US 20190165038A1

(19) **United States**

(12) **Patent Application Publication**

CHAE et al.

(10) **Pub. No.: US 2019/0165038 A1**

(43) **Pub. Date: May 30, 2019**

(54) LED UNIT FOR DISPLAY AND DISPLAY APPARATUS HAVING THE SAME

(71) Applicant: **SEOUL VIOSYS CO., LTD.**, Ansan-si (KR)

(72) Inventors: **Jong Hyeon CHAE**, Ansan-si (KR); **Chung Hoon Lee**, Ansan-si (KR); **Seong Gyu Jang**, Ansan-si (KR); **Chang Yeon Kim**, Ansan-si (KR); **Ho Joon Lee**, Ansan-si (KR)

(21) Appl. No.: **16/198,796**

(22) Filed: **Nov. 22, 2018**

Related U.S. Application Data

(60) Provisional application No. 62/590,810, filed on Nov. 27, 2017, provisional application No. 62/590,854, filed on Nov. 27, 2017, provisional application No. 62/590,870, filed on Nov. 27, 2017, provisional application No. 62/621,503, filed on Jan. 24, 2018, provisional application No. 62/635,284, filed on Feb. 26, 2018.

Publication Classification

(51) **Int. Cl.**

H01L 27/15	(2006.01)
H01L 33/40	(2006.01)
H01L 33/50	(2006.01)
H01L 33/10	(2006.01)
H01L 33/30	(2006.01)

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

CPC ***H01L 27/156*** (2013.01); ***H01L 33/405*** (2013.01); ***H01L 33/30*** (2013.01); ***H01L 33/10*** (2013.01); ***H01L 33/504*** (2013.01)

(57) **ABSTRACT**

A light emitting diode (LED) stack for a display includes a first LED sub-unit having a first surface and a second surface, a second LED sub-unit disposed on the first surface of the first LED sub-unit, a third LED sub-unit disposed on the second LED sub-unit, a reflective electrode disposed on the second side of the second LED sub-unit and forming ohmic contact with the first LED sub-unit, and an ohmic electrode interposed between the first LED sub-unit and the second LED sub-unit and forming ohmic contact with the first LED sub-unit, in which the second LED sub-unit and the third LED sub-unit are configured to transmit light generated from the first LED sub-unit, and the third LED sub-unit is configured to transmit light generated from the second LED sub-unit.

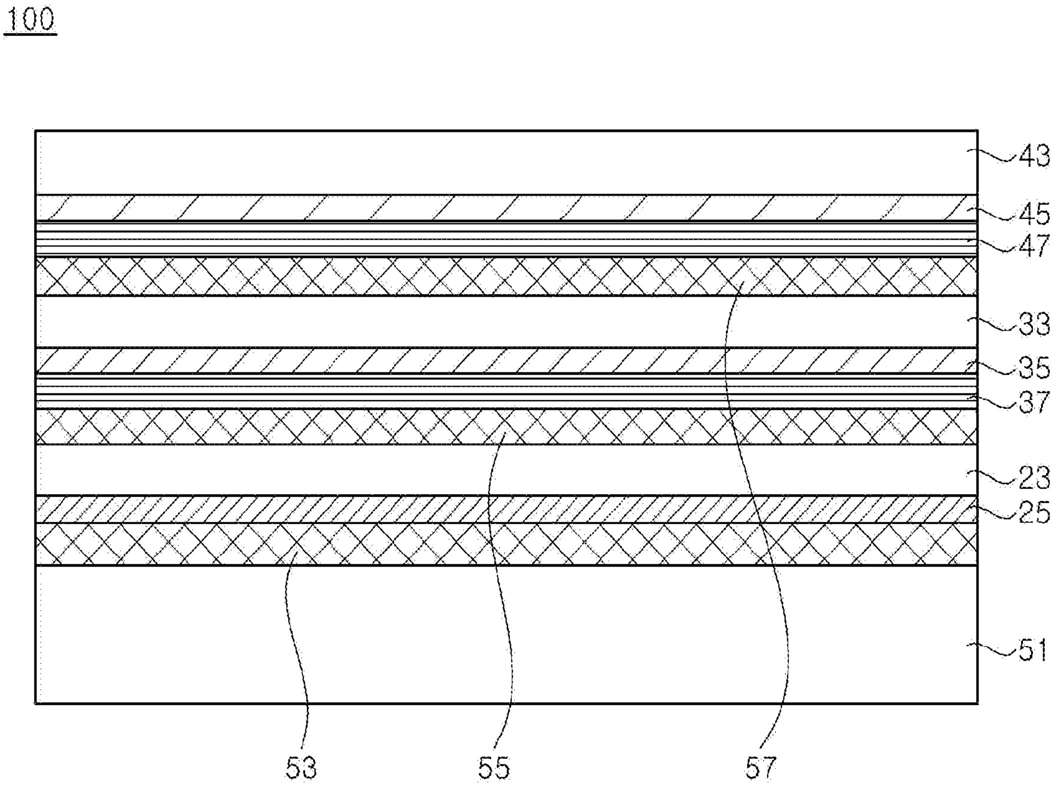


FIG. 1

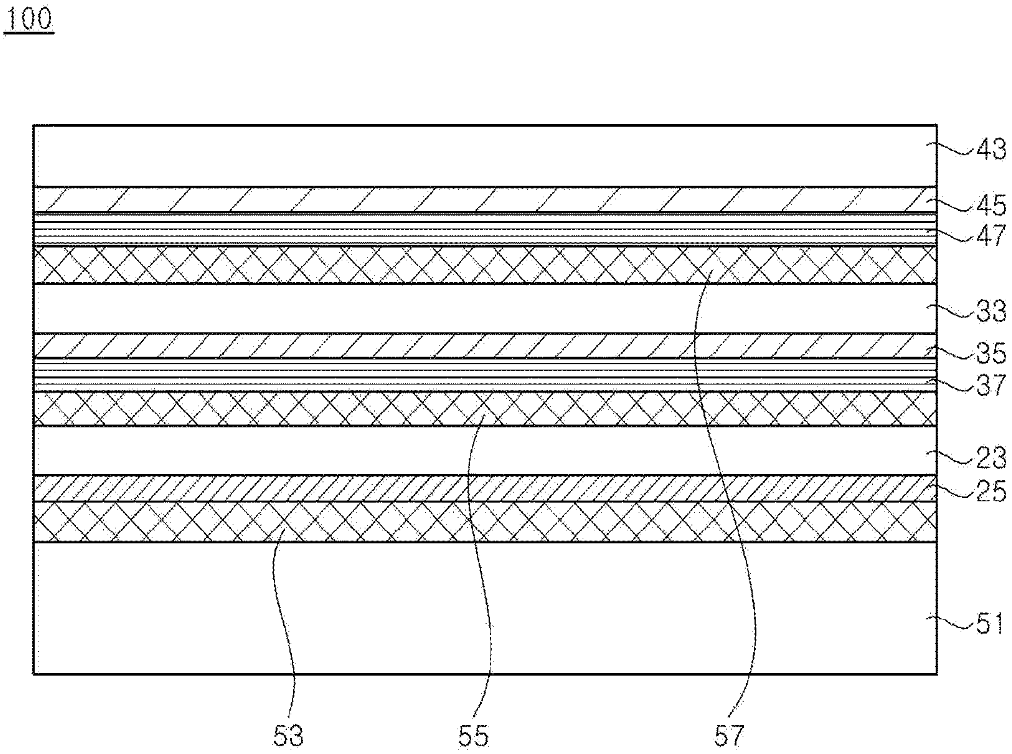
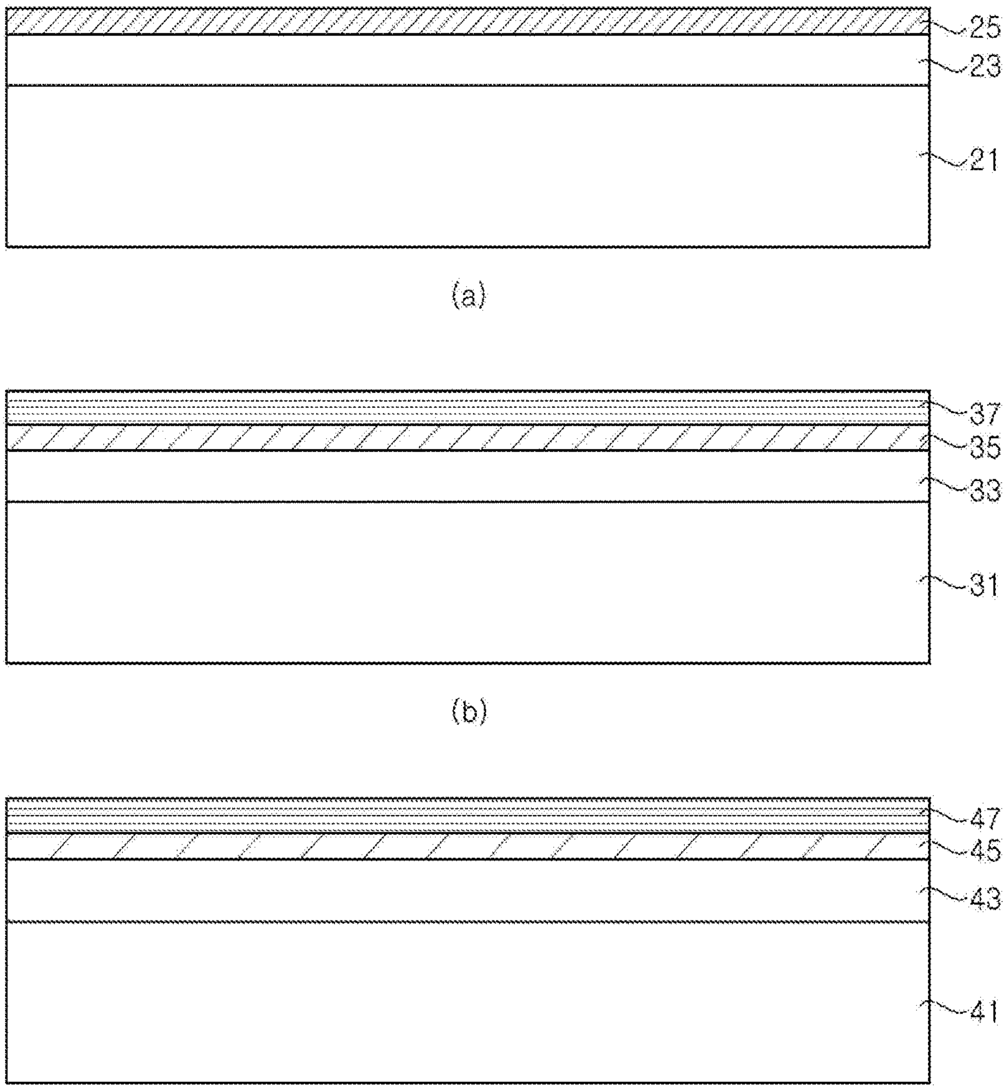


FIG. 2



(a)

(b)

(c)

