micro-LEDs can be lifted-off from the laser-transparent substrate through a contactless action. As described above, the contactless action is applied without contact. For example, the contactless action is at least one of gravity, electrostatic force and electromagnetic force. These actions can be applied according to the manner described above.

[0223] According to the present invention, a repair can be performed after the micro-LEDs are transferred to the receiving substrate, or a repair can be performed on the laser-transparent substrate before the transfer. For example, good micro-LEDs are formed at the position of the lifted-off micro-LEDs on the laser-transparent substrate. The good micro-LEDs can be formed at the defect positions by using the repairing method described above.

[0224] In another embodiment, the present invention further provides a method for manufacturing a micro-LED device. The manufacturing method comprises pre-screening defect micro-LEDs defects on a laser-transparent substrate by using the method for prescreening defect micro-LEDs according to this embodiment. For example, the receiving substrate is a display screen or display substrate. The micro-LED device is a display device, for example.

[0225] In another embodiment, the present invention further provides a micro-LED device, such as a display device. The micro-LED device can be manufactured by using the method for manufacturing a micro-LED device according to said embodiment.

[0226] In another embodiment, the present invention further provides an electronic apparatus. The electronic apparatus contains a micro-LED device according to the embodiment. For example, the electronic apparatus can be a mobile phone, a pad and so on.

[0227] In the prior art, both good micro-LEDs and defect micro-LEDs on a substrate are transferred to a receiving substrate during the transfer. However, according to the solution of this invention, only known-good micro-LEDs are transferred to the receiving substrate.

[0228] FIGS. **14**A to **14**C show an example for pre-screening defect micro-LEDs according to the present invention.

[0229] In this example, the defect pattern on a laser-transparent substrate is obtained through an automatic visual inspection (AVI), a photoluminescence (PL), an electro-optical test, or an electric-performance test, etc. Then, the laser-transparent substrate is mounted onto a UV tape. As shown in FIG. **14**A, the UV tape **804** is placed on a support body **805**. The laser-transparent substrate **801** is mounted onto the UV tape **804** via micro-LEDs **803**. The substrate **801** is irradiated with laser in the defect pattern, to lift off the defect micro-LEDs from the substrate **801**.

[0230] As shown in FIG. **14**B, the UV tape **804** is partially exposed with an ultra violet radiation **806** from the side of the support body **805**.

[0231] As shown in FIG. **14**C, after the partial exposure, the UV tape **804** still remains a certain residual stiction sufficient to separate the laser-lifted-off micro-LEDs **803***b* from the substrate **801**, while leaving the un-laser-lifted-off micro-LEDs **803***a* on the substrate **801**.

[0232] FIGS. **15**A to **15**B show another example for pre-screening defect micro-LEDs according to the present invention.

[0233] As shown in FIG. **15**A, the substrate (wafer) **901** has good micro-LEDs **902** and defect micro-LEDs **903** thereon. The defect micro-LEDs **903** are pre-screened before the micro-LEDs are transferred from the substrate **901** to a receiving substrate (not shown), by means of the method of this invention. FIG. **15**B shows the substrate **901** after the defect micro-LEDs are pre-screened.

[0234] FIGS. **16**A to **16**B is an enlarged view of the area "A" of FIG. **15**B. As shown in FIG. **16**A, the defect micro-LED at the position **903***a* is pre-screened. As shown in FIG. **16**B, a repair can be performed directly on the substrate **901**, to form a good micro-LED at the position **903***a*. Alternatively, the repair can be performed after the micro-LEDs are transferred from the substrate **901** to a receiving substrate.

[0235] FIG. **17** shows a flow chart of still another illustrative embodiment of the method for transferring micro-LED at wafer level according to the present invention.

[0236] As shown in FIG. **17**, at step S**7100**, micro-LEDs on a laser-transparent original substrate are temporarily bonded onto a carrier substrate via a first bonding layer.

[0237] For example, the first bonding layer can be a UV or light releasable tape. For example, the carrier substrate can be a PET plate. The PET plate is rigid and can provide a sufficient support to the UV or light releasable tape to prevent a displacement of the transferred micro-LEDs.

[0238] At step **S7200**, the original substrate is irradiated from the original substrate side with laser, to lift-off selected micro-LEDs from the original substrate.

[0239] At step **S7300**, a partial release is performed on the first bonding layer, to transfer the selected micro-LEDs to the carrier substrate.

