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(54) **MICRO-LED WITH VERTICAL STRUCTURE, DISPLAY DEVICE, ELECTRONICS APPARATUS AND MANUFACTURING METHOD**

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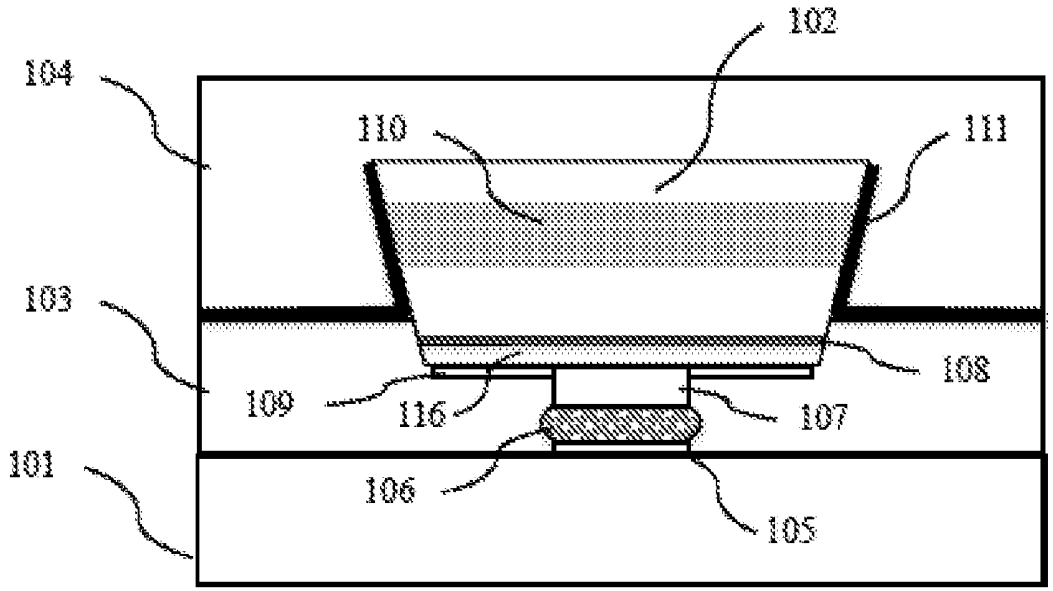
(57) **ABSTRACT**

The present invention discloses a micro-LED with vertical structure, display device, electronics apparatus and manufacturing method. The micro-LED with vertical structure comprises: a bottom electrode bonded on a display substrate; a first type doped region provided above the bottom electrode; a second type doped region provided above the first type doped region; and a side-contact electrode covering at least one part of a peripheral of the second type doped region.



