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(54) **MICRO-LED DEVICE, DISPLAY APPARATUS AND METHOD FOR MANUFACTURING A MICRO-LED DEVICE**

(71) Applicant: **Goertek Inc.**, Weifang City, Shandong (CN)

(72) Inventors: **QUANBO ZOU**, Weifang City, Shandong (CN); **Peixuan CHEN**, Weifang City, Shandong (CN); **Xiangxu FENG**, Weifang City, Shandong (CN)

(73) Assignee: **Goertek Inc.**, Weifang City, Shandong (CN)

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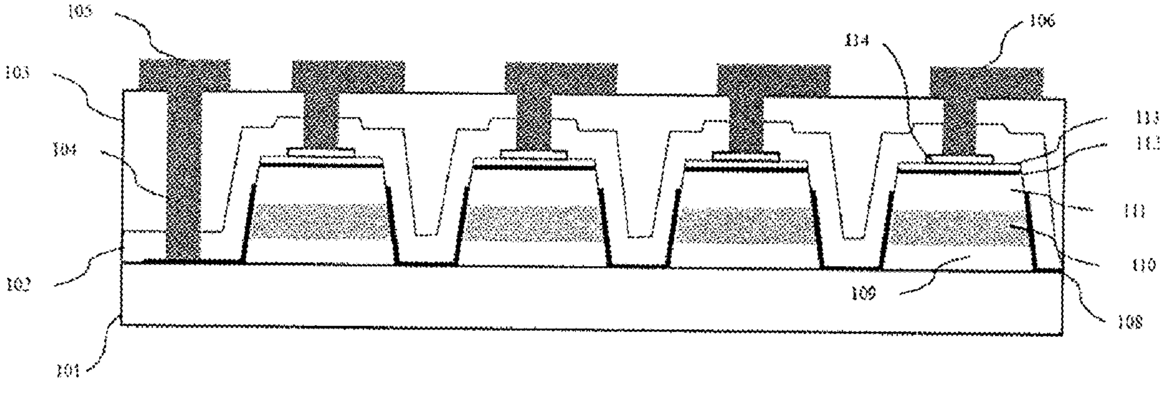
CPC ***H01L 27/153*** (2013.01); ***H01L 25/18*** (2013.01)

(57) ABSTRACT

A micro-LED device, a display apparatus and a method for manufacturing a micro-LED device are provided. The micro-LED device comprises: a growth substrate; a plurality of vertical micro-LEDs formed on the growth substrate; a first type electrode formed on top of each of the vertical micro-LEDs; and a second type electrode formed on side surface of each of the vertical micro-LEDs.