FIG. 3

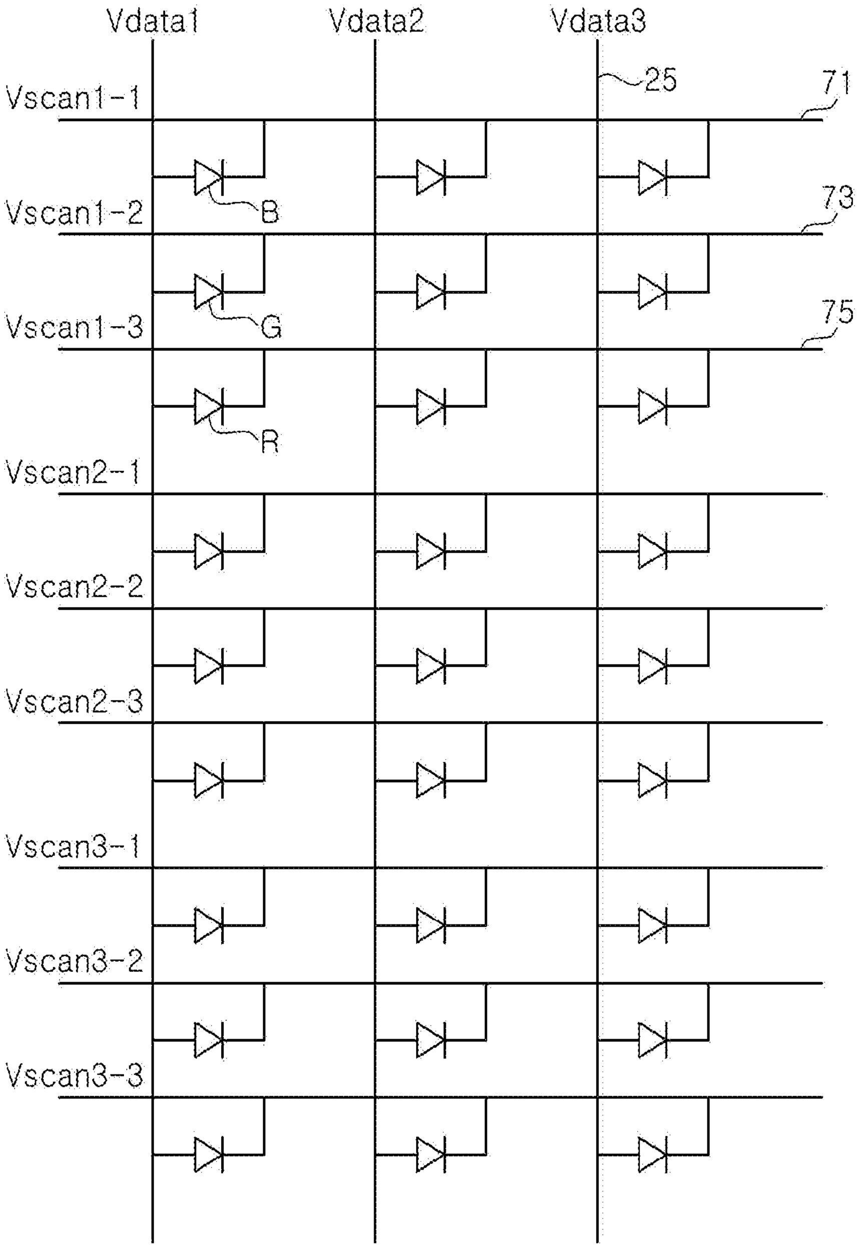

Vdata1
Vdata2
Vdata3
25
71
73
75
Vscan1-1
Vscan1-2
Vscan1-3
Vscan2-1
Vscan2-2
Vscan2-3
Vscan3-1
Vscan3-2
Vscan3-3
B
G
R