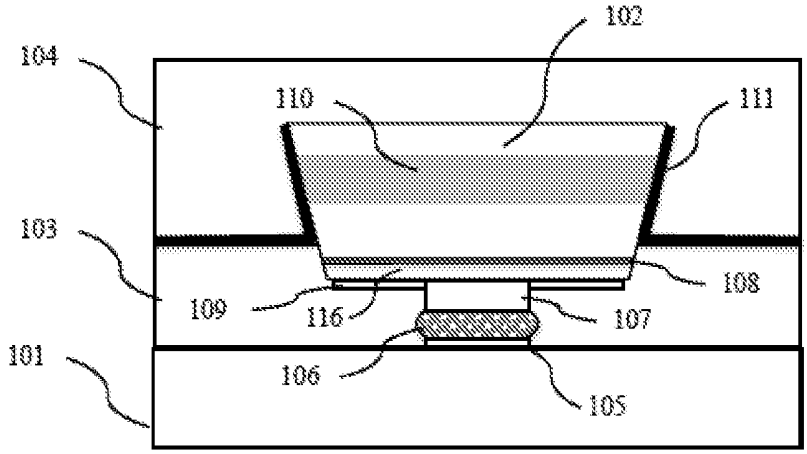

102
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FIG. 1

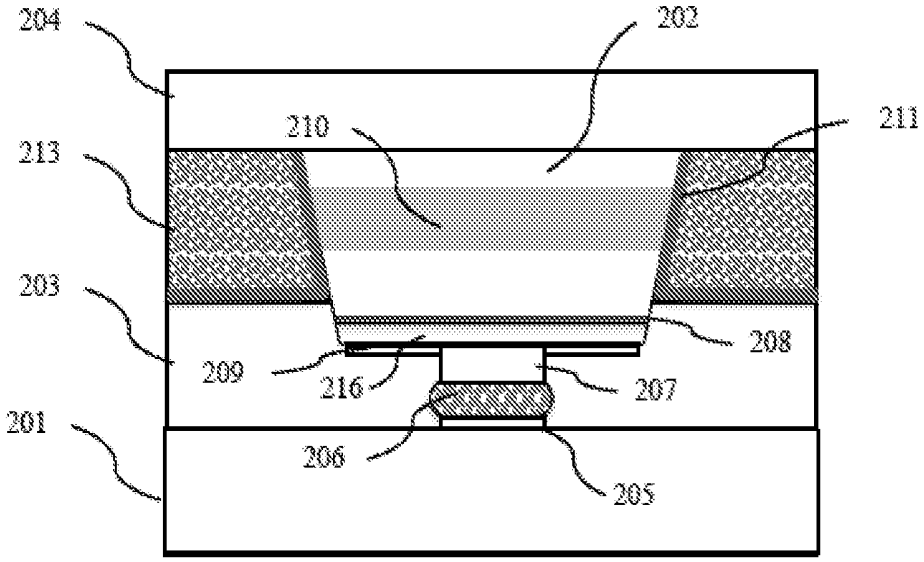
204
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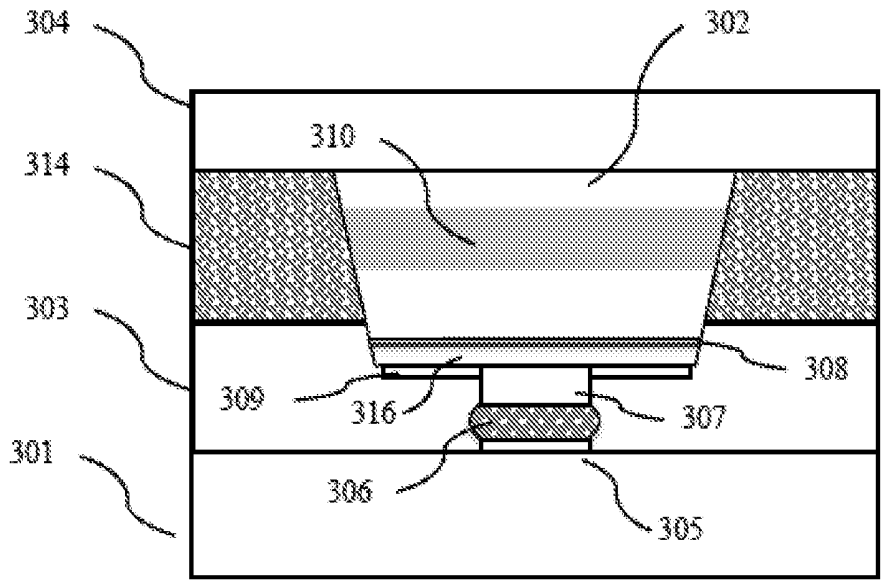
FIG. 2


304
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305

FIG.3

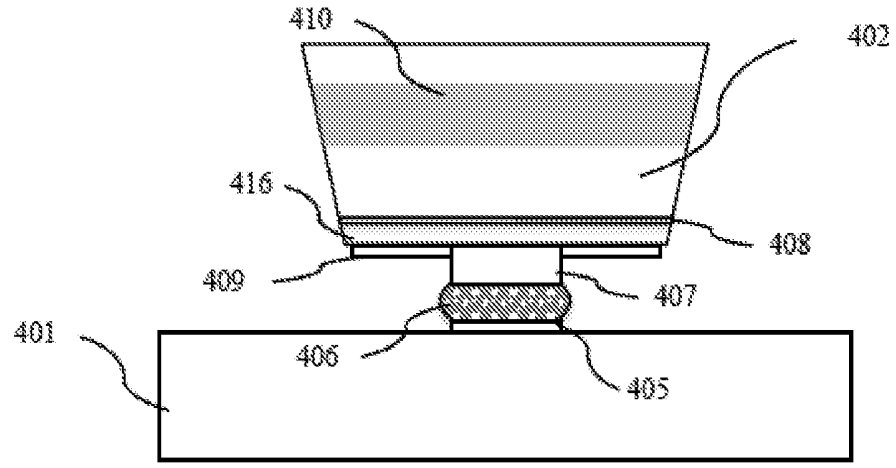
410
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FIG. 4