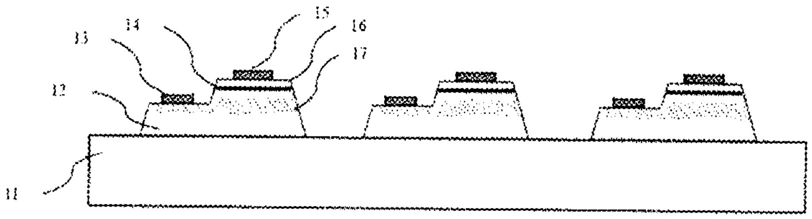


FIG. 1

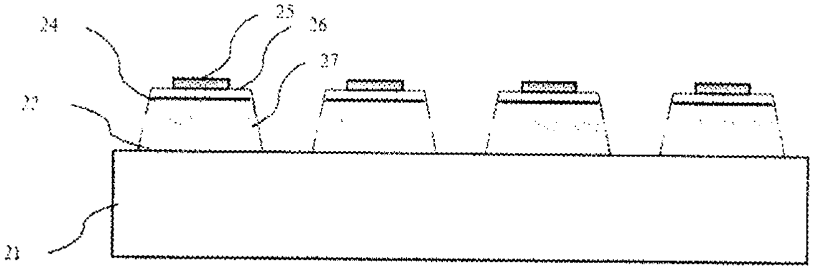


FIG. 2

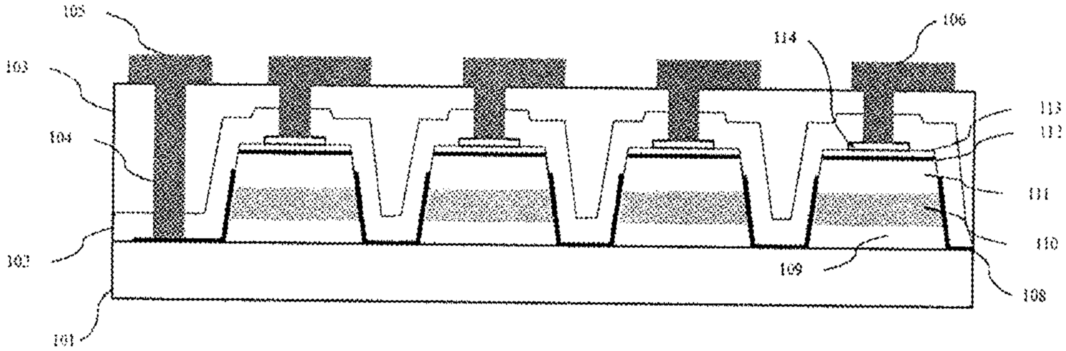


FIG. 3

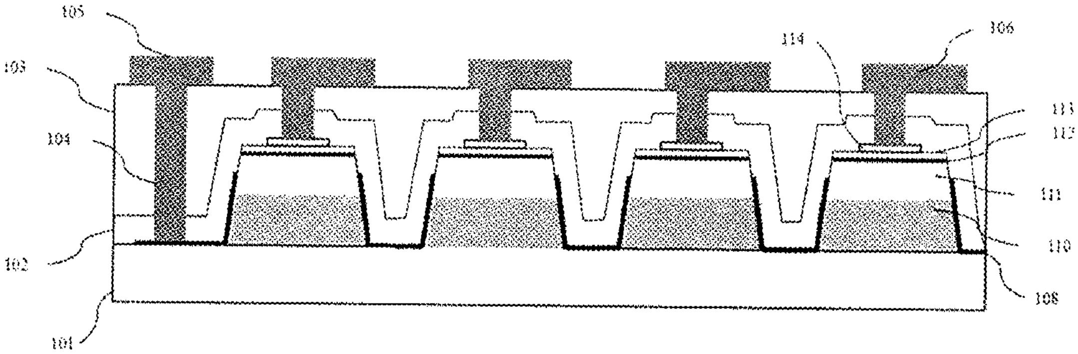


FIG. 4

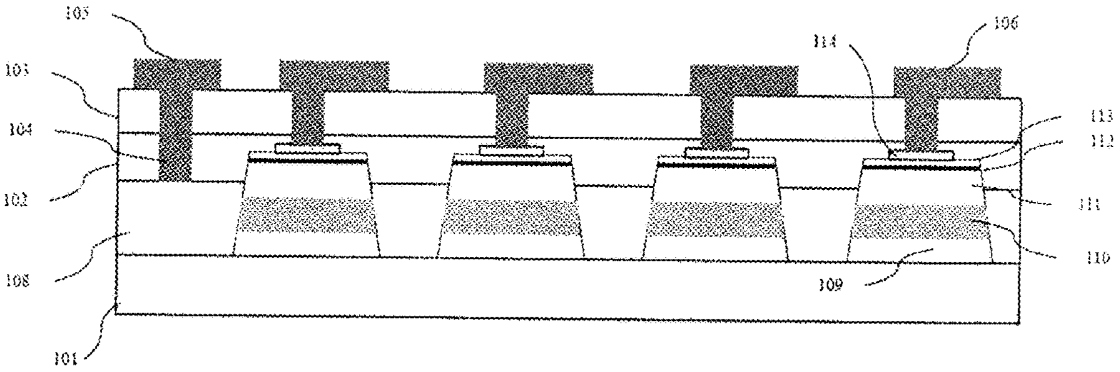


FIG. 5

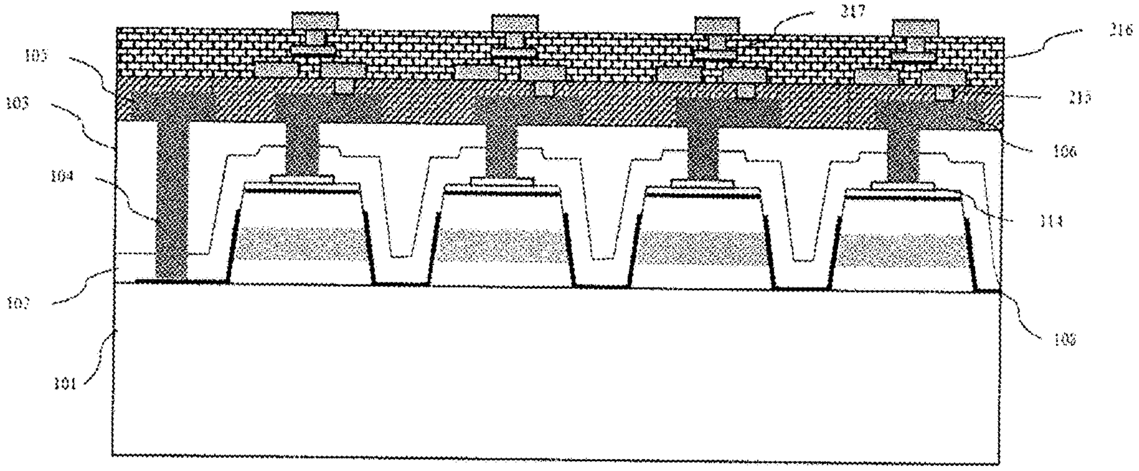


FIG. 6

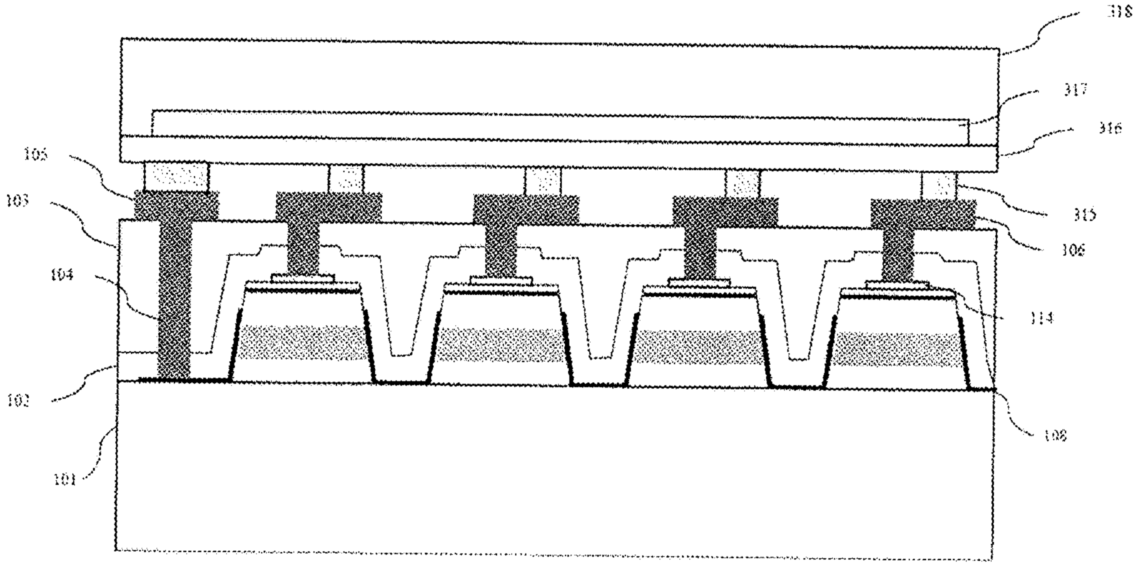


FIG. 7

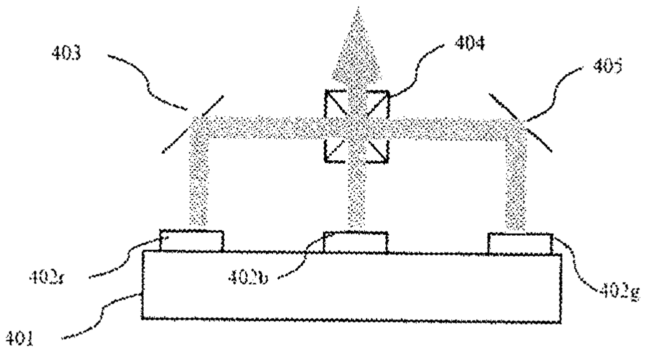

403
404
405
402r
402b
402g
401

FIG. 8

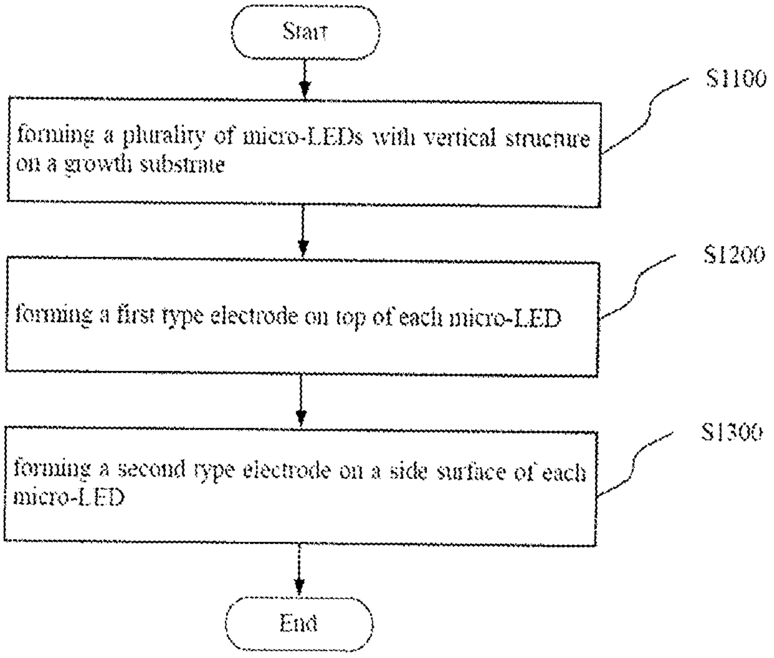

Start
S1100
forming a plurality of micro-LEDs with vertical structure on a growth substrate
S1200
forming a first type electrode on top of each micro-LED
S1300
forming a second type electrode on a side surface of each micro-LED
End

FIG. 9

MICRO-LED DEVICE, DISPLAY APPARATUS AND METHOD FOR MANUFACTURING A MICRO-LED DEVICE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a National Stage of International Application No. PCT/CN2017/072483 filed on Jan. 24, 2017 which is hereby incorporated by reference in its entirety.