FIG. 4

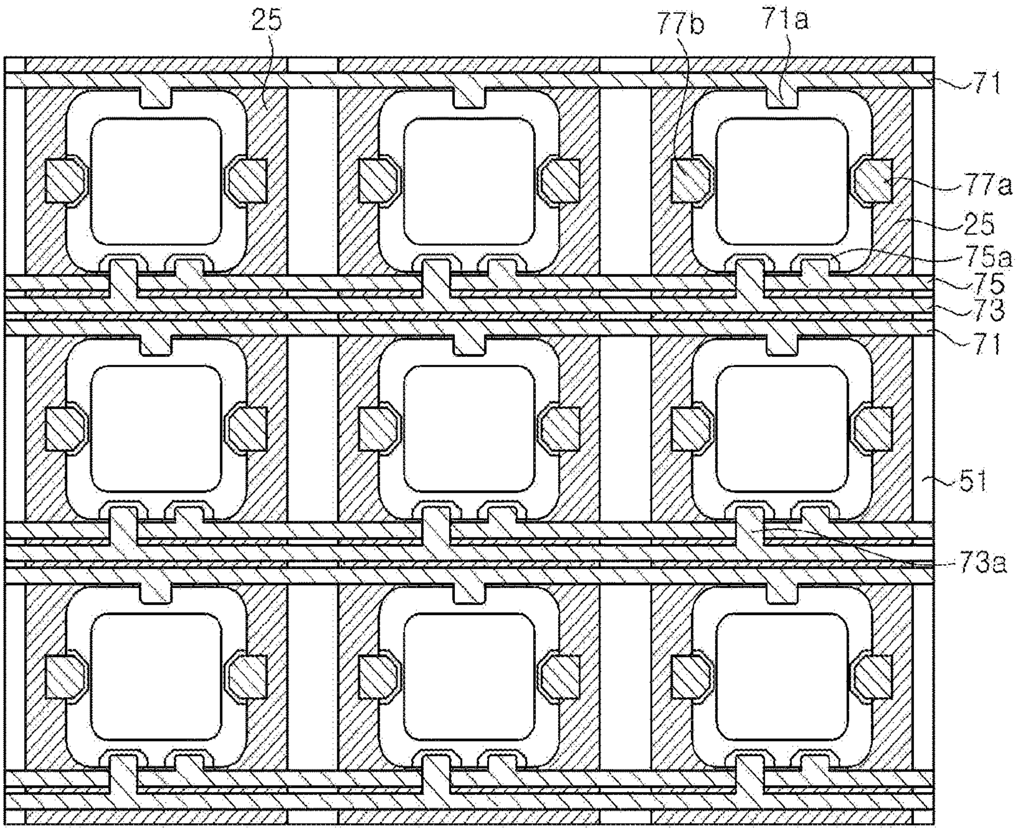

25
77b
71a
71
77a
25
75a
75
73
71
51
73a

FIG. 5

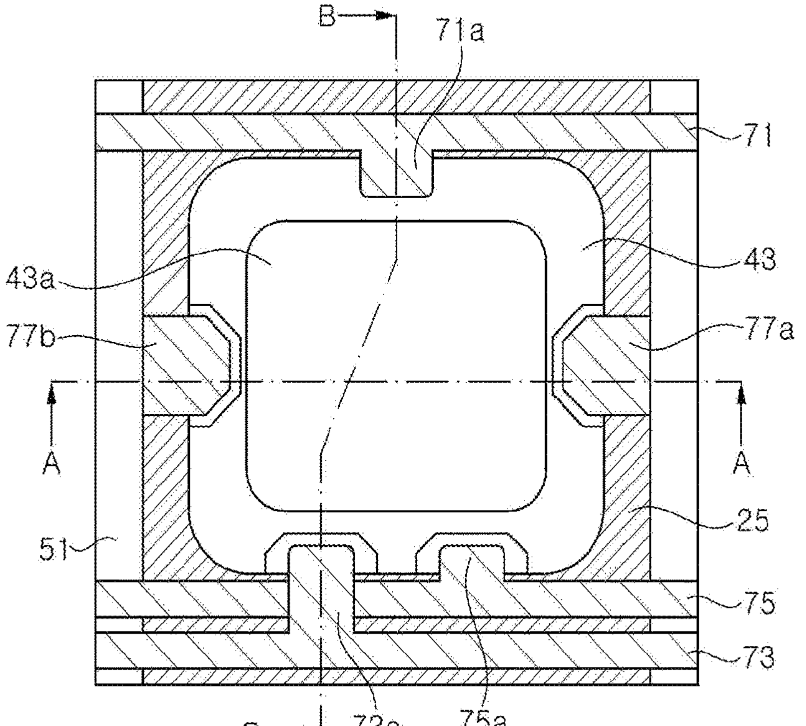

B
71a
71
43a
43
77b
77a
A
A
51
25
75
73
B
73a
75a

FIG. 6

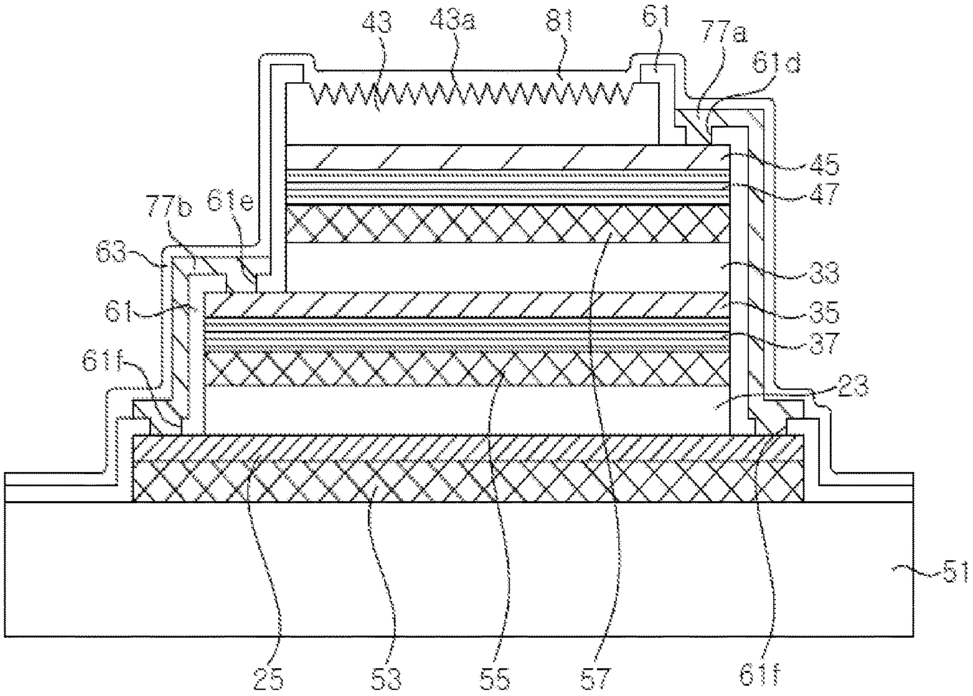

43
43a
81
61
77a
61d
45
47
77b
61e
63
33
61
35
37
61f
23
51
25
53
55
57
61f

FIG. 7

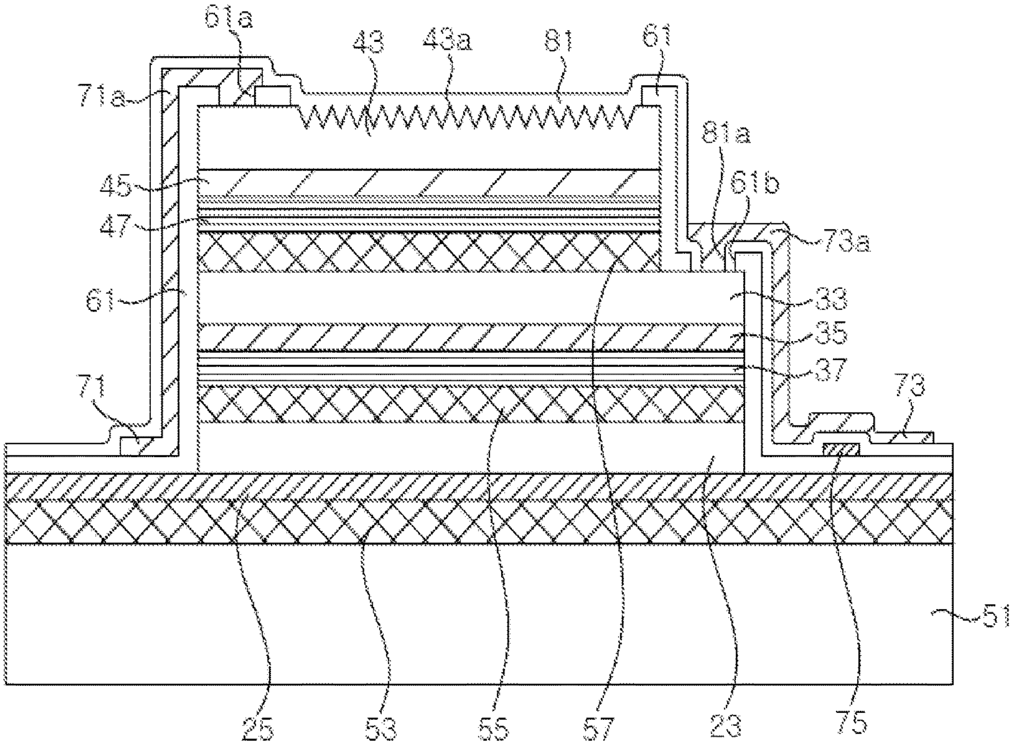

61a
43
43a
81
61
71a
81a
45
61b
73a
47
61
33
35
37
71
73
51
25
53
55
57
23
75

FIG. 8A

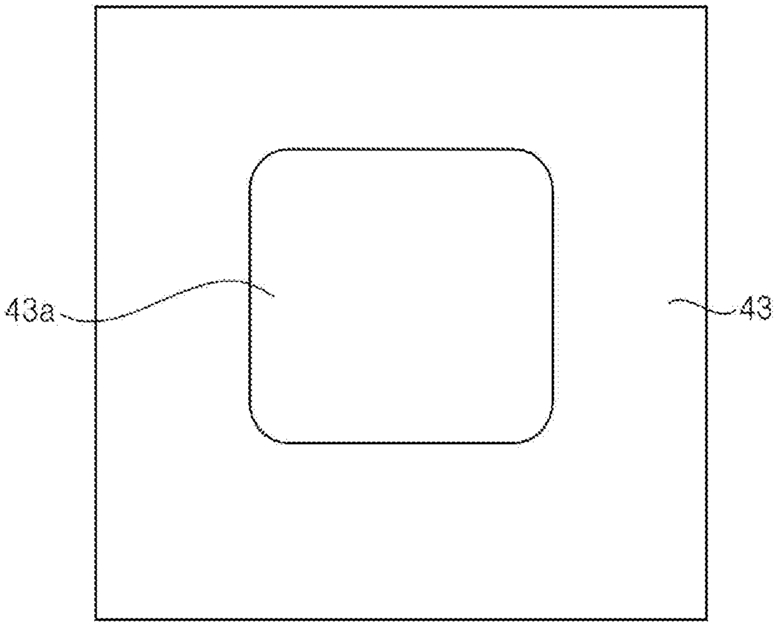


FIG. 8B