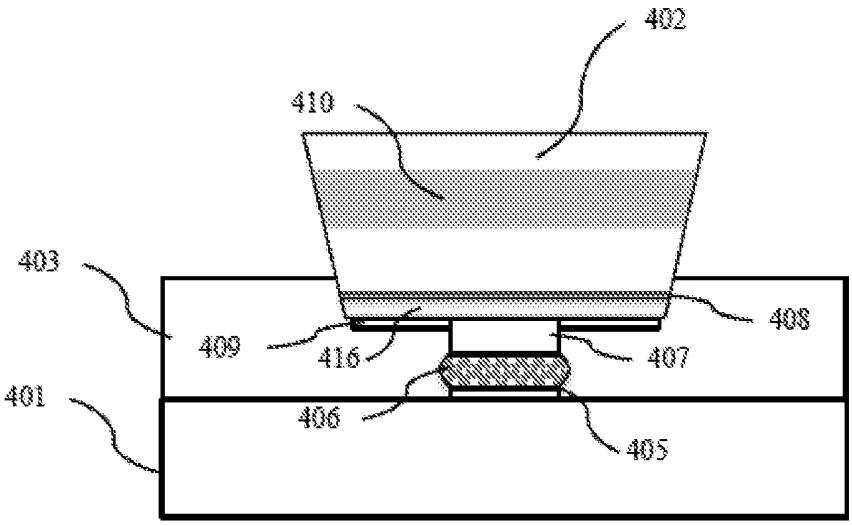
402
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FIG. 5

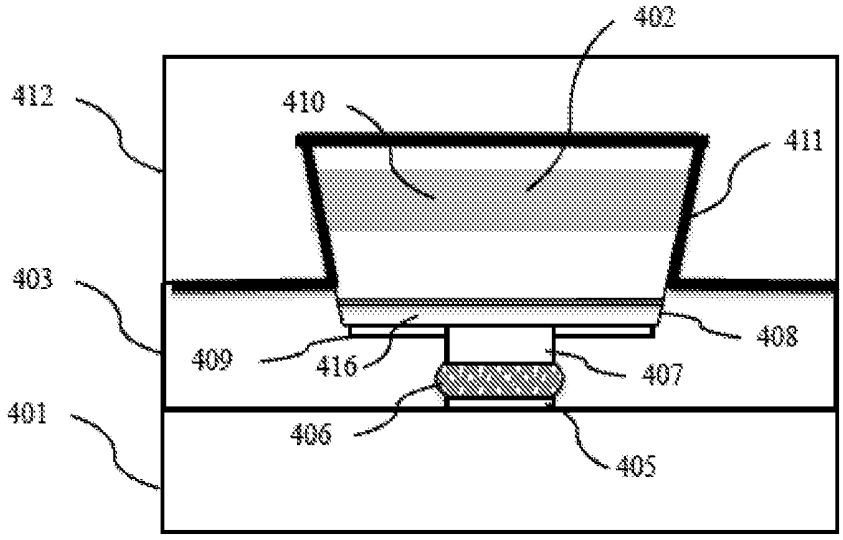
402
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FIG. 6

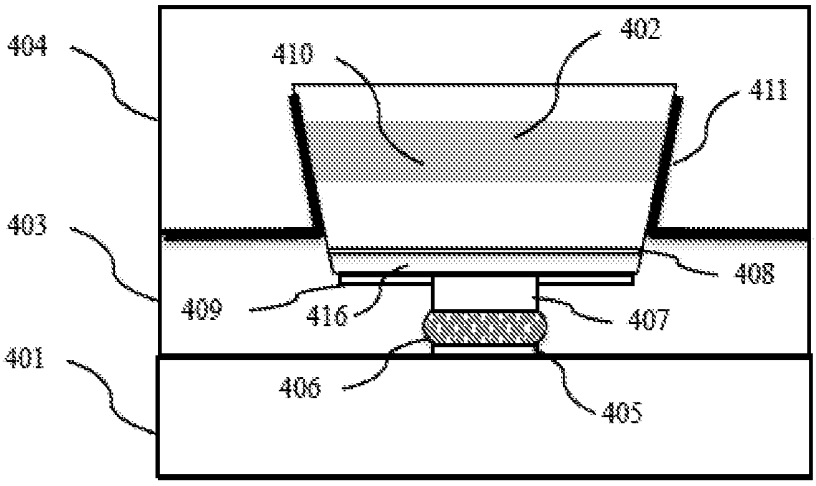

FIG.7

MICRO-LED WITH VERTICAL STRUCTURE, DISPLAY DEVICE, ELECTRONICS APPARATUS AND MANUFACTURING METHOD

FIELD OF THE INVENTION

[0001] The present invention relates to the field of micro-LED, and more specifically, relates to a micro-LED with vertical structure, a display device, an electronics apparatus and a method for manufacturing a display device.