FIELD OF THE INVENTION

[0002] The present invention relates to the technical field of micro-LED, and more specifically, to a micro-LED device, a display apparatus and a method for manufacturing 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-LEDs will have a deep affection on the conventional display products such as LCD/OLED that have already been put into the market.

[0004] Generally, a micro-LED is formed on a growth substrate through epitaxy growth. In the prior art, there are two kinds of structure for a micro-LED. The first one is a lateral structure and the second one is a vertical structure.

[0005] FIG. **1** shows a plurality of micro-LEDs with a lateral structure (or lateral micro-LEDs) formed on a growth substrate **11**. As shown in FIG. **1**, a lateral micro-LED includes an un-doped epitaxy layer **12**, a N-type doped layer **17** which includes a N-type heavily doped sub-layer (shown in dark), a multiple quantum well layer **14** and a P-type doped layer **16**. A N-metal electrode **13** and a P-metal electrode **15** are formed on top of the N-type heavily doped layer and the P-type doped layer **16**, respectively.

[0006] FIG. **2** shows a plurality of micro-LEDs with a vertical structure (or vertical micro-LEDs) formed on a growth substrate **21**. As shown in FIG. **1**, a vertical micro-LED includes, in sequence from the growth substrate **21**, an un-doped epitaxy layer **22**, a N-type doped layer **27** which includes a N-type heavily doped sub-layer (shown in dark), a multiple quantum well layer **24** and a P-type doped layer **26**. A P-metal electrode **25** is formed on top of the P-type doped layer **26**.