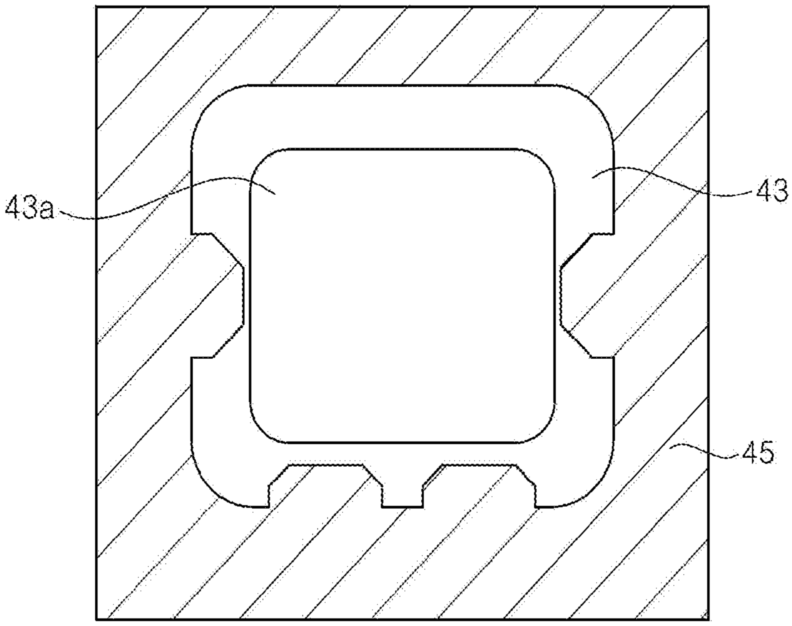


FIG. 8C

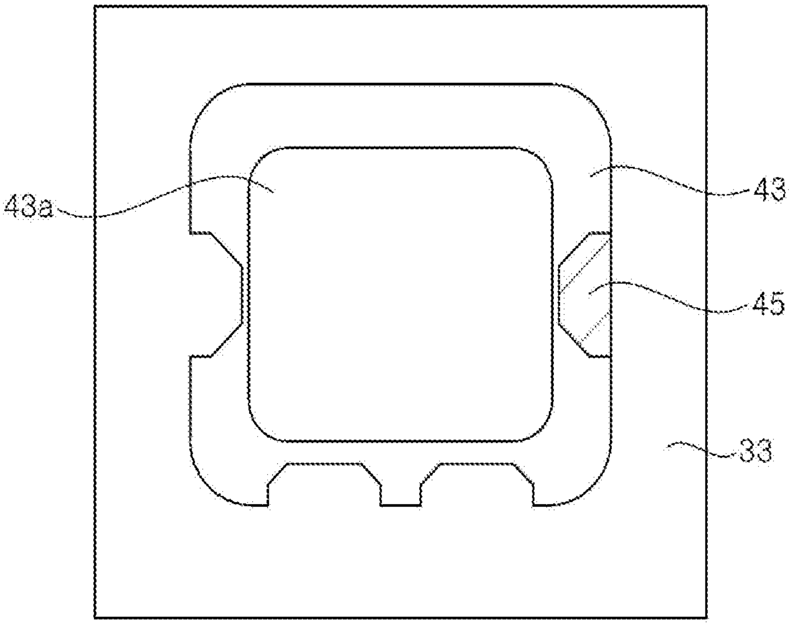


FIG. 8D

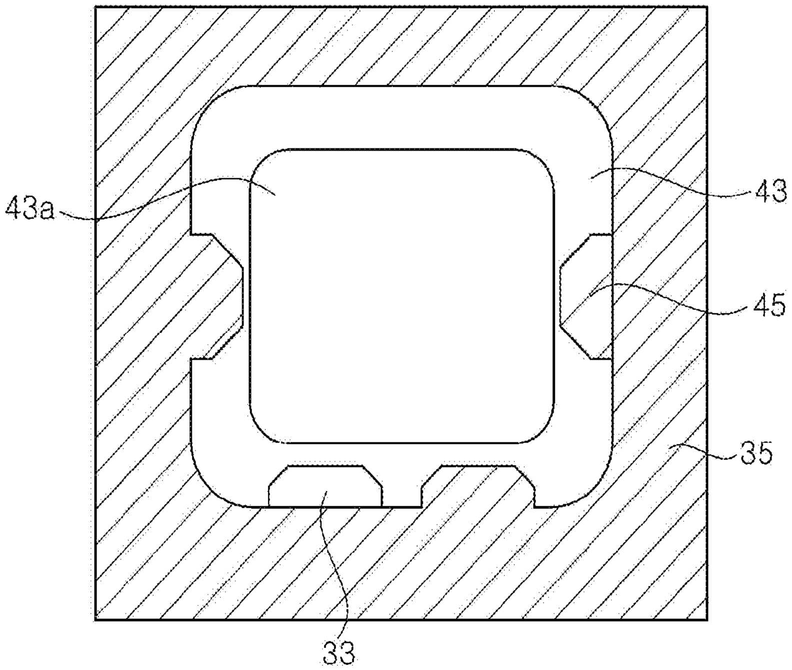


FIG. 8E

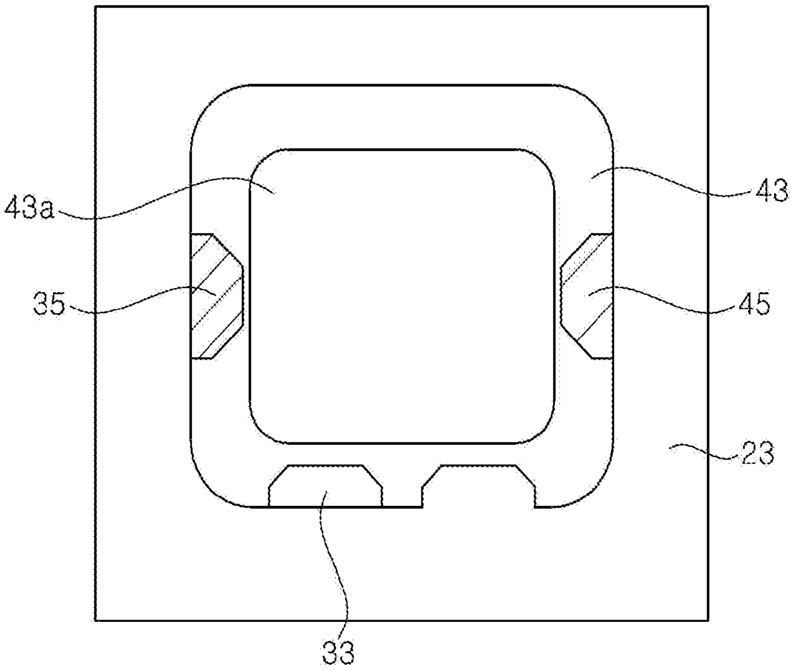


FIG. 8F

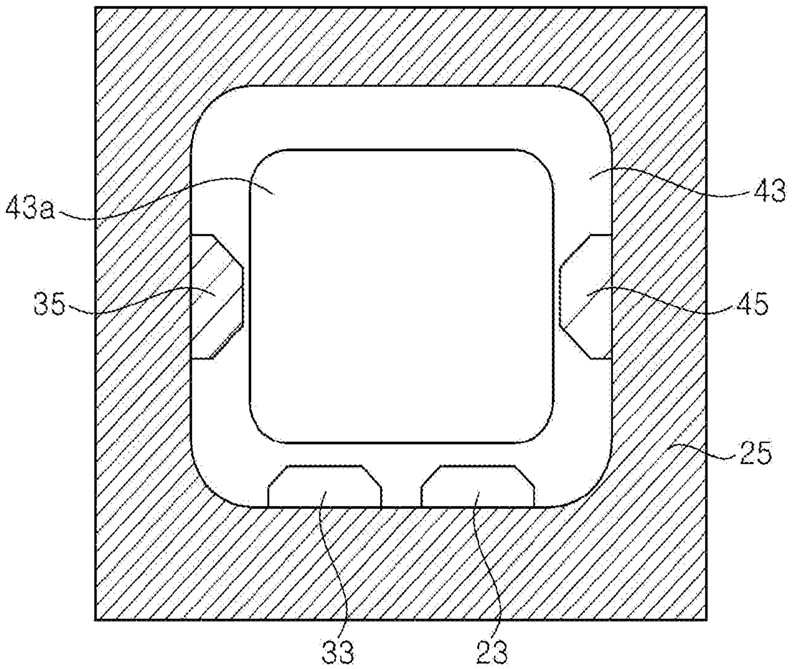


FIG. 8G

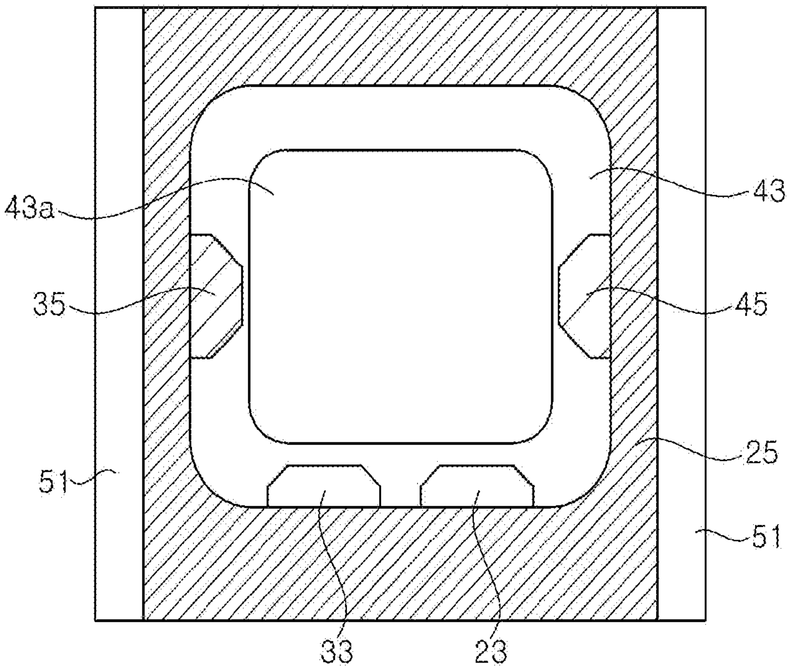


FIG. 8H

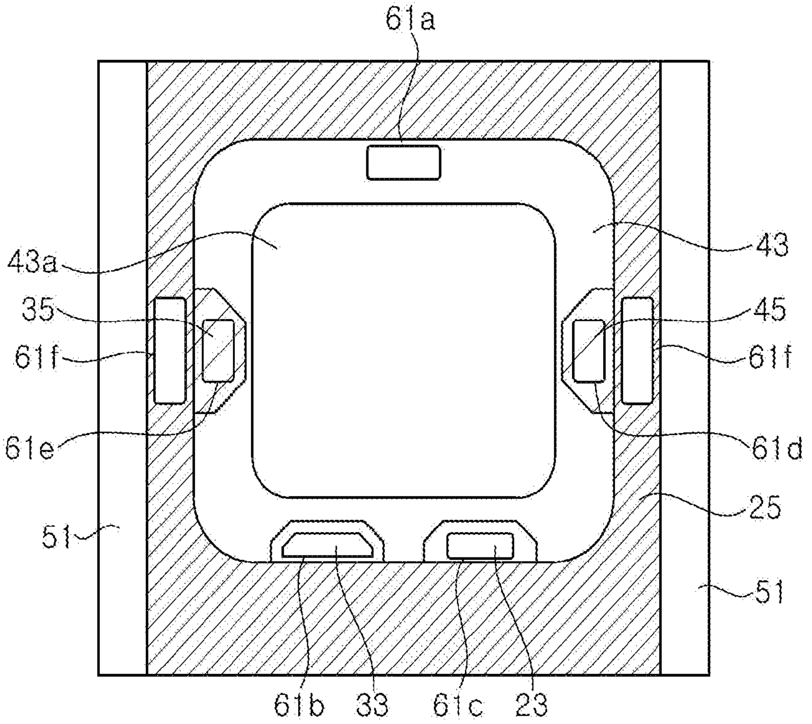

61a
43a
43
35
45
61f
61f
61e
61d
51
25
51
61b
33
61c
23

FIG. 8I

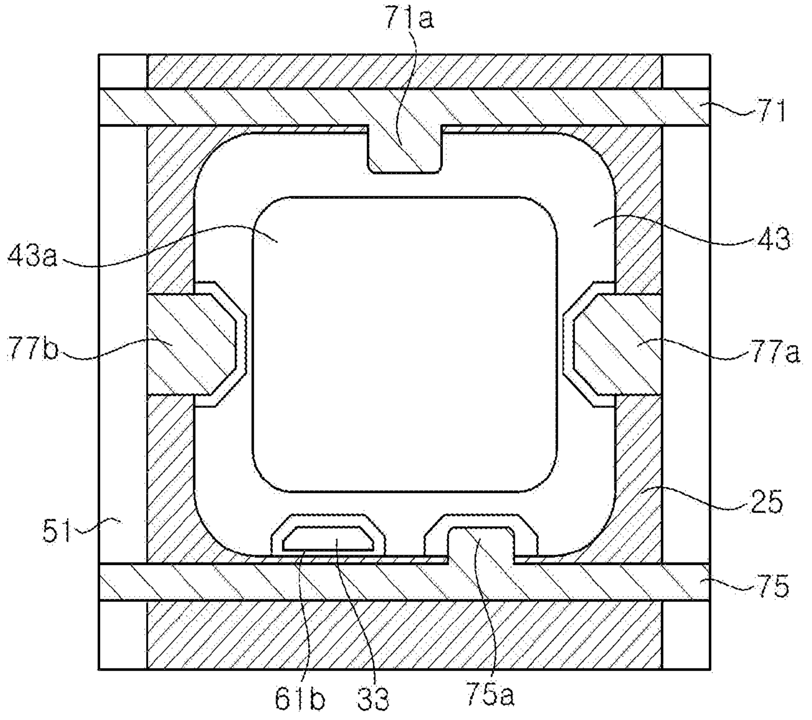

71a
71
43a
43
77b
77a
51
25
75
61b
33
75a

FIG. 8J

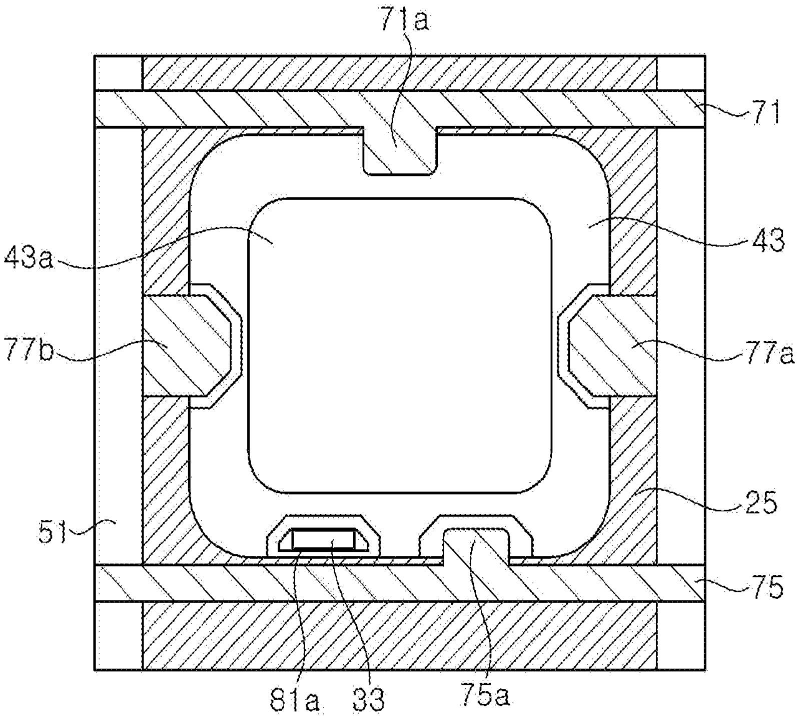