BACKGROUND OF THE INVENTION

[0002] 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.

[0003] In the prior art, a micro-LED arranged on a display device such as a display panel can have a vertical structure to achieve a high definition. In such a micro-LED, a top electrode is arranged on top of the micro-LED and contacts the top surface of the micro-LED to form a common electrode. The micro-LED emits light from the top surface. The top electrode is transparent.

[0004] For example, U.S. Pat. No. 9,367,094 B2 discloses a display module and system application, which is hereby incorporated herein by reference.

[0005] Generally, the top electrode is a cathode and is in an Ohmic contact with the n-EPI surface of the micro-LED. The n-EPI region shall be etched deeply to reach the heavy doping region of n-EPI (e.g., N++ GaN region). This deep etching will add processing complexity. As a result, a cost/yield/reliability issues will rise.

[0006] In addition, the conductive top electrode will degrade optical efficiency, to an extend of around 5~20%, for example, due to its imperfect optical transmittance.

[0007] In addition, in such a micro-LED, a side light leakage may decrease the optical efficiency thereof. This may become even more serious when a micro-LED has a small size, for example, equal to or less than 10 μm, for a high-resolution display.

[0008] In addition, in such a micro-LED, heat dissipation is limited to the bottom and top surfaces thereof. This is insufficient in a small micro-LED for a high resolution. This may cause an overheating issue. Accordingly, the efficiency and/or lifetime of the micro-LED may degrade.

[0009] Therefore, there is a demand in the art that a new solution for a micro-LED of vertical structure 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 with vertical structure.

[0011] According to a first aspect of the present invention, there is provided a micro-LED with vertical structure, comprising: a bottom electrode bonded on a display substrate; a first type doped region provided above the bottom electrode; a second type doped region provided above the first type doped region; and a side-contact electrode covering at least one part of a peripheral of the second type doped region.

[0012] Alternatively or optionally, a multiple quantum well layer is provided between the first type doped region and the second type doped region.

[0013] Alternatively or optionally, a mirror is provided below the first type doped region.

[0014] Alternatively or optionally, 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, the at least one part of the peripheral of the second type doped region includes a heavily doped second type region.

[0016] Alternatively or optionally, a protective layer is provided on top of the second type doped region.

[0017] Alternatively or optionally, a vacancy beside the side-contact electrode is filled with the protective layer.

[0018] Alternatively or optionally, a vacancy beside the side-contact electrode is filled with an encapsulation filler.

[0019] Alternatively or optionally, the side-contact electrode is a conductive encapsulation filler, which is at the peripheral of the second type doped region.

[0020] According to a second aspect of the present invention, there is provided display device, comprising a micro-LED with vertical structure according to the present invention.

[0021] According to a third aspect of the present invention, there is provided an electronics apparatus, comprising a display device according to the present invention.

[0022] According to a fourth aspect of the present invention, there is provided a method for manufacturing a display device, comprising: transferring a micro-LED with vertical structure onto a display substrate, wherein the micro-LED include a bottom electrode, a first type doped region provided above the bottom electrode and a second type doped region provided above the first type doped region, and wherein the bottom electrode is bonded on the display substrate; forming a dielectric layer at a peripheral of the micro-LED, wherein least one part of a peripheral of the second type doped region is exposed; forming a side-contact electrode covering at least one part of the peripheral of the second type doped region; and forming a protective layer on top of the micro-LED.

[0023] Alternatively or optionally, forming a side-contact electrode further comprises: depositing a material of the side-contact electrode on a surface of the second type doped region; coating and baking a photoresist outside the material of the side-contact electrode; etching back the photoresist to expose the material of the side-contact electrode on a top of the second type doped region; removing the material of the side-contact electrode on the top of the second type doped region; and stripping the photoresist.