[0007] Compared with a vertical micro-LED, a lateral micro-LED has a relatively larger size and thus the resolution may be lowered. In addition, the manufacturing of a lateral micro-LED requires at least two steps of epitaxy etching to form a mesa and a trench, and thus the fabrication may be complicated.

[0008] Typically, only P-metal electrode (or a pad or a contact) may be formed on a vertical micro-LED structure on a growth substrate. The vertical micro-LED shall be transferred to a receiving substrate, and then the N-side thereof shall be thinned and/or etched to make a N-metal electrode. The fabrication process for a vertical micro-LED may be complicated, and thus a yield/cost issue may b arise.

[0009] Therefore, there is a demand in the art that a new solution for processing the sensing signal of a sensor shall be proposed to address at least one of the problems in the prior art.

SUMMARY OF THE INVENTION

[0010] One object of this invention is to provide a new technical solution for a micro-LED device.

[0011] According to a first aspect of the present invention, there is provided a micro-LED device, comprising: a growth substrate; a plurality of vertical micro-LEDs formed on the growth substrate; a first type electrode formed on top of each of the vertical micro-LEDs; and a second type electrode formed on side surface of each of the vertical micro-LEDs.

[0012] Alternatively or optionally, the vertical micro-LEDs include at least one of green and blue vertical micro-LEDs, the growth substrate is a sapphire substrate, and the vertical micro-LEDs output light via the growth substrate.

[0013] Alternatively or optionally, each of the vertical micro-LEDs with vertical structure includes, in sequence above the growth substrate, a second type doped region, a multiple quantum well layer and a first type doped region, the second type doped region includes a second type heavily doped region, and the second type electrode covers a side surface of the second type heavily doped region.

[0014] Alternatively or optionally, the first type electrode is a P-type electrode, the second type electrode is a N-type electrode, the first type doped region is a P-type doped region and the second type doped region is a N-type doped region.

[0015] Alternatively or optionally, a dielectric layer is formed on surface of the vertical micro-LEDs, and the dielectric layer is a Distributed Bragg Reflector.

[0016] Alternatively or optionally, the second type electrode is a conductive layer lower than the multiple quantum well layer, and at least one of a dielectric layer or a planarization layer is formed on the conductive layer.

[0017] Alternatively or optionally, a control circuitry is formed above the vertical micro-LEDs. or the vertical micro-LEDs is bonded to an integrated circuit driver via a conductive bond layer.

[0018] According to a second aspect of the present invention, there is provided a display apparatus, including at least one micro-LED device according to an embodiment.

[0019] Alternatively or optionally, it includes a red micro-LED device with red micro-LEDs, a green micro-LED device with green micro-LEDs and a blue micro-LED device with blue micro-LEDs as light sub-sources, and light from the red, green and blue micro-LED devices are combined through an optical system; and wherein at least one of the green micro-LED device and the blue micro-LED device is the micro-LED device according to an embodiment.

[0020] According to a third aspect of the present invention, there is provided a method for manufacturing a micro-LED device, comprising: forming a plurality of vertical micro-LEDs on a growth substrate; forming a first type electrode on top of each micro-LED; and forming a second type electrode on side surface of each of the vertical micro-LEDs.

[0021] According to an embodiment of this invention, a finished device can be formed on a growth substrate. The fabrication thereof may be simplified.

[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** is a schematic diagram of a plurality of prior art lateral micro-LEDs on a growth substrate.

[0025] FIG. **2** is a schematic diagram of a plurality of prior art vertical micro-LEDs on a growth substrate.

[0026] FIG. **3** is schematic diagram of a micro-LED device with a plurality of vertical micro-LEDs on a growth substrate according to an embodiment of the present invention.

[0027] FIG. **4** is schematic diagram of a micro-LED device with a plurality of vertical micro-LEDs on a growth substrate according to another embodiment of the present invention.

[0028] FIG. **5** is schematic diagram of a micro-LED device with a plurality of vertical micro-LEDs on a growth substrate according to another embodiment of the present invention.