71a
71
43a
43
77b
77a
25
51
75
81a
33
75a

FIG. 8K

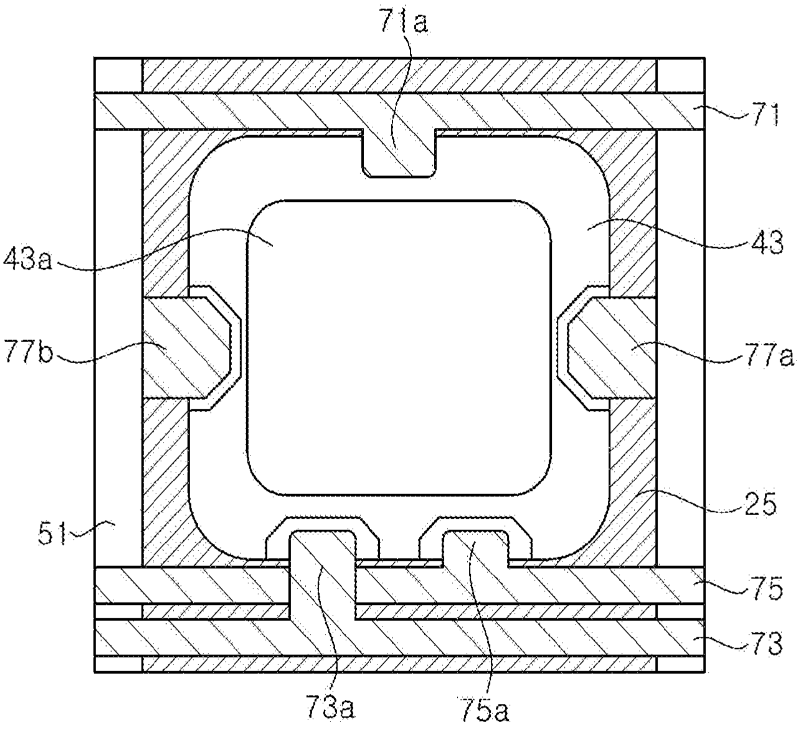

71a
71
43a
43
77b
77a
25
51
75
73
73a
75a

FIG. 9

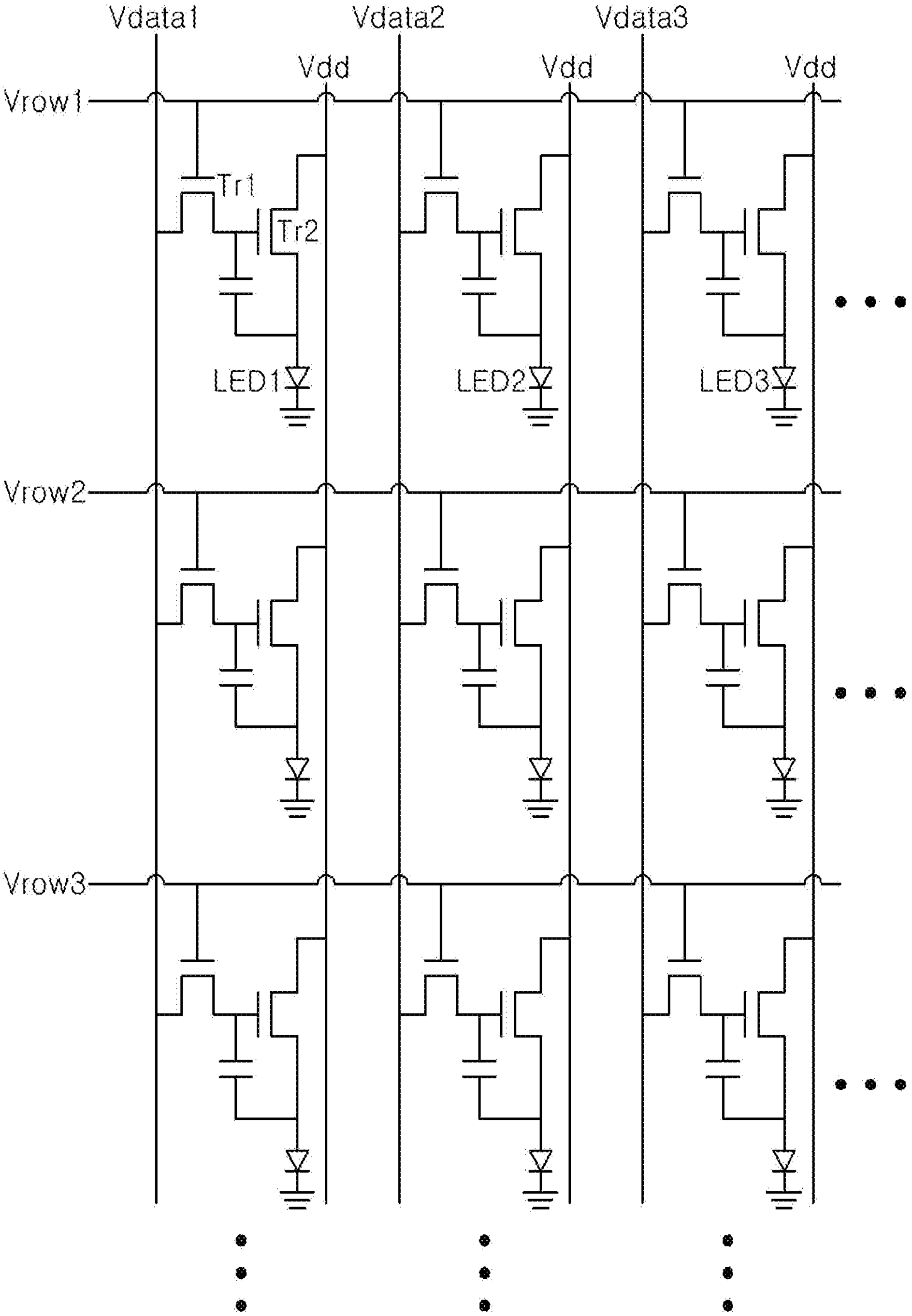

Vdata1
Vdata2
Vdata3
Vdd
Vdd
Vdd
Vrow1
Tr1
Tr2
LED1
LED2
LED3
Vrow2
Vrow3

FIG. 10

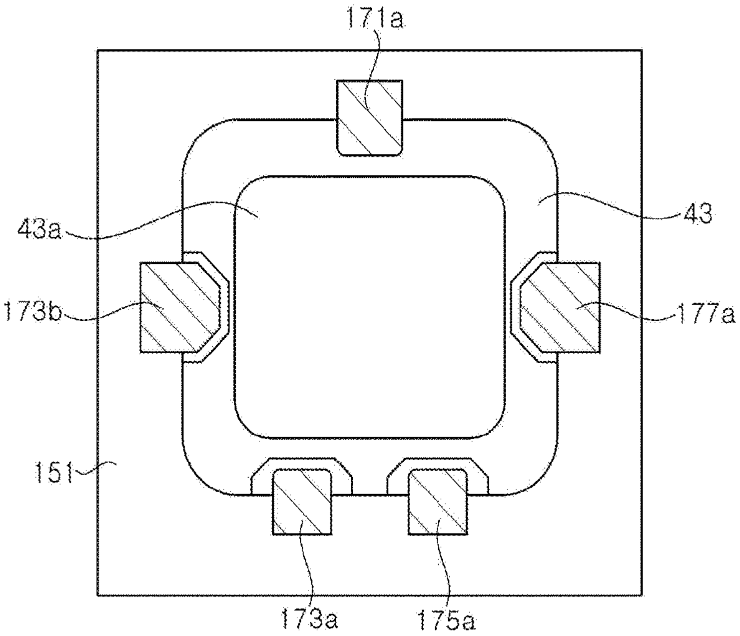

171a
43a
43
173b
177a
151
173a
175a

FIG. 11

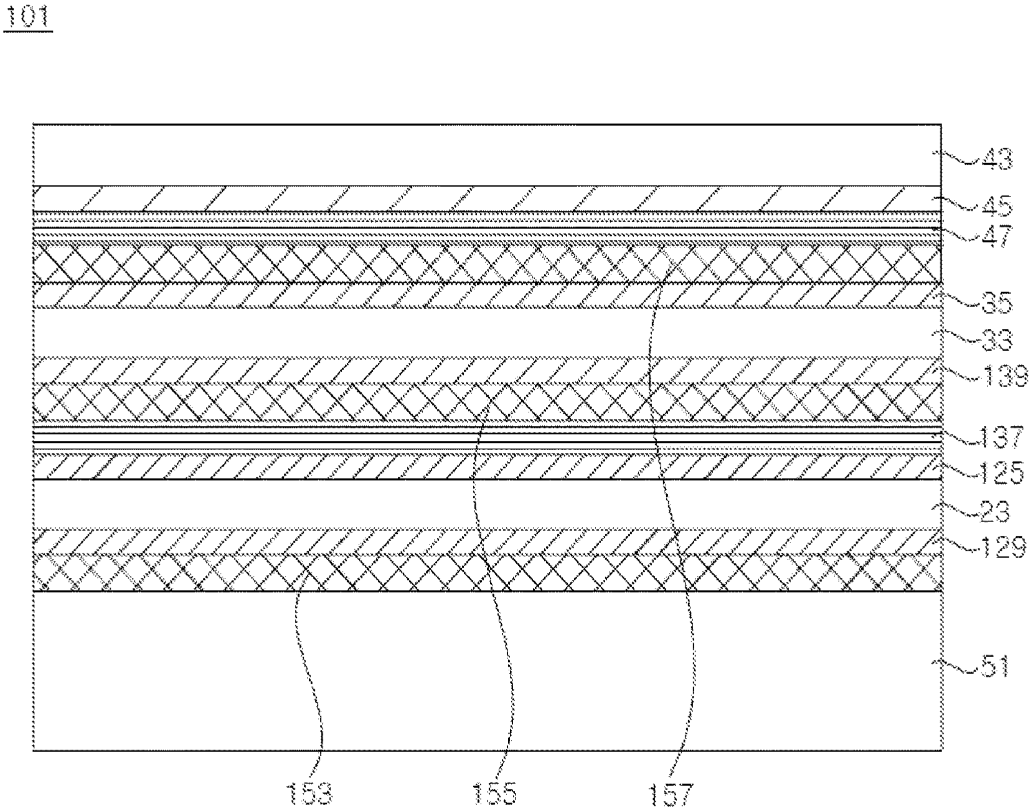

101
43
45
47
35
33
139
137
125
23
129
51
153
155
157

FIG. 12A

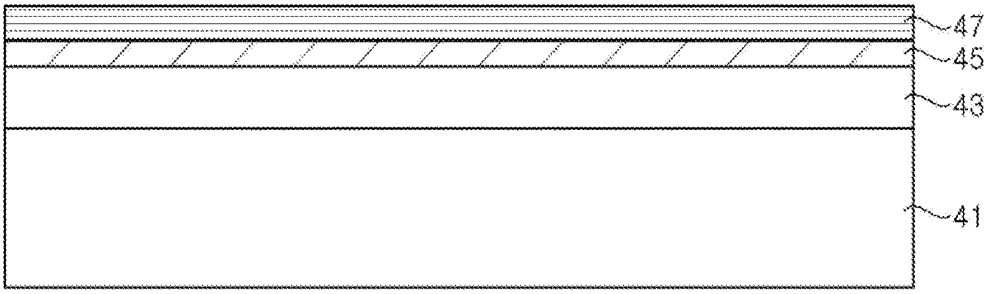


FIG. 12B

