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(54) **Title:** MICRO LASER DIODE DISPLAY DEVICE AND ELECTRONICS APPARATUS

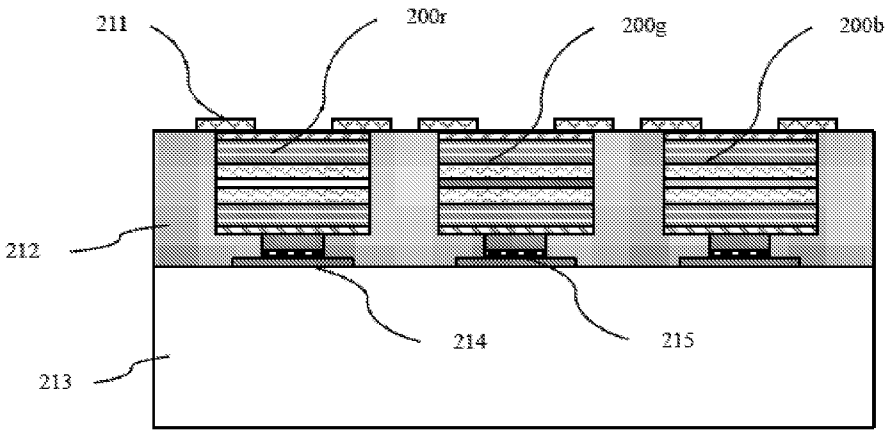

FIG. 2

(57) **Abstract:** A micro laser diode display device and an electronics apparatus are disclosed. The micro laser diode display device comprises: a substrate (213) / receiving substrate (513), wherein first type electrodes (214,514) are arranged on the substrate (213) / receiving substrate (513); a micro laser diode (200r, 200g, 200b, 400r, 400g, 400b, 500r, 500g, 500b) array of at least one color bonded on the substrate (213) / receiving substrate (513), wherein a first side of micro laser diodes (200r, 200g, 200b, 400r, 400g, 400b, 500r, 500g, 500b) in the micro laser diode array is connected to the first type electrodes (214, 514); and second type electrodes (211, 311, 511) connected to a second side of the micro laser diodes (200r, 200g, 200b, 400r, 400g, 400b, 500r, 500g, 500b).

WO 2018/102955 A1

MICRO LASER DIODE DISPLAY DEVICE AND ELECTRONICS APPARATUS

FIELD OF THE INVENTION

The present invention relates to micro laser diodes, and more specifically, to a micro laser diode display device and an electronics apparatus.

BACKGROUND OF THE INVENTION

The laser diode (LD) has been actively developed recently. Generally, a laser diode or a laser diode array is used as a light source for optical communications or a laser printer. The laser diode could be of a vertical cavity surface emitting laser (VCSEL) structure, which includes a lower contact layer, a lower Bragg reflector layer, a lower spacer layer, an active layer, an upper spacer layer, an upper Bragg reflector layer and an upper contact layer.

In the prior art, micro laser diodes are transferred onto a receiving substrate individually. The common electrode for the micro laser diodes is mounted at bottom on the receiving substrate. The top electrodes of the laser diodes are wire-bonded onto the receiving substrate. Although the laser diode is downsizing and thus an individual micro laser diode can be made, traditional assembling approaches are still used in transfer of the micro laser diode. They are not suitable for the application of a micro laser diode. Furthermore, they are not suitable for a display device using micro laser diodes, especially, a high definition (HD) display device.

US patent application No. 2016/0308333 A1 discloses a laser diode array, method of manufacturing the same, printer and optical communication device, which is hereby incorporated herein by reference.

Micro-LEDs can be used as display light source. But, they are not suitable for projection display. A projection display apparatus using micro-LEDs requires a complicated optical focusing system, which limits its application.

US patent No. 9,367,094 B2 discloses a display module and system applications, which is hereby incorporated herein by reference.

Therefore, there is a demand in the art that a new solution for a display device using

micro laser diodes shall be proposed to address at least one of the problems in the prior art.

Therefore, there is a demand in the art that a new solution for display using micro laser diodes shall be proposed to address at least one of the problems in the prior art.

SUMMARY OF THE INVENTION

One object of this invention is to provide a new technical solution for a display device using micro laser diodes.

According to a first aspect of the present invention, there is provided a micro laser diode display device, comprising: a substrate, wherein first type electrodes are arranged on the substrate; a micro laser diode array of at least one color bonded on the substrate, wherein a first side of micro laser diodes in the micro laser diode array is connected to the first type electrodes; and second type electrodes connected to a second side of the micro laser diodes.

Alternatively or optionally, the micro laser diodes are of vertical cavity surface emitting laser structure, which includes a lower contact layer, a lower Bragg reflector layer, a lower spacer layer, an active layer, an upper spacer layer, an upper Bragg reflector layer and an upper contact layer.