[0240] For example, the release degree of the first bonding layer can be controlled by controlling the intensity and/or the irradiation time of the UV or light irradiating the first bonding layer.

[0241] In an example, in order to sufficient guarantee the transfer of the lifted-off micro-LEDs onto the carrier substrate, a contactless action can be applied onto the micro-LEDs during the partial release. For example, the contactless action is at least one of gravity, electrostatic force and electromagnetic force.

[0242] At step **S7400**, the micro-LEDs on the carrier substrate are temporarily bonded onto a transfer head substrate via a second bonding layer.

[0243] At step **S7500**, a full release is performed on the first bonding layer, to transfer the micro-LEDs to the transfer head substrate.

[0244] For example, the partial release and the full release are performed by exposure using UV or light.

[0245] At step **S7600**, the micro-LEDs on the transfer head substrate is bonded onto a receiving substrate.

[0246] At step **S7700**, the transfer head substrate is removed by releasing the second bonding layer, to transfer the micro-LEDs to the receiving substrate.

[0247] For example, the second bonding layer can be released by a thermal release.

[0248] In an example, the transferred micro-LEDs are vertically structured. The vertically-structured micro-LEDs can provide a display panel with a higher resolution. The vertically-structured micro-LEDs are un-finished micro-LEDs. So, after the micro-LEDs are transferred to the receiving substrate, N electrodes are formed on the micro-LEDs on the receiving substrate and an encapsulation is performed on the N electrodes, to form complete micro-LEDs.

[0249] In order to improve the yield of the display panel, the micro-LEDs can be arranged on the receiving substrate in a redundant manner.

[0250] In another embodiment, the present invention further provides a method for manufacturing a micro-LED device. The manufacturing method comprises transferring micro-LEDs onto a receiving substrate of the micro-LED device by using the method for transferring micro-LED at wafer level according to this embodiment. For example, the receiving substrate is a display screen or display substrate. The micro-LED device is a display device, for example.

[0251] In another embodiment, the present invention further provides a micro-LED device, such as a display device. The micro-LED device can be manufactured by using the method for manufacturing a micro-LED device according to said embodiment.

[0252] In another embodiment, the present invention further provides an electronic apparatus. The electronic apparatus contains a micro-LED device according to the embodiment. For example, the electronic apparatus can be a mobile phone, a pad and so on.

[0253] FIGS. **18**A to **18**J show an example for transferring micro-LEDs at wafer level according to the present invention.

[0254] As shown in FIG. **18**A, micro-LEDs are formed on a laser-transparent original substrate **1001**. FIG. **18**A shows red micro-LEDs **1003***r*. The original substrate **1001** is a sapphire substrate, for example.

[0255] The micro-LEDs **1003***r* are temporarily bonded onto a carrier substrate **1005** via a first bonding layer **1004**. For example, the first bonding layer **1005** can be a UV or light releasable tape. For example, the carrier substrate can be a PET plate.

[0256] In FIG. **18**A, the original substrate **1001** is irradiated from the original substrate side with laser **1002**, to lift-off selected micro-LEDs from the original substrate.

[0257] In FIG. **18**B, a partial release is performed on the first bonding layer **1004**. As shown in FIG. **18**C, the selected micro-LEDs **1003***r* are transferred to the carrier substrate **1005**.

[0258] For example, the release degree of the first bonding layer **1004** can be controlled by controlling the intensity and/or the irradiation time of the UV or light **1006** irradiating the first bonding layer.

[0259] In order to improve the effect of the release, a contactless action can be applied onto the micro-LEDs during the partial release. For example, the contactless action is at least one of gravity, electrostatic force and electromagnetic force.

[0260] Next, in FIG. **18**D, the micro-LEDs **1003***r* are temporarily bonded onto a transfer head substrate **1008** via a second bonding layer **1007**.

[0261] In FIG. **18**E, a full release is performed on the first bonding layer **1004**. In FIG. **18**F, the micro-LEDs **1003***r* are transferred to the transfer head substrate **1008**.

[0262] For example, the partial release and the full release can be performed by exposure using UV or light.

[0263] FIGS. **18**G and **18**H show a transfer head substrate **1010** and a transfer head substrate **1012**, respectively. The transfer head substrate **1010** has green micro-LEDs **1003***g* and a second bonding layer **1009**. The transfer head substrate **1012** has blue micro-LEDs **1003***b* and a second bonding layer **1011**.

[0264] In FIG. **18**I, the micro-LEDs **1003***r* on the transfer head substrate is bonded onto a receiving substrate **1013** for finishing the transfer.