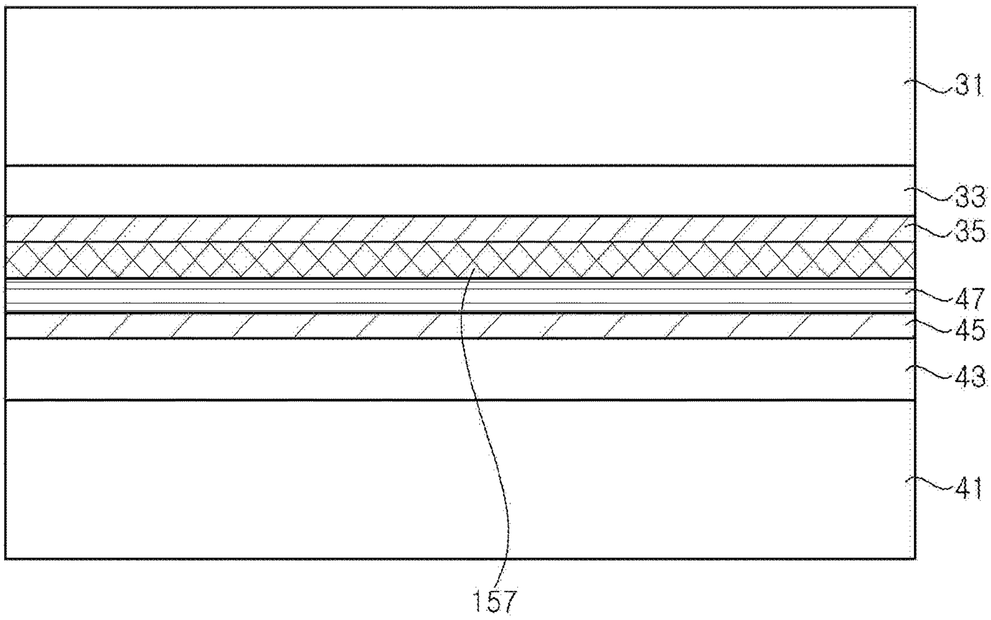


FIG. 12C

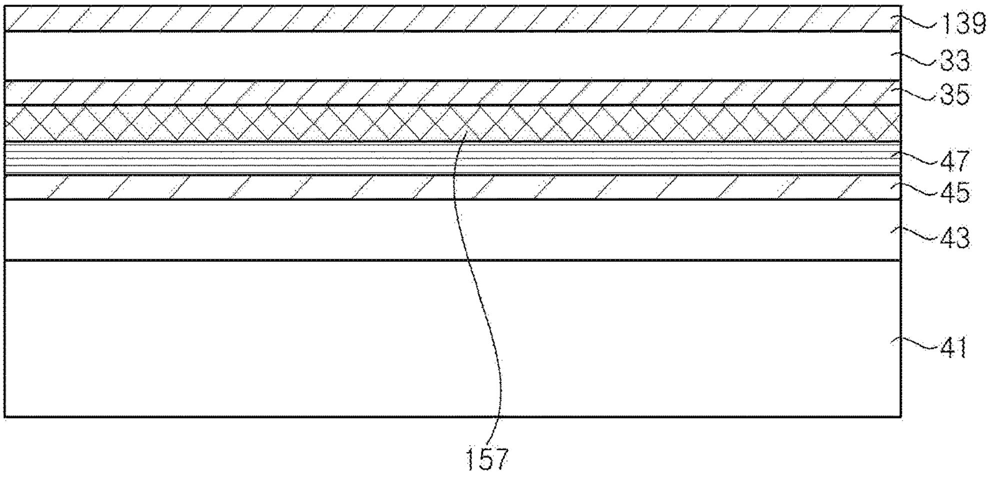


FIG. 12D

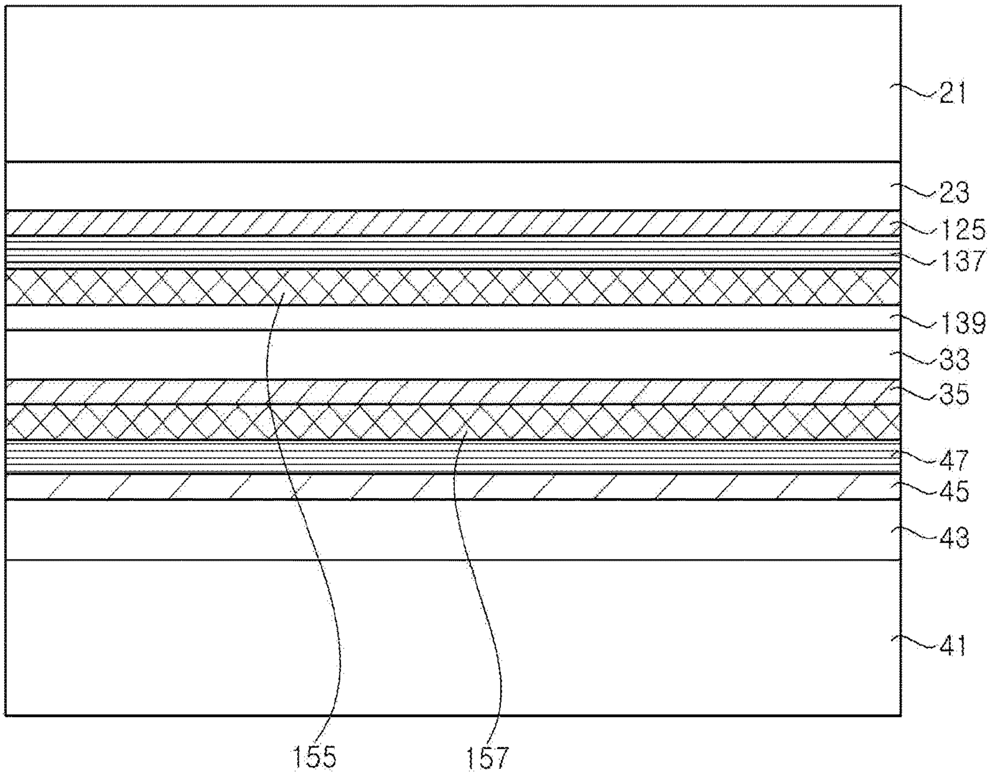


FIG. 12E

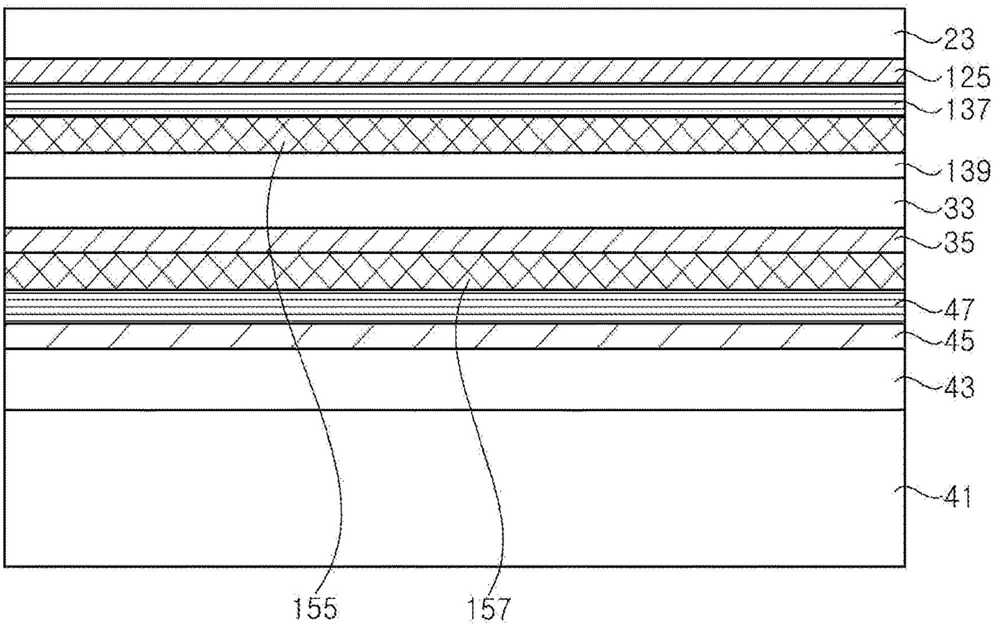


FIG. 12F

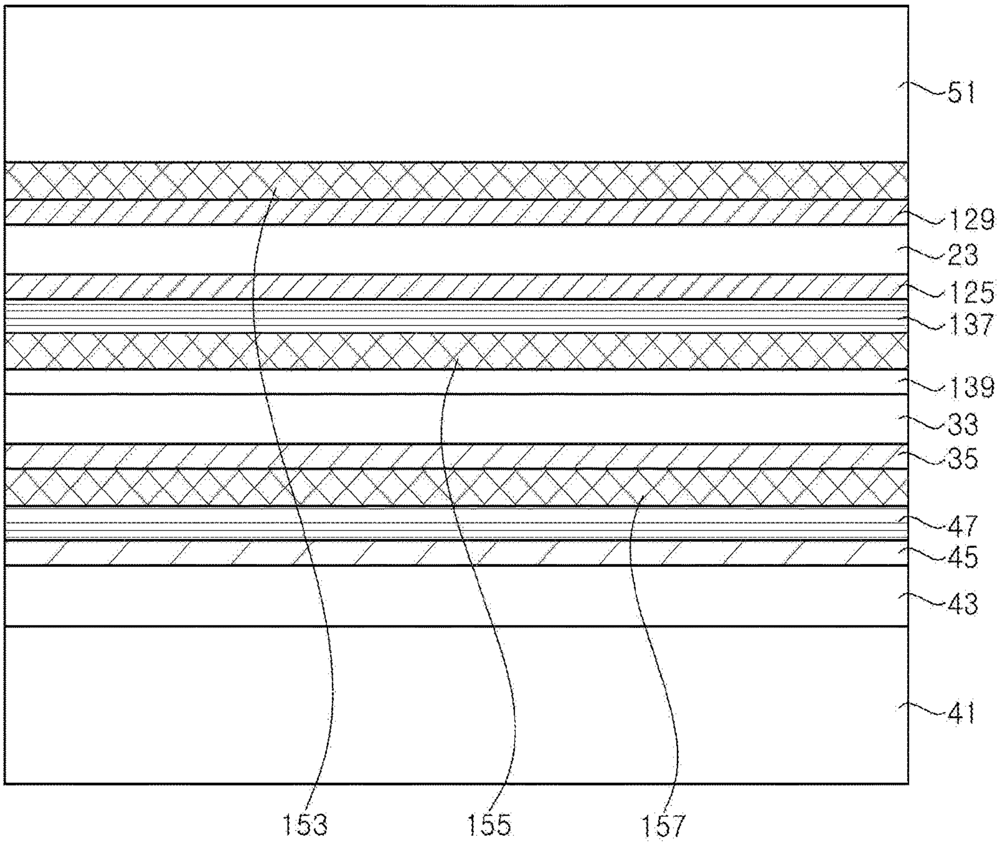


FIG. 13

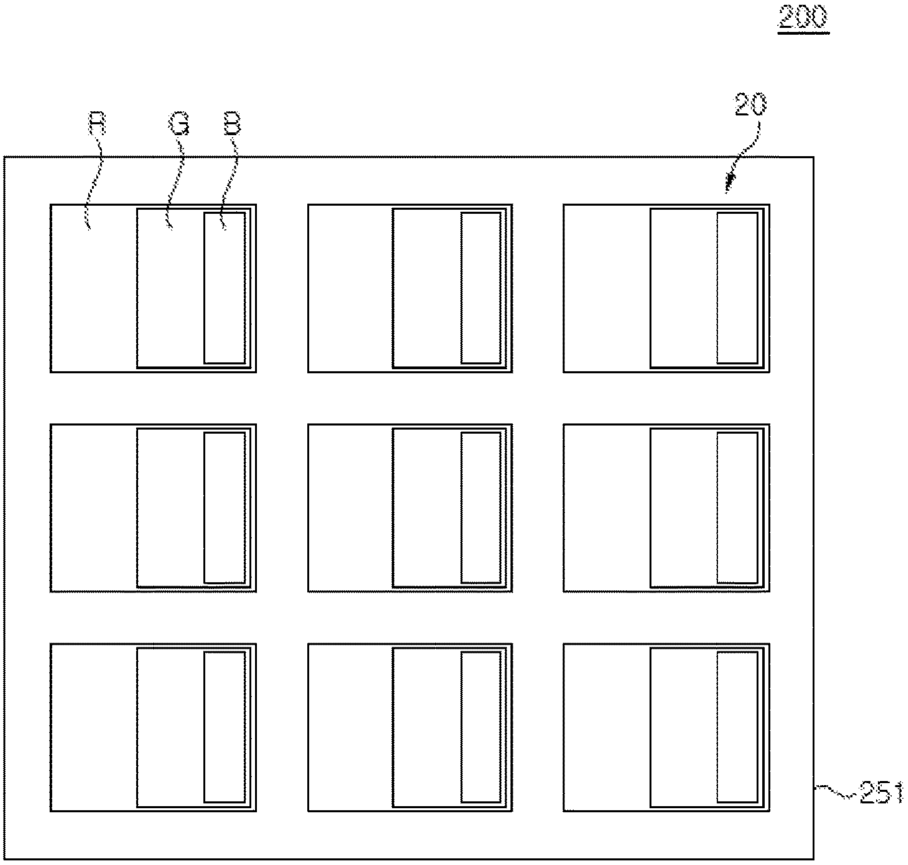


FIG. 14

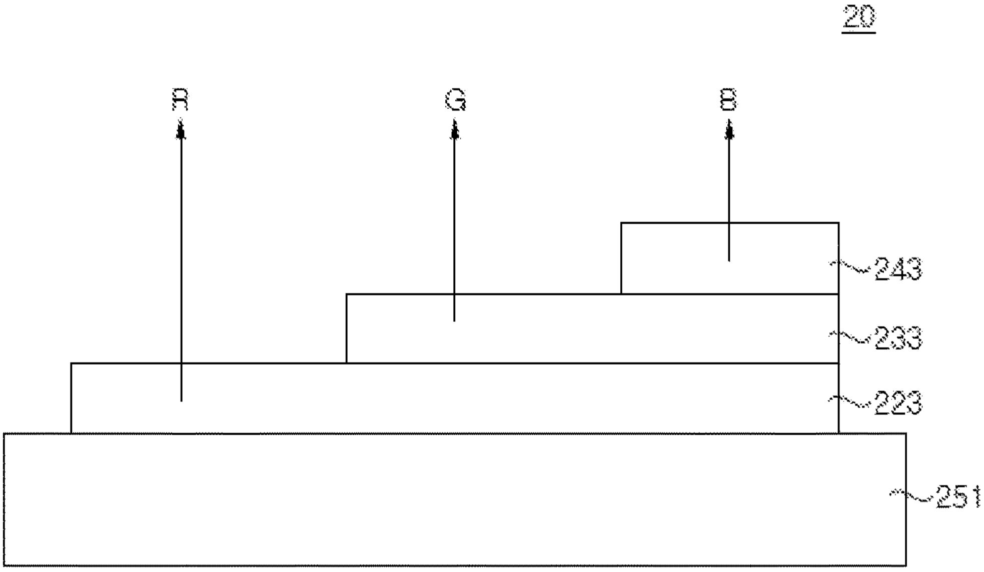


FIG. 15

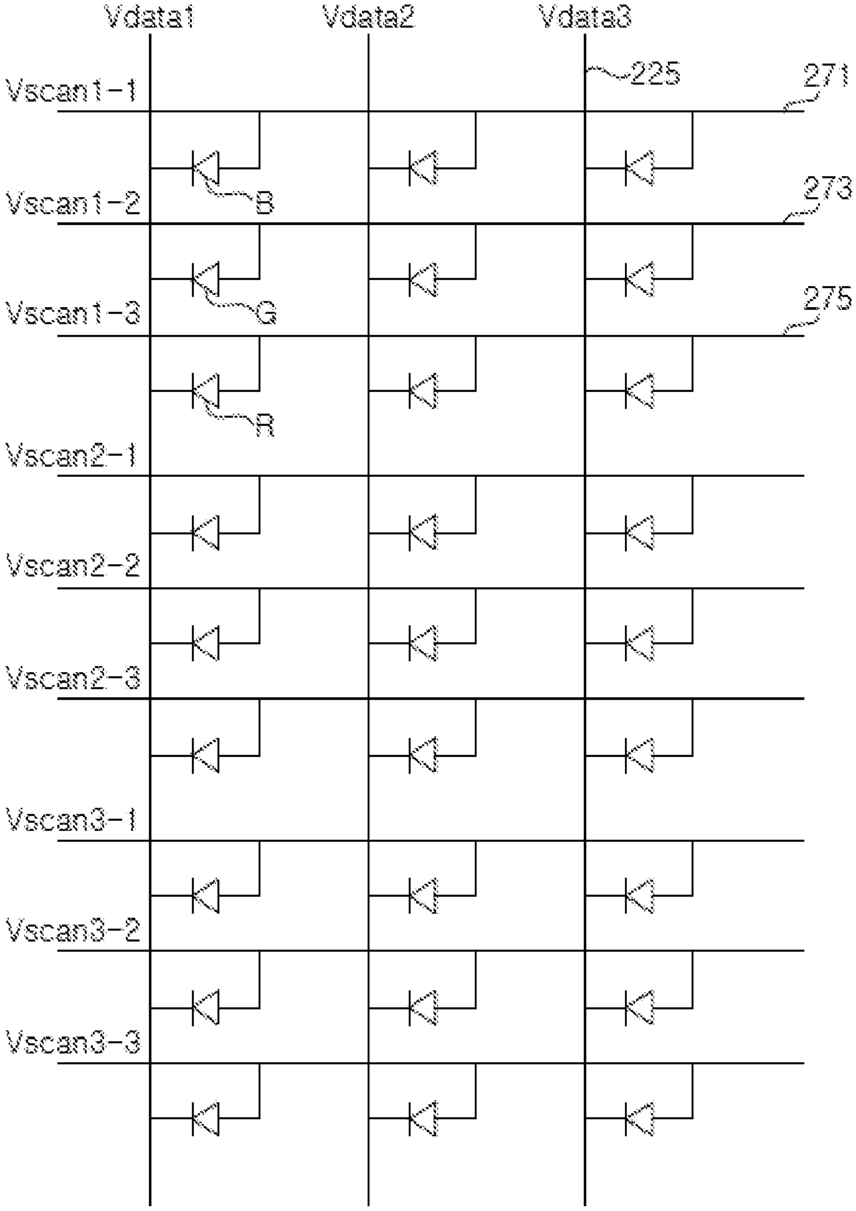

Vdata1
Vdata2
Vdata3
225
271
273
275
Vscan1-1
Vscan1-2
Vscan1-3
Vscan2-1
Vscan2-2
Vscan2-3
Vscan3-1
Vscan3-2
Vscan3-3
B
G
R