[0029] FIG. **6** is schematic diagram of a micro-LED device with a plurality of vertical micro-LEDs on a growth substrate according to another embodiment of the present invention.

[0030] FIG. **7** is schematic diagram of a micro-LED device with a plurality of vertical micro-LEDs on a growth substrate according to another embodiment of the present invention.

[0031] FIG. **8** is schematic diagram of a display apparatus according to another embodiment of the present invention.

[0032] FIG. **9** is schematic diagram of a method for manufacturing a micro-LED device according to another embodiment of the present invention.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0033] 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.

[0034] 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.

[0035] 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.

[0036] 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.

[0037] 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.

[0038] Embodiments and examples will be described below with reference to the drawings.

[0039] FIG. **3** is schematic diagram of a micro-LED device with a plurality of vertical micro-LEDs on a growth substrate according to an embodiment of the present invention. For example, the micro-LED device is a micro-LED display device.

[0040] As shown, in FIG. **3**, the micro-LED device comprises: a growth substrate **101**; a plurality of vertical micro-LEDs formed on the growth substrate **101**; a first type electrode **114** formed on top of each of the vertical micro-LEDs; and a second type electrode **108** formed on side surface (or peripheral) of each of the vertical micro-LEDs.

[0041] The micro-LED device can be a light source for a display apparatus or for other devices which use such a light source.

[0042] In this embodiment, the micro-LEDs are made on a growth substrate to form a finished device. In this manner, a transfer to another receiving substrate may be omitted and thus the fabrication may be simplified. In addition, the influence of the transfer onto the micro-LEDs may be reduced. Furthermore, the micro-LEDs are vertical micro-LEDs and the size thereof can be reduced. For example, the definition of the device can be improved.

[0043] Optionally, since the second type electrode is formed on side surface of a vertical micro-LED, so that this electrode can be used for thermal dispersion of the micro-LED. Accordingly, the thermal performance of such a device may be improved.

[0044] In an example, the vertical micro-LEDs are at least one of green and blue vertical micro-LEDs. The growth substrate **101** is a sapphire substrate. In this regard, the vertical micro-LEDs can output light via the growth substrate **101**.

[0045] Compared with a prior art vertical micro-LED, no electrode is not formed on light emitting size of the micro-LED in FIG. **3**, and the light can directly go though the sapphire substrate. The light emitting efficiency may be improved.

[0046] The other components of the vertical micro-LEDs can be the same as used in the prior art. For example, as shown in FIG. **3**, each of the vertical micro-LEDs includes, in sequence above the growth substrate, an un-doped epitaxy layer **109**, a second type doped region **111**, a multiple quantum well layer **112** and a first type doped region **113**. The second type doped region III may include a second type heavily doped region **110**. It shall be understood by a person skilled in the art that, the first type electrode **114** may formed on top of the first type doped region **113**. A dielectric layer **102** may be formed surface of the vertical micro-LEDs, for electric insulation. A planarization layer **103** may be formed for planarization of the device. Pads **106**, **105** may be formed on the planarization layer **103** and be connected with the first and second type electrodes **114**, **108**, respectively, through vertical interconnection vias **104**. It shall be appreciated by a person skilled in the art that the dielectric layer **102** and the planarization layer **103** may be merged in some examples.

[0047] It shall be understood by a person skilled in the art that, the second type electrode will be in contact with second type heavily doped region **110**, and thus it may covers a side surface of the second type heavily doped region. It shall be also understood by a person skilled in the art that, the second type electrode is lower than the multiple quantum well layer **112**, since the first type electrode is connected with the first type doped region.

[0048] For example, the first type electrode **114** is a P-type electrode (or P-metal), the second type electrode **108** is a N-type electrode, the first type doped region **113** is a P-type doped region and the second type doped region **111** is a N-type doped region.

[0049] In an example, the dielectric layer **102** may be a Distributed Bragg Reflector (DBR). In this manner, the light produced by a vertical micro-LED may be prevented from emitting to other directions except the direction the growth substrate **101**. Accordingly, the light emitting efficiency may be improved.

[0050] FIG. **4** shows schematic diagram of a micro-LED device with a plurality of vertical micro-LEDs on a growth substrate according to another embodiment of the present invention.