[0265] In FIG. **18**J, the second bonding layer is released and the transfer head substrate is removed. The red, green and blue micro-LEDs **1003***r*, **1003***g*, **1003***b* are transferred to the receiving substrate **1013**.

[0266] For example, the second bonding layer can be released by a thermal release.

[0267] The above micro-LEDs can be vertically structured. So, after the micro-LEDs are transferred to the receiving substrate **1013**, N electrodes are formed on the micro-LEDs and an encapsulation is performed on the N electrodes, to form complete micro-LEDs (not shown).

[0268] FIG. **19** shows a flow chart of still another illustrative embodiment of the method for transferring micro-LED according to the present invention.

[0269] As shown in FIG. **19**, at step **S8100**, a mask layer is formed on the backside of a laser-transparent original substrate, wherein micro-LEDs are formed on the front-side of the original substrate.

[0270] For example, the original substrate can be a sapphire substrate. The thickness range of the original substrate can 20-1000 μm, or 50-500 μm, or 100-300 μm.

[0271] In this embodiment, the mask layer is used to selectively lift-off micro-LEDs, which can provide a relatively high display resolution. In the prior art, the display resolution is normally larger than 50 μm. For example, according this invention, the spatial resolution range of the mask layer can be 1-50 μm.

[0272] For example, the material of the mask layer is selected from photoresist, polymer, metal/metal compound, metal/metal alloy, metal/metal composite, silicon and silicide.

[0273] For example, the micro-LEDs can be vertical micro-LEDs or can be lateral micro-LEDs.

[0274] At step **S8200**, the micro-LEDs on the original substrate is brought into contact with preset pads on a receiving substrate.

[0275] For example, the micro-LEDs are in contact with the pad through micro-bump bonding. The micro-bump bonding can be solder, alloy, metal, paste, adhesive, ink, etc.

[0276] At step **S8300**, the original substrate is irradiated from the original substrate side with laser through the mask layer, to lift-off micro-LEDs from the original substrate.

[0277] For example, during the micro-LEDs is lifted-off from the original substrate, a contactless action can be applied onto the micro-LEDs to ensure the lift-off of the micro-LEDs. For example, the contactless action is at least one of gravity, electrostatic force and electromagnetic force.

[0278] In this invention, since a mask layer is used to select micro-LEDs to be lifted-off, the control of laser beams can be simplified. For example, it is unnecessary to control the laser to select micro-LEDs to be lifted-off. Furthermore, in this invention, it is unnecessary to us a laser with small beam size to improve the resolution and thus the requirement for laser beam size is lowered. In an example, the usage of a relatively large laser beam can improve the lifting-off speed. For example, the laser beam size of the laser is 50-5000 μm.

[0279] In an example, the micro-LEDs can be arranged on the receiving substrate in a redundant manner to improve the yield of production.

[0280] In another embodiment, the present invention further provides a method for manufacturing a micro-LED device. The manufacturing method comprises transferring micro-LEDs onto a receiving substrate of the micro-LED device by using the method for transferring micro-LED according to this embodiment. For example, the receiving substrate is a display screen or display substrate. The micro-LED device is a display device, for example.

[0281] In another embodiment, the present invention further provides a micro-LED device, such as a display device. The micro-LED device can be manufactured by using the method for manufacturing a micro-LED device according to said embodiment.

[0282] In another embodiment, the present invention further provides an electronic apparatus. The electronic apparatus contains a micro-LED device according to the embodiment. For example, the electronic apparatus can be a mobile phone, a pad and so on.

[0283] FIGS. **20**A to **20**I show another example for transferring micro-LED according to the present invention.

[0284] As shown in FIG. **20**A, the substrate **1102***r* such as a sapphire substrate has red micro-LEDs on its front-side and has a mask **1101***r* on its backside. A receiving substrate **1106** is provided with leads and pads **1105**. For example, solder **1104** is provided on the pads corresponding to the micro-LEDs to be lifted-off.

[0285] As shown in FIG. **20**B, the red micro-LEDs **1103***r* are brought into contact with pads **1105** through the solder **1104**. A laser **1107***r* is used to irradiate the substrate **1102***r* through the mask **1101***r*, to lift-off the red micro-LEDs **1103***r*. In this procedure, a contactless action, such as gravity, electrostatic force, electromagnetic force and so on, can be applied onto the micro-LEDs **1103***r*, to guarantee a complete lift-off.