Alternatively or optionally, dielectric filler layer is filled among the micro laser diodes.

Alternatively or optionally, at least one part of the second type electrodes is formed at a lateral side of the micro laser diodes.

Alternatively or optionally, the second type electrodes are formed on top of the micro laser diodes and the dielectric filler layer, and are patterned so that the micro laser diodes are exposed.

Alternatively or optionally, the second type electrodes are common electrodes.

Alternatively or optionally, the at least one color includes red color, blue color and green color.

Alternatively or optionally, the first type electrodes are anodes and the second type electrodes are cathode.

Alternatively or optionally, the micro laser diode display device is a projection display device.

According to a second aspect of the present invention, there is provided an electronics apparatus, comprising the micro laser diode display device according to the present invention as a projection display source.

According to an embodiment of this invention, the present invention can provide a new solution for a display device by using micro laser diodes.

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 DISCRIPTION OF THE DRAWINGS

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.

Fig. 1 is a schematic cross-section view of a micro laser diode of VCSEL.

Fig. 2 is a schematic cross-section view of a micro laser diode device according to an embodiment of the present invention.

Fig. 3 is a schematic cross-section view of a micro laser diode device according to another embodiment of the present invention.

Fig. 4 is a schematic diagram of a top view of a micro laser diode device according to an embodiment of the present invention.

Figs. 5-9 schematically show the process of transferring micro laser diodes from carrier substrates to a receiving substrate according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE EMBODIMENTS

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.

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.

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.

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.

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.

Embodiments and examples of the present invention will be described with reference to the drawings.

Fig. 1 shows a schematic cross-section view of a micro laser diode of VCSEL. The VCSEL micro laser diode can be used in the embodiments of the present invention.

As shown in Fig.1, the micro laser diode 100 includes a lower contact layer 107, a lower Bragg reflector layer 106, a lower spacer layer 105, an active layer 104, an upper spacer layer 103, an upper Bragg reflector layer 102 and an upper contact layer 101.

For example, the micro laser diode 100 can be mounted on a lower metal electrode 108.

Fig. 2 shows a schematic cross-section view of a micro laser diode device according to an embodiment of the present invention.

In Fig. 2, the micro laser diode display device comprises a substrate 213. First type electrodes 214 are arranged on the substrate 213. The substrate 213 may have control and drive circuitries, such as AM TFT (active matrix, thin-film transistor). For example, the substrate 213 may a silicon substrate with CMOS circuitries. Alternatively, the substrate 213 may a glass backplane with TFT circuitries. Optionally, the substrate 213 may flexible with circuitries. For example, it may be a flexible printed circuitry board (FPCB).

The micro laser diode display device further comprises a micro laser diode array of

at least one color 200r, 200g, 200b and second type electrodes 211. The micro laser diode array is bonded on the substrate 213. The first side (lower side) of micro laser diodes 200r, 200g, 200b is connected to the first type electrodes 214, for example, via a bonding layer 215. The second type electrodes 211 are connected to a second side of the micro laser diodes 200r, 200g, 200b.

For example, the micro laser diodes can be of VCSEL structure as shown in Fig. 1. The at least one color can include red color, blue color and green color.

For example, the first type electrodes are anodes and the second type electrodes are cathode.

For example, the diameter of the micro laser diodes may be 1-500μm, preferably 10-100μm and further preferably 20-50μm. In an example, the diameter of the micro laser diodes may be less than 100μm.

In the prior art, a laser diode is not used in a display device. In this invention, it is used for display. For example, the micro laser diode display device can be a projection display device and it is used as a light source of a projector. It can project light onto a display screen (display surface). Because of the highly collimated light emitted by the micro laser diodes, it can offer a focus-free display. Compared with a micro-LED projection display device requiring a complicated optical focusing system due to its limited focal depth, the display solution using micro laser diodes will have advantages. This will lead to a new technical trend for display different from that of micro-LED.

As shown in Fig. 2, a dielectric filler layer 212 is filled among the micro laser diodes 200r, 200g, 200b. This structure is suitable for semiconductor processing. For example, it will facilitate forming the second type electrodes (cathodes) on top of the micro laser diodes. Furthermore, it may provide support to the micro laser diodes. Optionally, it may provide isolation between adjacent micro laser diodes.

Fig. 3 shows a schematic cross-section view of a micro laser diode device according to another embodiment of the present invention. The differences between the micro laser diode devices of Fig. 2 and Fig. 3 lie in the second type electrodes 311 and the dielectric filler layer 312.