[0024] Alternatively or optionally, forming a side-contact electrode further comprises: depositing a material of the side-contact electrode on a surface of the second type doped region; filling an encapsulation filler outside the material of the side-contact electrode; and grinding the encapsulation filler to remove the material of the side-contact electrode on the top of the second type doped region.

[0025] Alternatively or optionally, forming a side-contact electrode further comprises: filling a conductive encapsulation filler as the side-contact electrode at the peripheral of the second type doped region.

[0026] Alternatively or optionally, filling a conductive encapsulation filler further comprises: grinding and polishing the conductive encapsulation filler.

[0027] According to an embodiment of this invention, the present invention can provide a side-contact electrode for a micro-LED to reduce the optical loss caused by an electrode on the top of a micro-LED.

[0028] 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

[0029] 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.

[0030] FIG. **1** schematically shows a structure of a micro-LED according to an embodiment of this invention.

[0031] FIG. **2** schematically shows a structure of a micro-LED according to another embodiment of this invention.

[0032] FIG. **3** schematically shows a structure of a micro-LED according to another embodiment of this invention.

[0033] FIGS. **4-7** schematically shows a process of manufacturing a display device according to another embodiment of this invention.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0034] 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.

[0035] 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.

[0036] 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.

[0037] 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.

[0038] 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.

[0039] The present invention has proposed to introduce a side electrode for a top common electrode in a micro-LED with vertical structure.

[0040] Embodiments and examples will be described with reference to the drawings in details.

[0041] FIG. **1** schematically shows a structure of a micro-LED according to an embodiment of this invention.

[0042] As shown in FIG. **1**, the micro-LED with vertical structure comprises: a bottom electrode **107** bonded on a display substrate **101**, a first type doped region **116** provided above the bottom electrode **107**, a second type doped region **102** provided above the first type doped region **116** and a side-contact electrode **111** covering at least one part of a peripheral of the second type doped region **102**.

[0043] For example, the side-contact electrode **111** may include Ag, Al, Cr, Au, Ni, NiV, or ITO.

[0044] For example, the first type doped region **116** is a p-type doped region, and the second type doped region **102** is a n-type doped region. The at least one part of the peripheral of the second type doped region **102** may include a heavily doped second type region **110**, which may be a N++ GaN region.

[0045] As also shown in FIG. **1**, a multiple quantum well layer MQW **108** may be provided between the first type doped region **116** and the second type doped region **102**. A mirror **109** may be provided below the first type doped region **116**. The mirror **109** may reflect the light to the top of the micro-LED.

[0046] The bottom electrode **107** may be bonded to an electrode **105** such as an anode of the display substrate **101** via a bonding layer **106**. The bonding layer **106** may be solder.

[0047] In FIG. **1**, a dielectric layer **103** may be deposited at the peripheral of the first type doped region **116** and part of the second type doped region **102**. The dielectric layer **103** may be polymer such as BCB, PBO and Polyimide, or be SiO2, SiNx, SOG and so on.

[0048] A protective layer **104** may be provided on top of the second type doped region **102**. For example, a vacancy beside the side-contact electrode **111** is also filled with the protective layer **104**. That is, the top and peripheral of the second type doped region **102** are protected by the protective layer **104**.

[0049] In this embodiment, since a side-contact electrode is provided, the EPI region may not be deeply etched and thus the processing may be simplified.

[0050] Because the electrode is not arranged on the top of the micro-LED, the optical loss due to electrode transmittance will be cancelled. This may provide a higher optical efficiency.

[0051] Because the electrode is arranged on the side of the micro-LED, it may be used to prevent light leakage. For example, the side-contact electrode is a reflective side-contact metal.

[0052] The side-contact electrode may be side-contact metallic electrode and it can enhance the heat dissipation to the display substrate. This may provide a better thermal power management.

[0053] FIG. **2** schematically shows a structure of a micro-LED according to another embodiment of this invention.

[0054] In FIG. **2**, the bottom electrode **207** of the micro-LED is bonded to an electrode **205** such as an anode of a display substrate **201** via a bonding layer **206**. The first type doped region **216** is above the bottom electrode **207**. The bottom of the first type doped region **216** is covered with a mirror **209**. A dielectric layer **203** may be deposited at the peripheral of the first type doped region **216** and part of the second type doped region **202**.

[0055] The second type doped region **202** is above the first type doped region **216**. A multiple quantum well layer MQW **208** is provided between the first type doped region **216** and the second type doped region **202**.