[0286] As shown in FIG. **20**C, the red micro-LEDs are transferred onto the receiving substrate **1106**.

[0287] FIGS. **20**D and **20**E show the procedure of transferring green micro-LEDs. As shown in FIG. **20**D, a laser **1107***g* is used to irradiate a substrate **1102***g* through a mask **1101***g* to lift-off green micro-LEDs **1103***g*. FIG. **20**E shows the receiving substrate **1106** after the lifting-off.

[0288] FIGS. **20**F and **20**G show the procedure of transferring blue micro-LEDs. As shown in FIG. **20**F, a laser **1107***b* is used to irradiate a substrate **1102***b* through a mask **1101***b* to lift-off blue micro-LEDs **1103***b*. FIG. **20**G shows the receiving substrate **1106** after the lifting-off.

[0289] Post processing can be done on the receiving substrate **1106** after the transfer. For example, the micro-LEDs can be vertical micro-LEDs. As shown in FIG. **20**H, polymer **1108** is coated on the micro-LEDs **1103***r*, **1103***g*, **1103***b*, to protect the micro-LEDs. The polymer **1108** is etched to expose the epitaxial layers of the micro-LEDs. As shown in FIG. **20**I, N-metal electrodes are formed on the epitaxial layers of the micro-LEDs to finish the micro-LEDs.

[0290] Although some specific embodiments of the present invention have been demonstrated in detail with examples, it should be understood by a person skilled in the art that the above examples are only intended to be illustrative but not to limit the scope of the present invention. It should be understood by a person skilled in the art that the above embodiments can be modified without departing from the scope and spirit of the present invention. The scope of the present invention is defined by the attached claims.

What is claimed is:

1. A method for transferring micro-LEDs, comprising:

forming a mask layer on the backside of a laser-transparent original substrate, wherein micro-LEDs are formed on the front-side of the original substrate;

bringing the micro-LEDs on the original substrate in contact with preset pads on a receiving substrate; and

irradiating the original substrate from the original substrate side with laser through the mask layer, to lift-off micro-LEDs from the original substrate.

2. The method according to claim **1**, wherein the original substrate is a sapphire substrate, and the thickness range of the original substrate is 20-1000 μm, or 50-500 μm, or 100-300 μm.

3. The method according to claim **1**, wherein the spatial resolution range of the mask layer is 1-50 μm.

4. The method according to claim **1**, wherein the material of the mask layer is selected from photoresist, polymer, metal/metal compound, metal/metal alloy, metal/metal composite, silicon and silicide.

5. The method according to claim **1**, wherein the micro-LEDs are in contact with the pad through micro-bump bonding.

6. The method according to claim **1**, wherein during the micro-LEDs is lifted-off from the original substrate, a contactless action is applied onto the micro-LEDs.

7. The method according to claim **6**, wherein the contactless action is at least one of gravity, electrostatic force and electromagnetic force.

8. The method according to claim **1**, wherein the laser beam size of the laser is 50-5000 μm.

9. The method according to claim **1**, wherein the micro-LEDs are arranged on the receiving substrate in a redundant manner.

10. A method for manufacturing a micro-LED device, comprising transferring micro-LEDs onto a receiving substrate of the micro-LED device by using the method according to claim **1**.

11. A micro-LED device, which is manufactured by using the method according to claim **10**.

* * * * *

专利名称(译)	微型led的转移方法，制造方法，装置和电子设备		
公开(公告)号	US20180069149A1	公开(公告)日	2018-03-08
申请号	US15/559801	申请日	2015-11-04
[标]申请(专利权)人(译)	歌尔声学股份有限公司		
申请(专利权)人(译)	GOERTEK.INC		
当前申请(专利权)人(译)	GOERTEK.INC		
[标]发明人	ZOU QUANBO LU MANEN WANG ZHE		
发明人	ZOU, QUANBO LU, MANEN WANG, ZHE		
IPC分类号	H01L33/00 H01L27/15 H01L25/075 H01L33/20 H01L21/68 H01L21/786		
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外部链接	Espacenet USPTO		

摘要(译)

本发明公开了一种微型LED的转移方法，制造方法，装置和电子设备。转移微LED的方法包括：在激光透明的原始基板的背面上形成掩模层，其中微LED形成在原始基板的正面上;使原始基板上的微型LED与接收基板上的预设焊盘接触;用激光通过掩模层从原始衬底侧照射原始衬底，以从原始衬底剥离微LED。