In an example, as shown in Fig. 3, the dielectric filler layer 312 is lower than the micro laser diodes 200r, 200g, 200b. At least one part of the second type electrodes 311 is formed at a lateral side of the micro laser diodes 200r, 200g, 200b. In this way, it may provide a better Ohmic contact between the electrodes and the diodes. Optionally, this may further provide a better thermal dispersion for the micro laser diode.

In another example, as shown in Fig.3, the second type electrodes 311 are formed on top of the micro laser diodes and the dielectric filler layer. The second type electrodes 311 are patterned so that the micro laser diodes 200r, 200g, 200b are exposed. Compared with the micro laser diode display device of Fig. 2, the area of the second type electrode is enlarged. This may improve the thermal dispersion of the device.

Alternatively, the second type electrodes 311 may be transparent and is un-patterned. This will simplify the manufacturing of the device.

The second type electrodes can be a common electrode and/or be shorted.

It would be understood by a person skilled in the art that although the above two examples are shown in one figure, they can be implemented separately or in combination.

Fig. 4 shows a schematic diagram of a top view of a micro laser diode device according to an embodiment of the present invention.

As shown in Fig. 4, the micro laser diode device 450 includes red color micro laser diodes 400r, green color micro laser diodes 400g and blue color micro laser diodes 400b. They are arranged in multiple units. Each unit includes one red color micro laser diode 400r, two green color micro laser diodes 400g and one blue color micro laser diode 400b.

As shown in Fig. 4, the green micro laser diodes 400g are redundant. This may improve yield/reliability.

The micro laser diode display device according to the embodiments of the present invention can used in an electronics apparatus as a projection display source. The electronics apparatus can be a projector, a projection television, a smart phone with projection display and so on.

Below, a method for transferring micro laser diodes will be described with reference to Figs. 5-9.

Figs. 5-9 schematically show the process of transferring micro laser diodes from carrier substrates to a receiving substrate according to an embodiment of the present invention.

As shown in Fig. 5, a bonding layer 515 is formed on a receiving substrate 513. First type electrodes 514 are connected to the bonding layer 515. The first type electrodes 514 can be anodes.

A first side (lower side) of the micro laser diodes 500r on a carrier substrate 520 is brought into contact with the bonding layer 514. The carrier substrate 520 is laser-transparent.

In Fig. 5, the micro laser diodes 500r is of red color, for example. It can be the micro laser diodes of VCSEL structure as shown in Fig. 1.

Selected micro laser diodes 500r are irradiated with laser 521 from the side of the carrier substrate 520 to lift-off the selected micro laser diodes 500r from the carrier substrate 520.

For example, during lifting-off, the micro laser diodes 500r are kept on the receiving substrate 513 through a gravity force. Alternatively, an adhesion force of the bonding layer 515 may also be used to keep the micro laser diodes 500r. Further alternatively, an electrostatic force may be applied to the micro laser diodes 500r to keep it on the receiving substrate 513. Even further alternatively, an electromagnetic force may be applied to the micro laser diodes 500r to keep it on the receiving substrate 513. The above approaches can be used individually or in any combination.

This embodiment proposes a new approach for transferring micro laser diodes. Compared with the prior solution of picking up laser diodes individual with a pick-up head, this embodiment is more suitable for semiconductor processing. For example, it can improve yield. Optionally, it can provide a more efficient transfer. Optionally, the definition of the micro laser diodes may be improved.

As shown in Fig. 6, green color micro laser diodes 500g on a carrier substrate 522 may selectively be transferred to the receiving substrate 513 by using the selective laser 523. As shown in Fig. 7, blue color micro laser diodes 500b on a carrier substrate 524 may

selectively be transferred to the receiving substrate 513 by using the selective laser 525. The processing is similar with the transferring of red color micro laser diodes shown in Fig. 5, and thus is omitted.

After transferring, the bonding layer 515 may be cured.

As shown in Fig. 8, a dielectric filler material is filled among the micro laser diodes 500r, 500g, 500b to form a dielectric filler layer 512. The dielectric filler layer 512 may be flush with the upper surface of the micro laser diodes. Alternatively, it can be etched back lower than the upper surface of the micro laser diodes so that a top electrode may be formed to be in contact with at least one part of the lateral side of a micro laser LED, as shown in Fig. 3.

This processing may provide flexibility for a designer or a manufacturer in designing and manufacturing a micro laser diodes device.

As shown in Fig. 9, second type electrodes 511 are formed to be connected to a second side (upper side) of the micro laser diodes 500r, 500g, 500b.

For example, during the second type electrodes 511 are formed, an electrode layer are formed on the micro laser diodes 500r, 500g, 500b and the dielectric filler layer 512. Then, the electrode layer is patterned to expose the micro laser diodes to form the second type electrodes 511.

Alternatively, the electrode layer is transparent and may not be patterned. This will simplify the manufacture processing and thus may reduce the cost.