FIG. 16

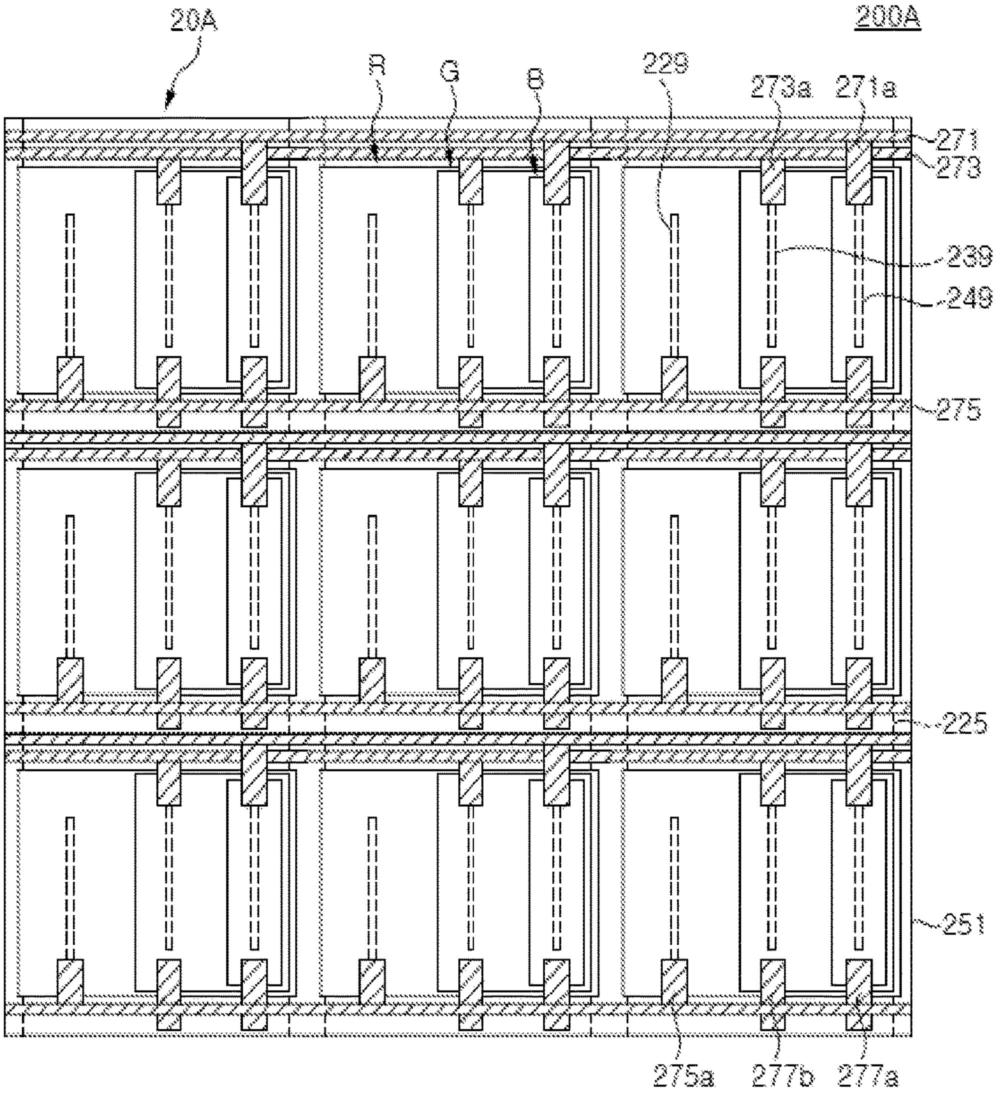

20A
200A
R
G
B
229
273a
271a
271
273
239
249
275
225
251
275a
277b
277a

FIG. 17

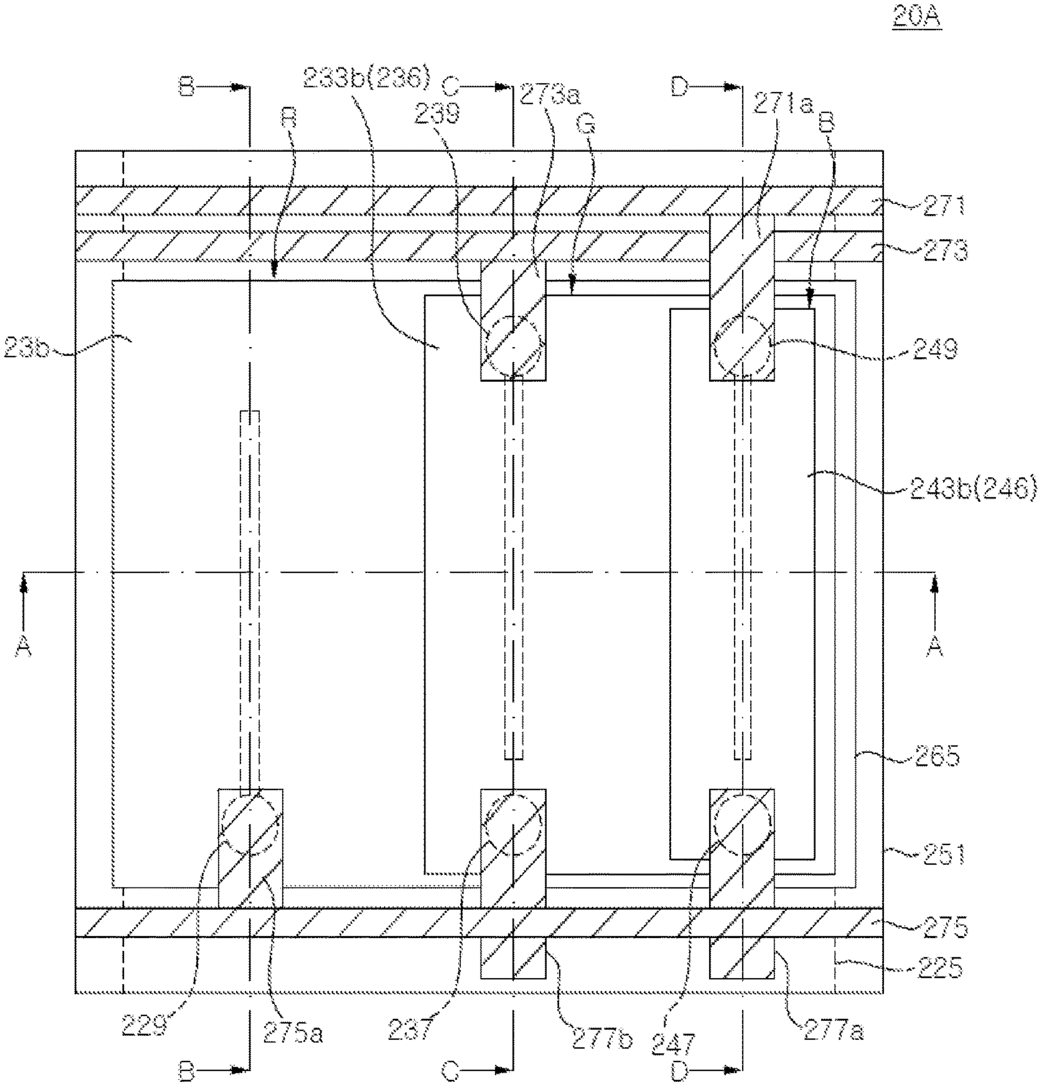

20A
B
233b(236)
C
273a
D
271a
R
239
G
B
271
273
23b
249
243b(246)
A
A
265
251
275
225
229
275a
237
277b
247
277a
B
C
D