[0056] A side-contact electrode **211** covers at least one part of a peripheral of the second type doped region **202**

including a heavily doped second type region **210**. A protective layer **204** is provided on top of the second type doped region **202**.

[0057] The difference between the embodiments of FIG. **1** and FIG. **2** lies in that a vacancy beside the side-contact electrode is filled with an encapsulation filler **213**. The description repetitive with the embodiment of FIG. **1** will be omitted.

[0058] With the structure of FIG. **2**, during manufacturing of the micro-LED, the encapsulation filler **213** may be filled, for example, after a deposition of the side-contact electrode **211** outside the second type doped region **202**.

[0059] For example, the encapsulation filler **213** can be photoresist, and it can be formed by coating. The encapsulation filler **213** may be thinned through etch-back by plasma or reactive ion etching (ME). The electrode on top of the second type doped region **202** may be removed through wet chemical etching or dry etching.

[0060] Alternatively, the encapsulation filler **213** may be molding compound, curable paste, polymer or elastomer. For example, the side-contact electrode **211** on the top of the second type doped region **202** may be removed by simply grinding and/or polish the encapsulation filler **213** and the side-contact electrode **211**.

[0061] FIG. **3** schematically shows a structure of a micro-LED according to another embodiment of this invention.

[0062] In FIG. **3**, the bottom electrode **307** of the micro-LED is bonded to an electrode **305** such as an anode of a display substrate **301** via a bonding layer **306**. The first type doped region **316** is above the bottom electrode **307**. The bottom of the first type doped region **316** is covered with a mirror **309**. A dielectric layer **303** may be deposited at the peripheral of the first type doped region **316** and part of the second type doped region **302**.

[0063] The second type doped region **302** is above the first type doped region **316**. A multiple quantum well layer MQW **308** is provided between the first type doped region **316** and the second type doped region **302**.

[0064] A protective layer **304** is provided on top of the second type doped region **302**.

[0065] The difference between the embodiments of FIG. **1** and FIG. **2** lies in that the side-contact electrode is a conductive encapsulation filler **314**, which is at the peripheral of the second type doped region **302**. The description repetitive with the above embodiments will be omitted.

[0066] In this embodiment, the conductive encapsulation filler **314** can be filled around the second type doped region **302**. It can be etched back, be ground and/or polished to expose the top of the region **302**. In this regard, an electrode deposition is not necessary and the manufacture processing may be simplified. For example, the conductive encapsulation filler **314** may be silver paste. Because the top electrode is generally a common electrode, the conductive encapsulation filler **314** will not have influence on the performance and functionality of the micro-LED.

[0067] It can be understood by a person skilled in the art that the side-contact electrode may be patterned or unpatterned according a design.

[0068] FIGS. **4-7** schematically shows a process of manufacturing a display device according to another embodiment of this invention.

[0069] As shown in FIG. **4**, a micro-LED with vertical structure is transferred onto a display substrate **401**. The micro-LED include a bottom electrode **407**, a first type doped region **416** provided above the bottom electrode **407** and a second type doped region **402** provided above the first type doped region **416**. The bottom electrode **407** is bonded on an electrode **405** such as an anode of the display substrate **401** via a bonding layer **406** such as solder.

[0070] A multiple quantum well layer MQW **408** is provided between the first type doped region **416** and the second type doped region **402**. A mirror **409** is provided below the first type doped region **416**. The second type doped region **402** includes a heavily doped second type region **410**.

[0071] As shown in FIG. **5** a dielectric layer **403** is formed at a peripheral of the micro-LED, wherein least one part of a peripheral of the second type doped region **402** is exposed. The exposed part includes the heavily doped second type region **410**. The multiple quantum well layer MQW **408** is not exposed and is encapsulated by the dielectric layer **403**.

[0072] As shown in FIG. **6**, a side-contact electrode is formed, which covers at least one part of the peripheral of the second type doped region **402**.

[0073] In FIG. **6**, the side-contact electrode **411** may be formed by depositing a material of the side-contact electrode on a surface of the second type doped region **402**; coating and baking a photoresist **412** outside the material of the side-contact electrode **411**; etching back the photoresist **412** to expose the material of the side-contact electrode **411** on a top of the second type doped region **402**; removing the material of the side-contact electrode **411** on the top of the second type doped region **402**; and stripping the photoresist **412**. This approach may form a micro-LED like that in FIG. **1**.

[0074] Alternatively, a micro-LED like that in FIG. **2** or **3** may be formed.