Although it is not shown, at least one part of the second type electrodes 511 may be formed at a lateral side of the micro laser diodes 500r, 500g, 500b.

For example, the second type electrode 511 may be a common electrode.

For example, the first type electrodes 514 are anodes and the second type electrodes 511 are cathode.

For example, the diameter of the micro laser diodes 500r, 500g, 500b may be less than 100μm.

For example, a protection layer may be applied on the top of the transferred micro laser diodes.

In another embodiment, a method for manufacturing a micro laser diode device may include transferring micro laser diodes to a receiving substrate of the micro laser diode device by using the method according to any of the embodiments of the present invention.

For example, the manufacturing method can be used to manufacture the micro laser diode display device according to the embodiments of the present invention. Alternatively, the method can further be used in manufacturing a micro laser diode device, and the micro laser diode device may be used in micro laser printers, optical communications, collimated light sourcing, micro-displays, micro-projections and so on.

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.

CLAIMS

What is claimed is:

1. A micro laser diode display device, comprising:

a substrate, wherein first type electrodes are arranged on the substrate;

a micro laser diode array of at least one color bonded on the substrate, wherein a first side of micro laser diodes in the micro laser diode array is connected to the first type electrodes; and

second type electrodes connected to a second side of the micro laser diodes.

2. The micro laser diode display device according to claim 1, wherein the micro laser diodes are of vertical cavity surface emitting laser structure, which includes a lower contact layer, a lower Bragg reflector layer, a lower spacer layer, an active layer, an upper spacer layer, an upper Bragg reflector layer and an upper contact layer.

3. The micro laser diode display device according to claim 1 or 2, wherein dielectric filler layer is filled among the micro laser diodes.

4. The micro laser diode display device according to any of claims 1-3, wherein at least one part of the second type electrodes is formed at a lateral side of the micro laser diodes.

5. The micro laser diode display device according to any of claims 1-4, wherein the second type electrodes are formed on top of the micro laser diodes and the dielectric filler layer, and are patterned so that the micro laser diodes are exposed.

6. The micro laser diode display device according to any of claims 1-5, wherein the second type electrodes are common electrodes.

7. The micro laser diode display device according to any of claims 1-6, wherein the at least one color includes red color, blue color and green color.

8. The micro laser diode display device according to any of claims 1-7, wherein the first type electrodes are anodes and the second type electrodes are cathode.

9. The micro laser diode display device according to any of claims 1-8, wherein the micro laser diode display device is a projection display device.

10. An electronics apparatus, comprising the micro laser diode display device according to any of claims 1-9 as a projection display source.

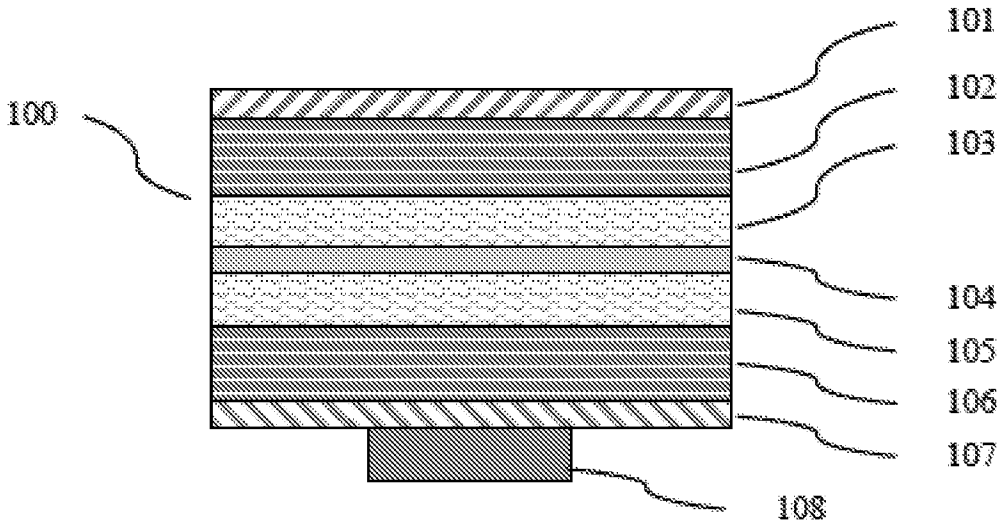
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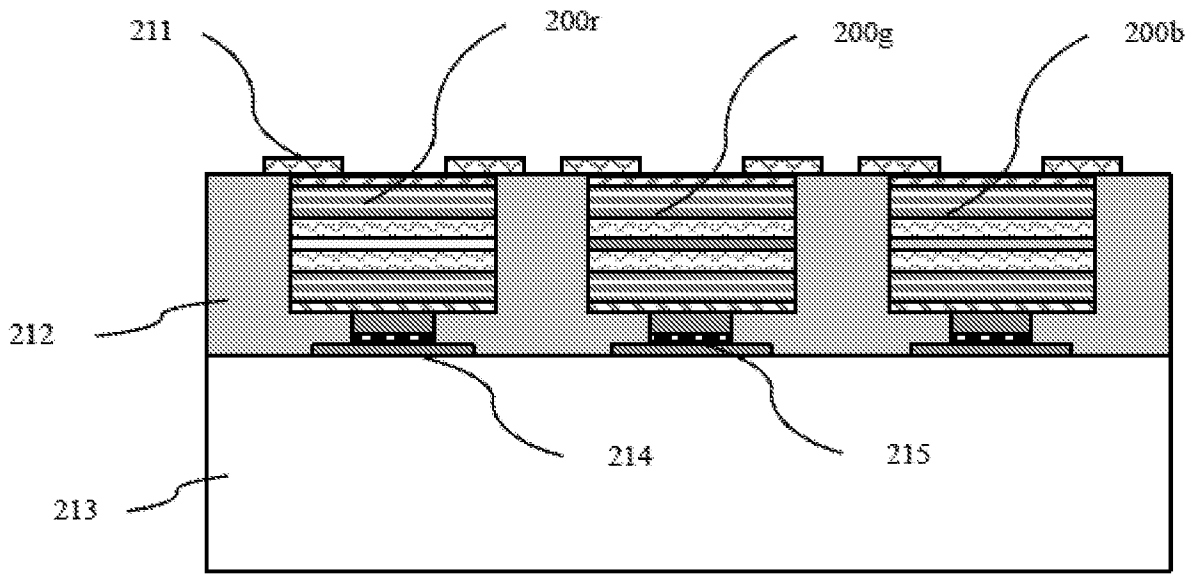
FIG. 1