[0051] The difference between FIG. **4** and FIG. **3** lies in that the second type doped region **111** is directly formed on the growth substrate **101**, without a un-doped epitaxy layer **109**. The other components of FIG. **4** are the same as those of FIG. **3** and thus are omitted.

[0052] FIG. **5** is schematic diagram of a micro-LED device with a plurality of vertical micro-LEDs on a growth substrate according to another embodiment of the present invention.

[0053] In FIG. **5**, the second type electrode **108** is a conductive layer lower than the multiple quantum well layer **112**. In this embodiment, the second type electrode **108** is not a coating on the peripheral of a vertical micro-LED, and is a layer deposited between the vertical micro-LEDs. At least one of a dielectric layer **102** or a planarization layer **103** is formed on the conductive layer **108**. The other components of FIG. **5** are the same as those of FIG. **3** or **4** and thus are omitted.

[0054] In this embodiment, a conductive layer **108** is used as a common electrode. This may improve the thermal dispersion of the device. Furthermore, the fabrication for the device may further be simplified.

[0055] FIG. **6** is schematic diagram of a micro-LED device with a plurality of vertical micro-LEDs on a growth substrate according to another embodiment of the present invention.

[0056] In FIG. **6**, a control circuitry **216** is formed above the vertical micro-LEDs. The control circuitry **216** may be connected with the pads **105**, **106** via a bonding layer **215**. The control circuitry **216** may include thin film transistors (TFTs) **217**.

[0057] The other components of FIG. **6** may be the same as those of FIG. **3**, **4** or **5** and thus are omitted.

[0058] FIG. **7** is schematic diagram of a micro-LED device with a plurality of vertical micro-LEDs on a growth substrate according to another embodiment of the present invention.

[0059] In FIG. **7**, the vertical micro-LEDs are bonded to an integrated circuit (IC) driver **317** via a conductive bond layer **315**. For example, the conductive bond layer **315** connects the pads **105**, **106** to a dielectric layer **316** with interconnections. The IC driver **317** is mounted on the dielectric layer **316** with interconnections. For example, the IC driver **317** is formed on a silicon substrate **318**.

[0060] The other components of FIG. **7** may be the same as those of FIG. **3**, **4** or **5** and thus are omitted.

[0061] The above micro-LED device may be used or included in a display apparatus, as a light source. For example, the display apparatus may include functionalities other than the display.

[0062] For example, the display apparatus may be a monochromatic display apparatus. The above micro-LED device may be directly used a light source thereof.

[0063] Alternatively, the display apparatus can be a full color display apparatus. FIG. **8** shows a schematic diagram of such a display apparatus.

[0064] For example, as shown in FIG. **8**, the display apparatus includes a red micro-LED device **402***r* with red micro-LEDs, a green micro-LED device **402***g* with green micro-LEDs and a blue micro-LED device **402***b* with blue micro-LEDs as light sub-sources. The micro-LED devices are mounted on a substrate **401**. Light from the red, green and blue micro-LED devices **402***r*, **402***g*, **402***b* are combined through an optical system. The optical system may includes mirrors **403**, **405** and an optical component **404** which can transmits one of the red, green and blue light and reflects the other color lights. For example, the optical component **404** may include dichroic mirrors.

[0065] In the prior art, it is relatively easier to manufacture a red micro-LED device. So, the red micro-LED device may be that of the prior art. At least one of the green micro-LED device and the blue micro-LED device is the micro-LED device as described above.

[0066] FIG. **9** shows schematic diagram of a method for manufacturing a micro-LED device according to another embodiment of the present invention.

[0067] As shown in FIG. **9**, at step **1100**, a plurality of vertical micro-LEDs are formed on a growth substrate.

[0068] This step may be the same as that in the prior art. It may include an epitaxy growth, micro-LED patterning on the growth substrate, epitaxy trench etching and so on. The detailed description thereof is omitted.

[0069] At step **S1200**, a first type electrode is formed on top of each micro-LED. Generally, the first type electrode is a P-type electrode, and it may be formed through patterning.