[0075] For example, the side-contact electrode **411** may be formed by depositing a material of the side-contact electrode on a surface of the second type doped region **402**; filling an encapsulation filler outside the material of the side-contact electrode **411**; and grinding the encapsulation filler to remove the material of the side-contact electrode **411** on the top of the second type doped region **402**.

[0076] For example, the side-contact electrode may be formed by filling a conductive encapsulation filler as the side-contact electrode at the peripheral of the second type doped region **402**. Then, the conductive encapsulation filler is ground and polished to expose the top of the region **402**.

[0077] As shown in FIG. **7**, a protective layer **404** is formed on top of the micro-LED.

[0078] In another embodiment, the present invention further includes a display device such as a display screen device or display panel, comprising a micro-LED with vertical structure according to any of the embodiments according to the present invention.

[0079] In another embodiment, the present invention further includes an electronic apparatus. The electronic apparatus contains a display device according to the present invention. For example, the electronic apparatus can be a mobile phone, a pad computer and so on.

[0080] 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 with vertical structure, comprising:
a bottom electrode bonded on a display substrate;
a first type doped region provided above the bottom electrode;
a second type doped region provided above the first type doped region; and
a side-contact electrode covering at least one part of a peripheral of the second type doped region.

2. The micro-LED according to claim 1, wherein the first type doped region is a p-type doped region, and the second type doped region is a n-type doped region.

3. The micro-LED according to claim 1, wherein the at least one part of the peripheral of the second type doped region includes a heavily doped second type region.

4. The micro-LED according to claim 1, wherein a vacancy beside the side-contact electrode is filled with an encapsulation filler.

5. The micro-LED according to claim 1, wherein the side-contact electrode is a conductive encapsulation filler, which is at the peripheral of the second type doped region.

6. A display device, comprising a micro-LED with vertical structure according to claim 1.

7. A method for manufacturing a display device, comprising:
transferring a micro-LED with vertical structure onto a display substrate, wherein the micro-LED include a bottom electrode, a first type doped region provided above the bottom electrode and a second type doped region provided above the first type doped region, and wherein the bottom electrode is bonded on the display substrate;
forming a dielectric layer at a peripheral of the micro-LED, wherein least one part of a peripheral of the second type doped region is exposed;
forming a side-contact electrode covering at least one part of the peripheral of the second type doped region; and
forming a protective layer on top of the micro-LED.

8. The method according to claim 7, wherein forming a side-contact electrode further comprises:
depositing a material of the side-contact electrode on a surface of the second type doped region;
coating and baking a photoresist outside the material of the side-contact electrode;
etching back the photoresist to expose the material of the side-contact electrode on a top of the second type doped region;
removing the material of the side-contact electrode on the top of the second type doped region; and
stripping the photoresist.

9. The method according to claim 7, wherein forming a side-contact electrode further comprises:
depositing a material of the side-contact electrode on a surface of the second type doped region;
filling an encapsulation filler outside the material of the side-contact electrode; and
grinding the encapsulation filler to remove the material of the side-contact electrode on the top of the second type doped region.

10. The method according to claim 7, wherein forming a side-contact electrode further comprises:
filling a conductive encapsulation filler as the side-contact electrode at the peripheral of the second type doped region.

* * * * *

专利名称(译)	具有垂直结构的微led，显示装置，电子设备和制造方法		
公开(公告)号	US20190334060A1	公开(公告)日	2019-10-31
申请号	US16/347603	申请日	2016-11-06
[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. INC		
当前申请(专利权)人(译)	歌尔声学. INC		
[标]发明人	ZOU QUANBO CHEN PEIXUAN		
发明人	ZOU, QUANBO CHEN, PEIXUAN FENG, XIANGXU		
IPC分类号	H01L33/38 H01L33/52 H01L33/40 H01L33/14 H01L27/32		
CPC分类号	H01L33/405 H01L2933/005 H01L2933/0016 H01L33/385 H01L33/14 H01L27/32 H01L33/52 H01L33/46		
外部链接	Espacenet USPTO		

摘要(译)

本发明公开了一种垂直结构的微型LED，显示装置，电子设备及制造方法。具有垂直结构的微型LED包括：底部电极，其结合在显示基板上；设置在底部电极上方的第一类型掺杂区；在第一类型掺杂区上方提供第二类型掺杂区；侧接触电极覆盖第二类型掺杂区域的外围的至少一部分。