211
200r
200g
200b
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215
213

FIG. 2

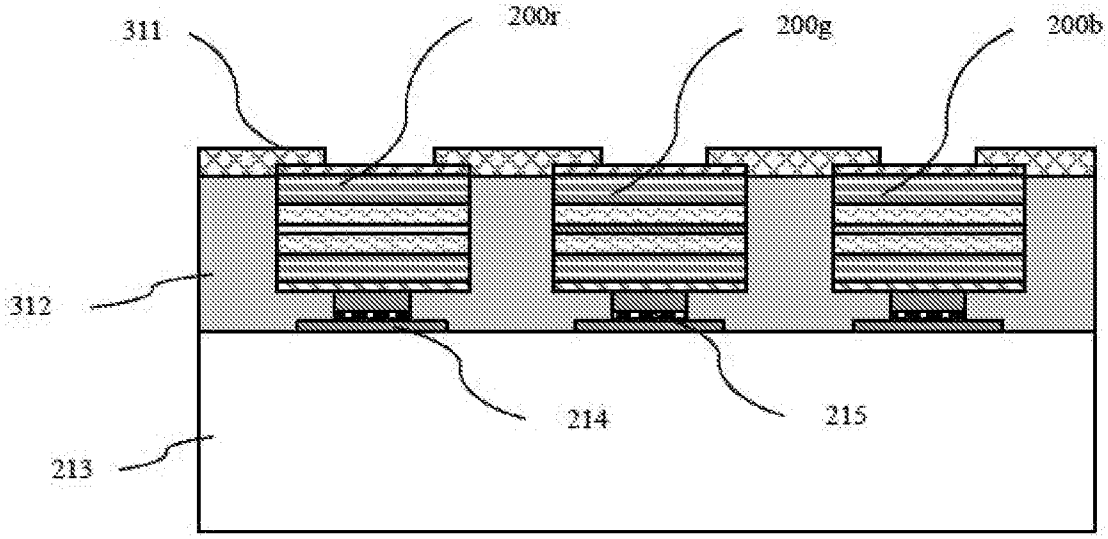

FIG. 3

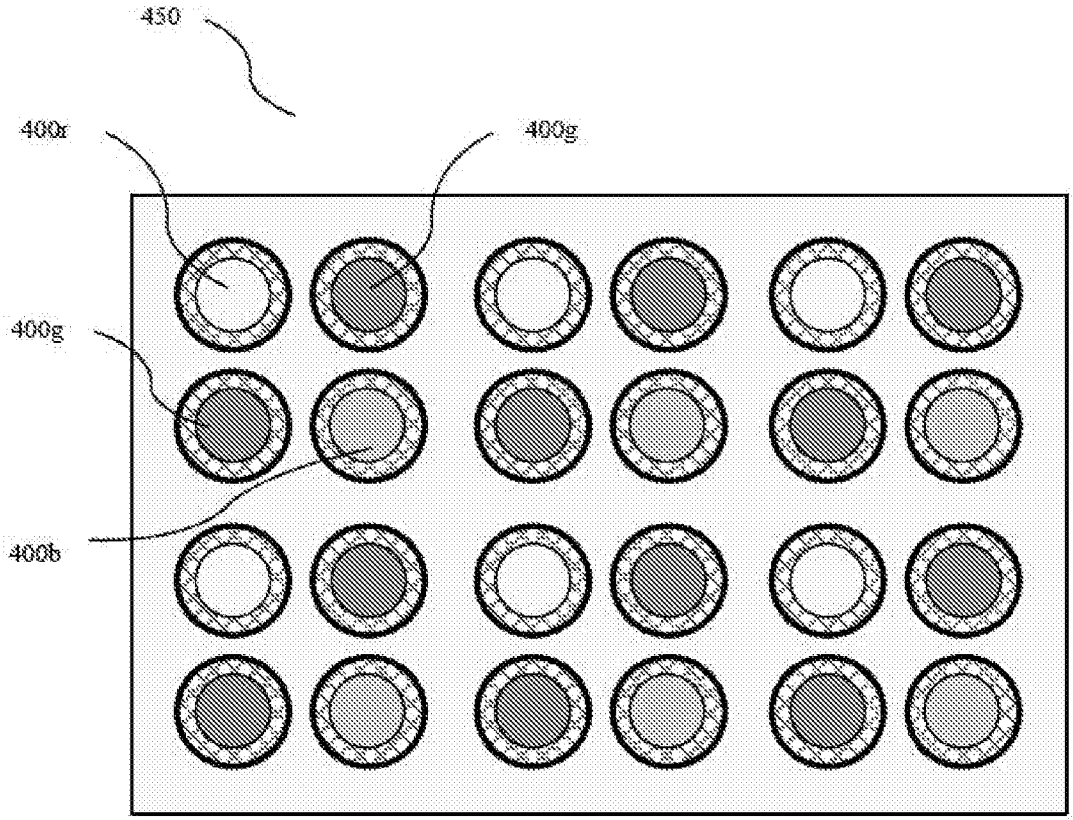

FIG. 4

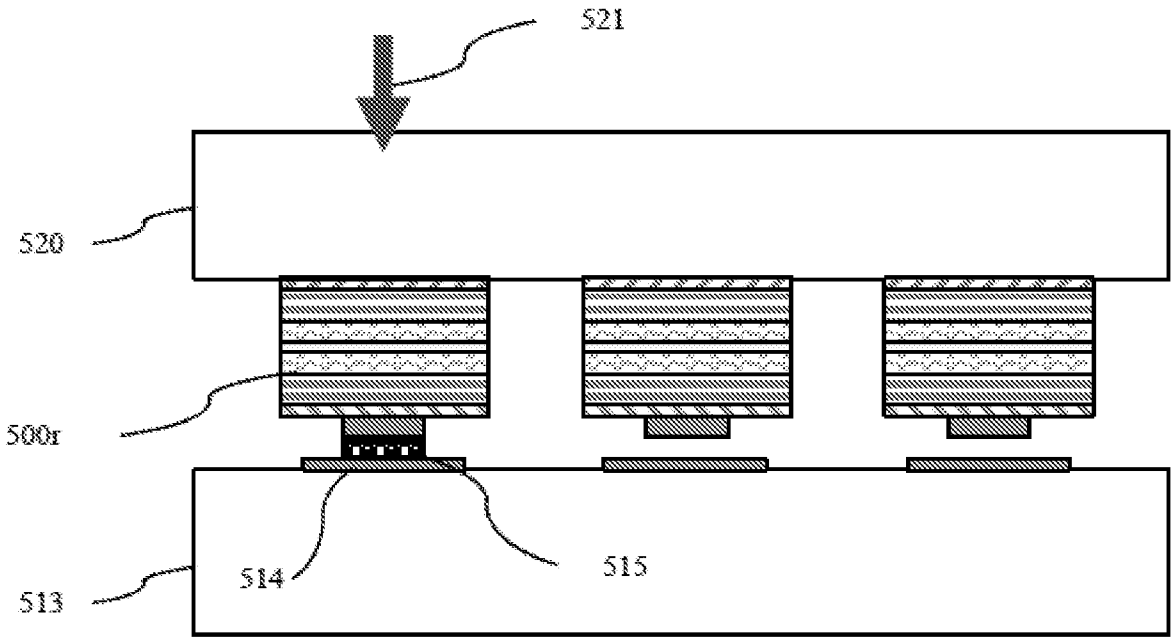

FIG. 5

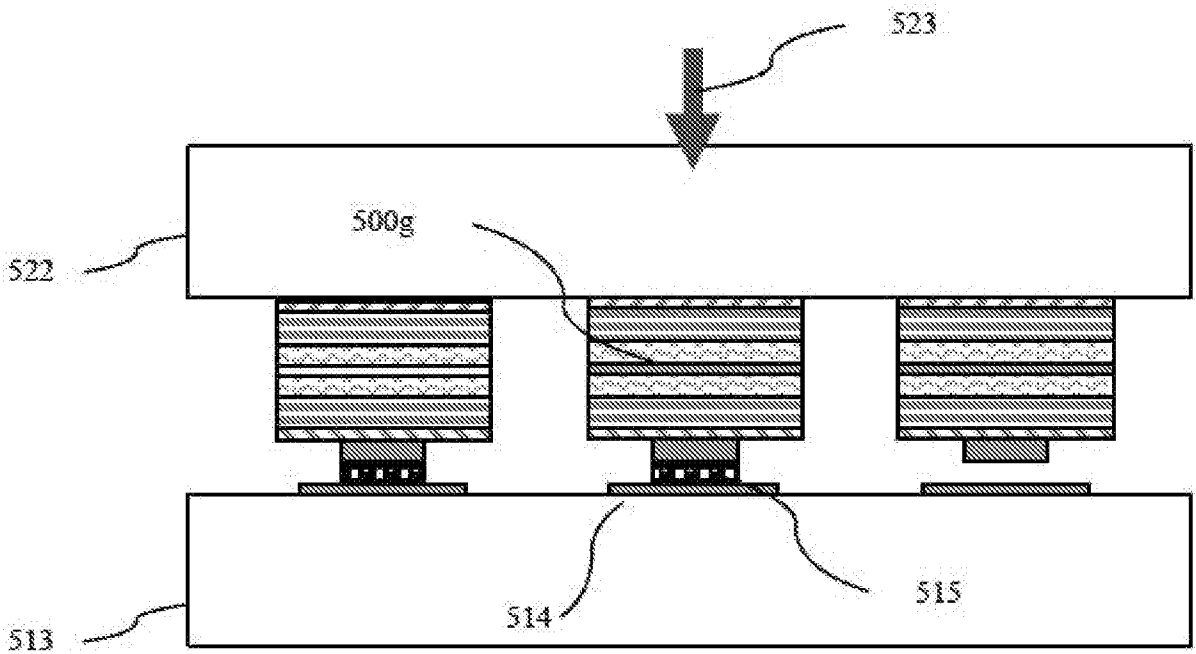

FIG. 6

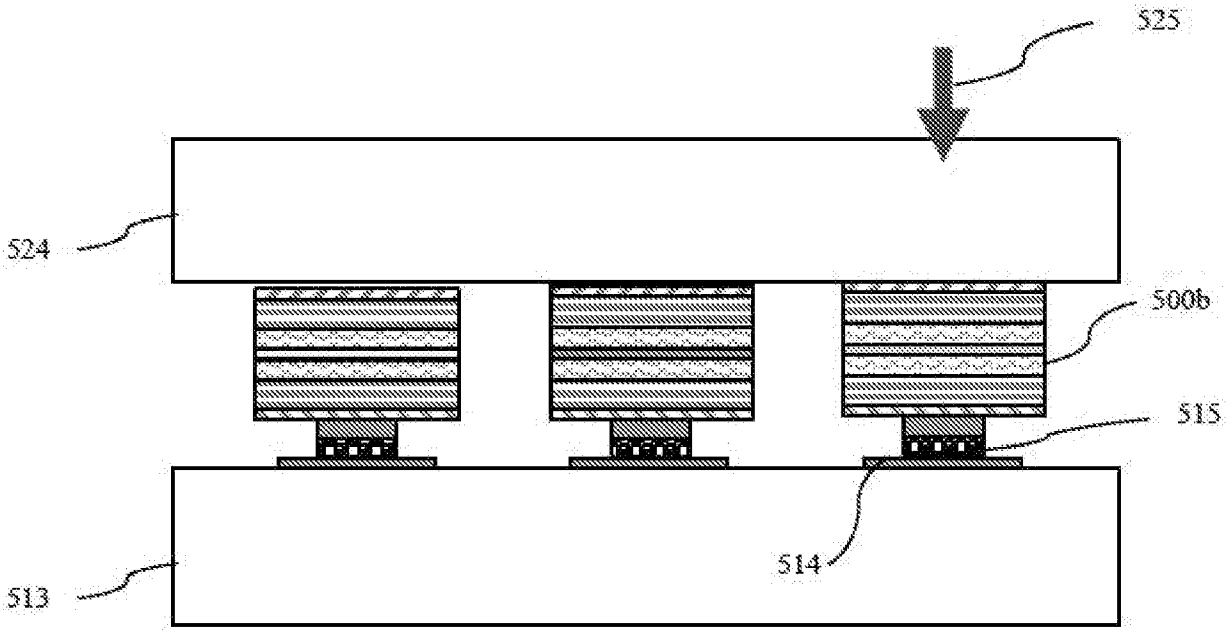

FIG. 7

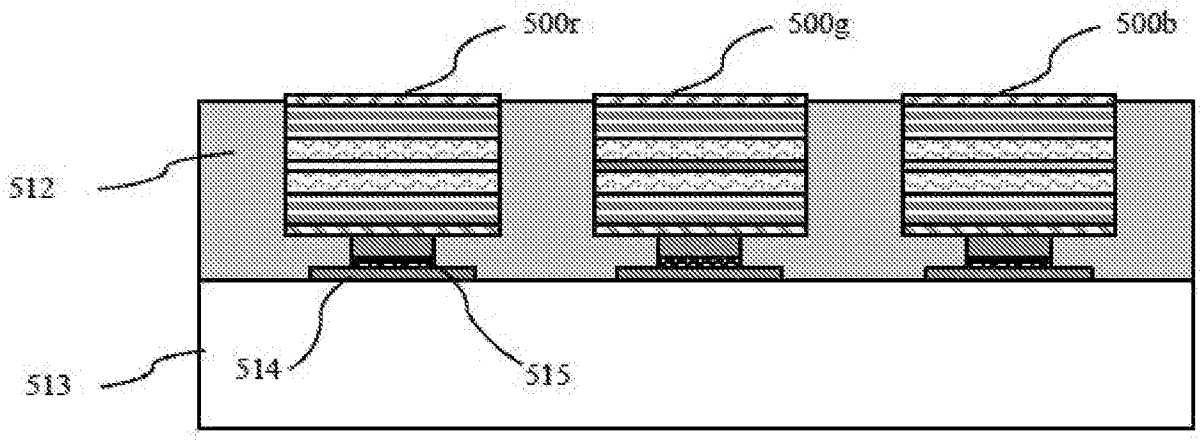