[0070] At step **S1300**, a second type electrode is formed on a side surface of each vertical micro-LED. The second type electrode may be a N-type electrode. For example, it may be formed on bottom side of the vertical micro-LEDs through patterning.

[0071] In this method, a side-contact electrode is introduced so that a finished device can be formed using a growth substrate.

[0072] The subsequent processes may be similar with those in the prior art. For example, a dielectric layer and a planarization layer may be deposited on the growth substrate and the vertical micro-LEDs. The dielectric layer and the planarization layer may be combined, for example. Then, vias may be formed in the dielectric layer and the planarization layer and be connected to the electrodes. Pads may be formed on top of the planarization layer and be connected with the vias.

[0073] Optionally, a control circuitry with TFTs may be built up on top of the vertical micro-LEDs. Alternatively, an IC driver may be bonded to the pads to control and drive the micro-LED device.

[0074] 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.

1. A micro-LED device, comprising:
- a growth substrate;
- a plurality of vertical micro-LEDs formed on the growth substrate, each having a top;
- a first type electrode formed on the top of each of the vertical micro-LEDs; and
- a second type electrode formed on aside surface of each of the vertical micro-LEDs.

2. The micro-LED device according to claim **1**, wherein the vertical micro-LEDs include at least one of green and blue vertical micro-LEDs, the growth substrate is a sapphire substrate, and the vertical micro-LEDs output light via the growth substrate.

3. The micro-LED device according to claim **1**, wherein each of the vertical micro-LEDs includes, in sequence above the growth substrate, a second type doped region, a multiple quantum well layer and a first type doped region, the second type doped region includes a second type heavily doped region, and the second type electrode covers a side surface of the second type heavily doped region.

4. The micro-LED device according to claim **3**, wherein the first type electrode is a P-type electrode, the second type electrode is a N-type electrode, the first type doped region is a P-type doped region and the second type doped region is a N-type doped region.

5. The micro-LED device according to claim **1**, wherein a dielectric layer is formed on a surface of the vertical micro-LEDs, and the dielectric layer is a Distributed Bragg Reflector.

6. The micro-LED device according to claim **4**, wherein the second type electrode is a conductive layer lower than the multiple quantum well layer, and at least one of a dielectric layer or a planarization layer is formed on the conductive layer.

7. The micro-LED device according to claim **1**, wherein a control circuitry is formed above the vertical micro-LEDs.

8. A display apparatus, including at least one micro-LED device according to claim **1**.

9. The display apparatus according to claim **8**, further including a red micro-LED device with red micro-LEDs, a green micro-LED device with green micro-LEDs and a blue micro-LED device with blue micro-LEDs as light sub-sources, and light from the red, green and blue micro-LED devices are combined through an optical system; and
- wherein at least one of the green micro-LED device and the blue micro-LED device is the micro-LED device according to claim **1**.

10. A method for manufacturing a micro-LED device, comprising:
- forming a plurality of vertical micro-LEDs on a growth substrate, each having a top;
- forming a first type electrode on the top of each of the micro-LEDs; and
- forming a second type electrode on a side surface of each of the vertical micro-LEDs.

11. The micro-LED device according to claim **1**, wherein the vertical micro-LEDs is bonded to an integrated circuit driver via a conductive bond layer.

* * * * *

专利名称(译)	微led装置，显示设备和制造微led装置的方法		
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申请号	US16/473538	申请日	2017-01-24
[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)	歌尔声学股份有限公司.		
当前申请(专利权)人(译)	歌尔声学股份有限公司.		
[标]发明人	ZOU QUANBO CHEN PEIXUAN		
发明人	ZOU, QUANBO CHEN, PEIXUAN FENG, XIANGXU		
IPC分类号	H01L27/15 H01L25/18		
CPC分类号	H01L25/18 H01L27/153 H01L33/46 H01L33/62 H01L33/385		
外部链接	Espacenet USPTO		

摘要(译)

提供了一种微型LED器件，显示装置和用于制造微型LED器件的方法。所述微型LED器件包括：生长衬底；以及 多个垂直微型LED形成在生长衬底上； 在每个垂直微型LED的顶部上形成的第一类型电极； 第二类型电极形成在每个垂直微型LED的侧面上。