FIG. 8

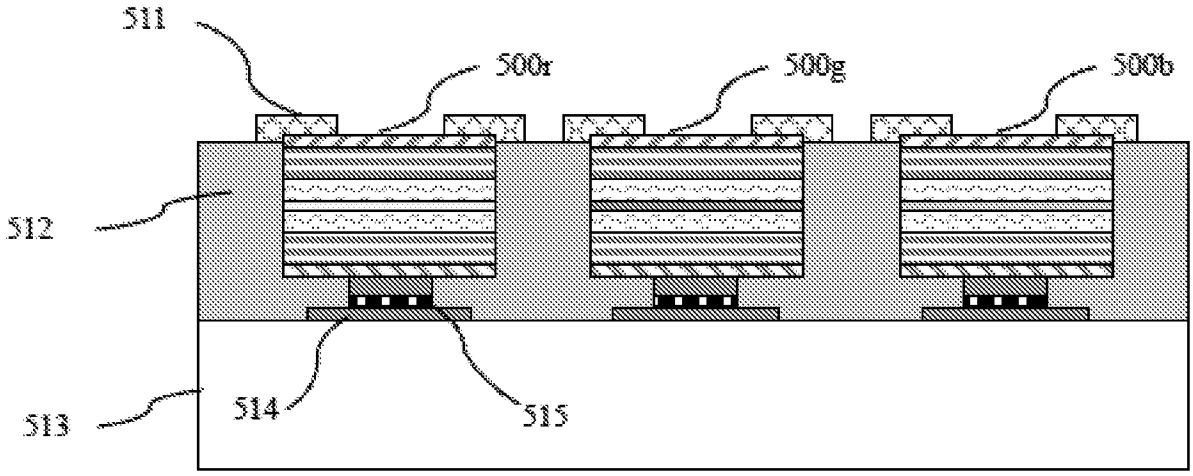

FIG. 9

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2016/108513

A. CLASSIFICATION OF SUBJECT MATTER

G02F 1/13(2006.01)i; H01S 5/18(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G02F;H01S;H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPODOC; WPI;CNABS;CNKI: micro+, LD?, μ, VCSEL?, laser?, diode?, electrode?, array, cathode?, anode?, goertek, display+, project+

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	CN 1957293 A (EASTMAN KODAK CO.) 02 May 2007 (2007-05-02) description, page 1, lines 15 to 25, page 5, line 23 to page 6, line 8, page 26, line 1 to page 28, line 5, page 32, lines 7 to 15 and figures 2-3	1-10
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☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
02 August 2017	**25 August 2017**

Name and mailing address of the ISA/CN	Authorized officer
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Facsimile No. **(86-10)62019451**	Telephone No. **(86-10)62413961**

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2016/108513

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