FIG. 18A

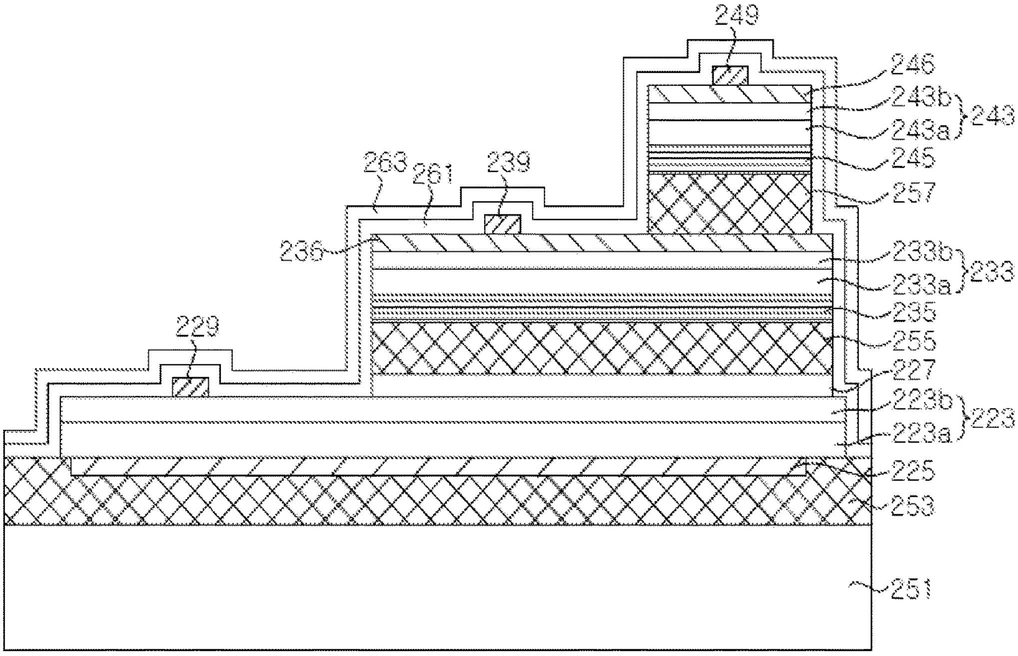


FIG. 18B

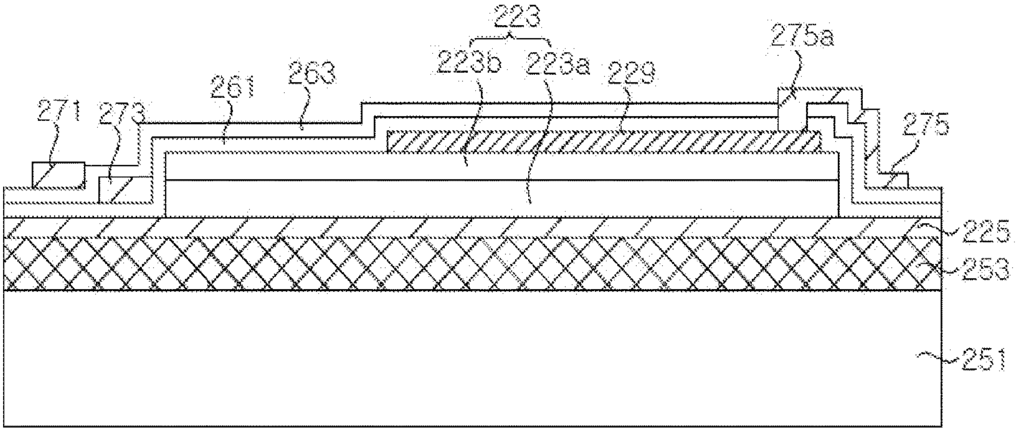


FIG. 18C

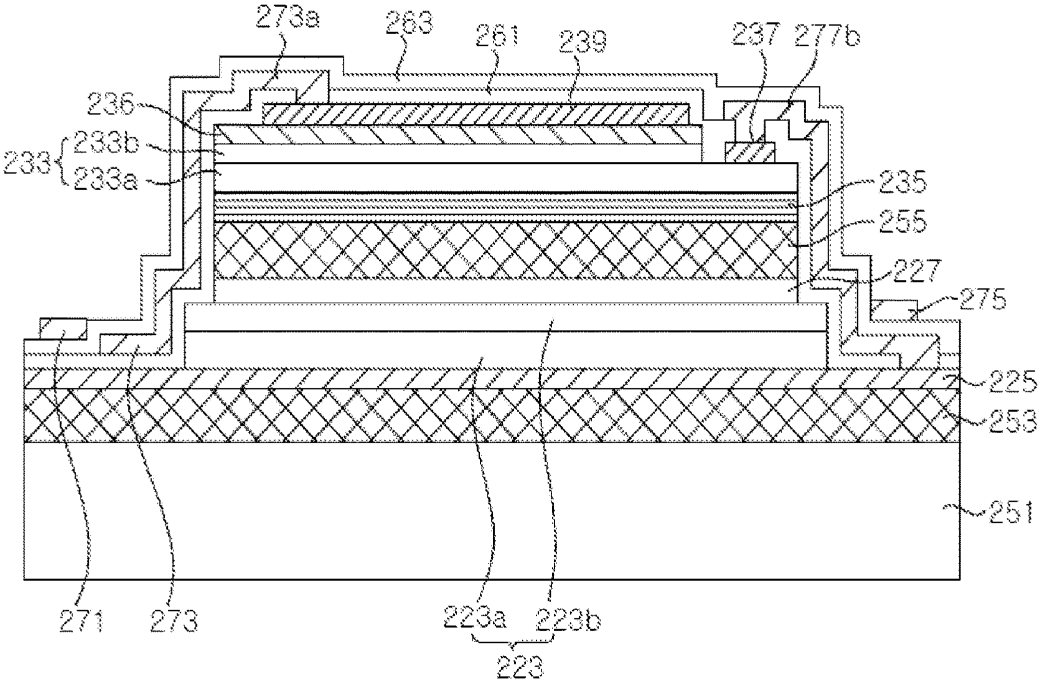


FIG. 18D

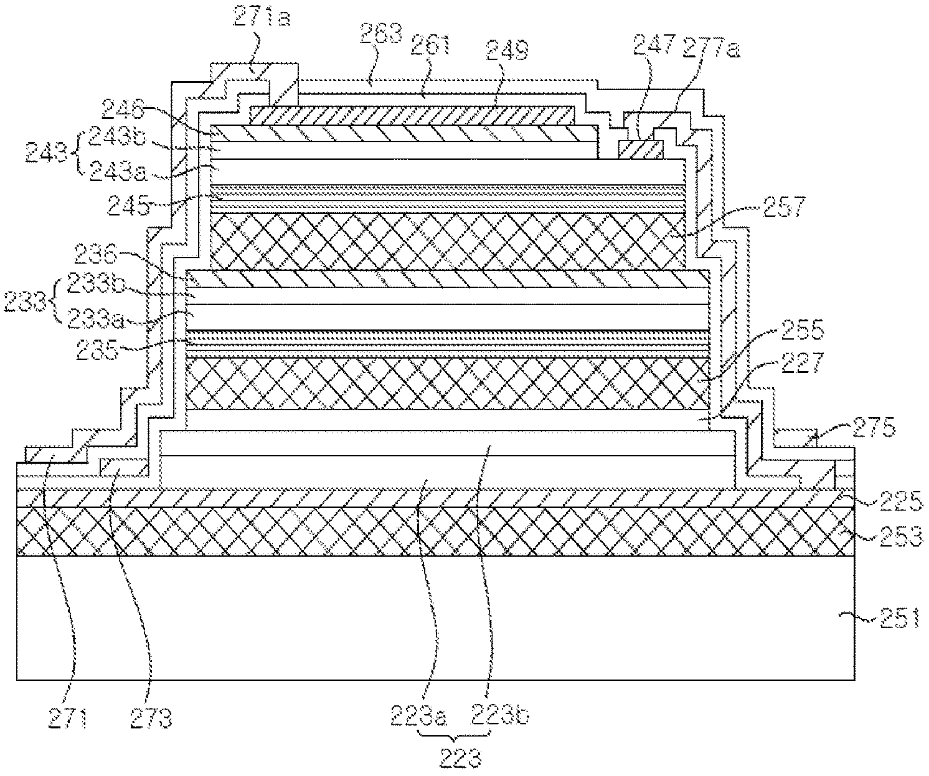


FIG. 19A

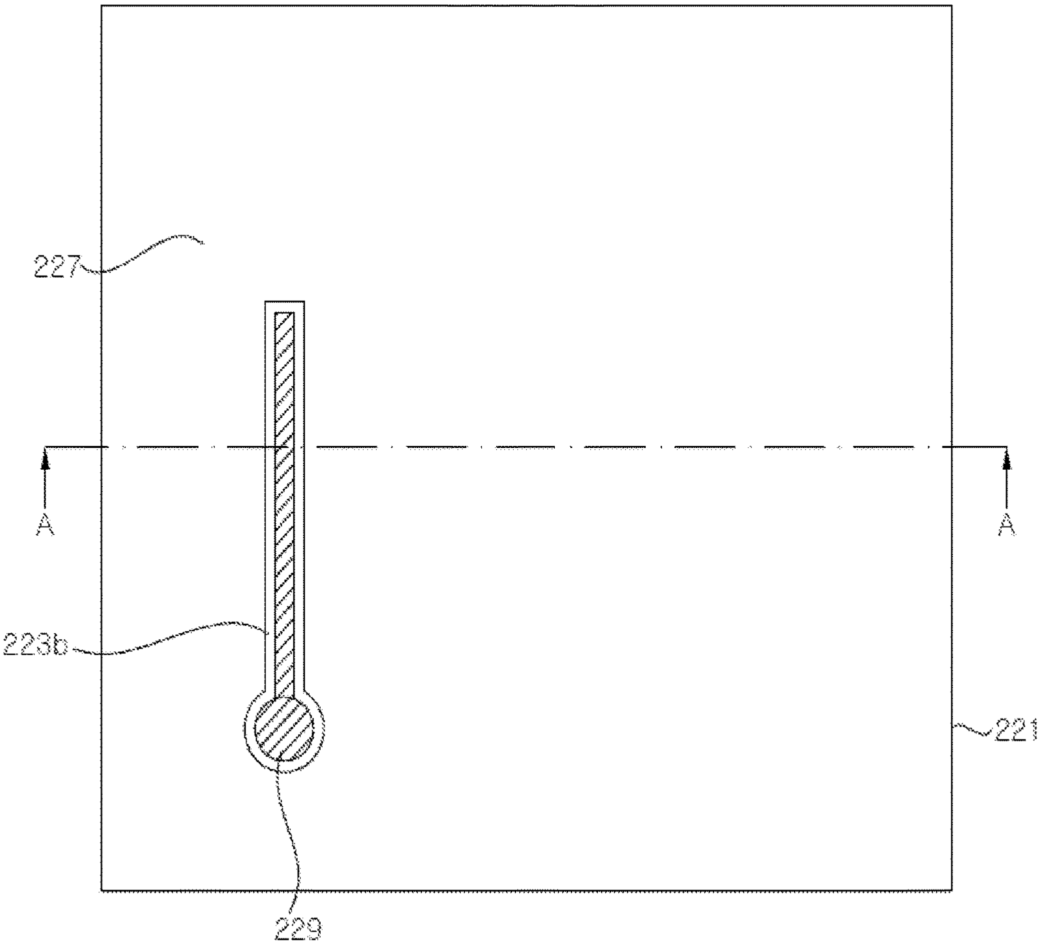


FIG. 19B

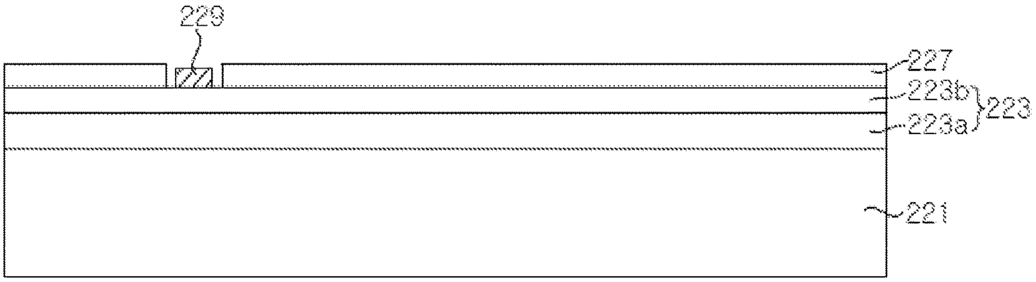


FIG. 20A

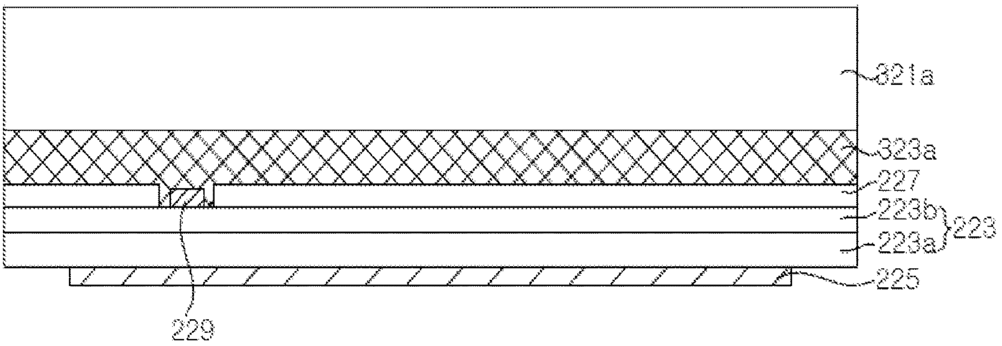


FIG. 20B

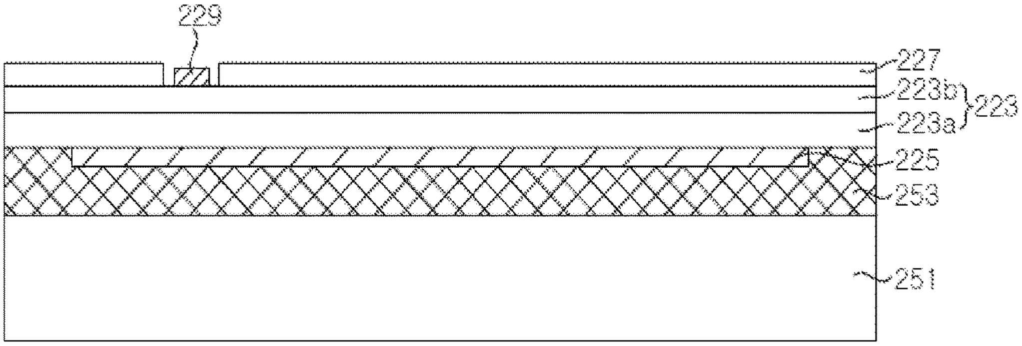


FIG. 21A

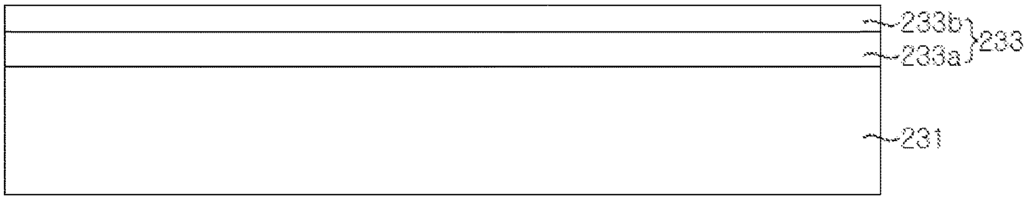


FIG. 21B

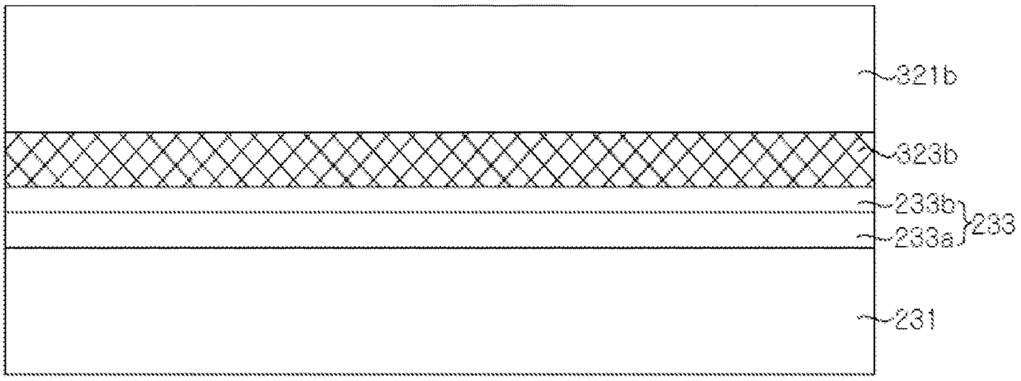


FIG. 21C

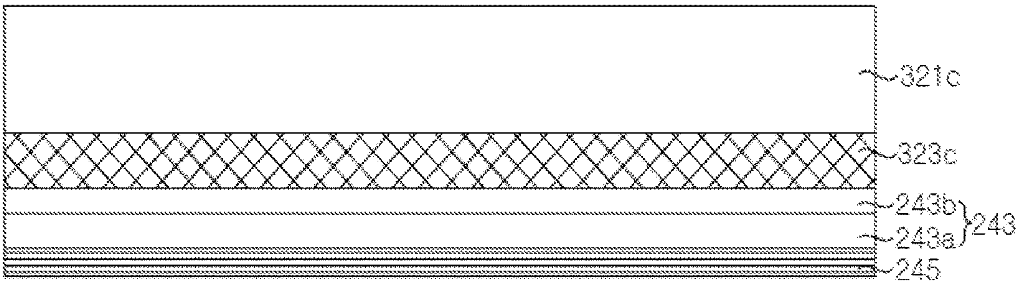


FIG. 22A

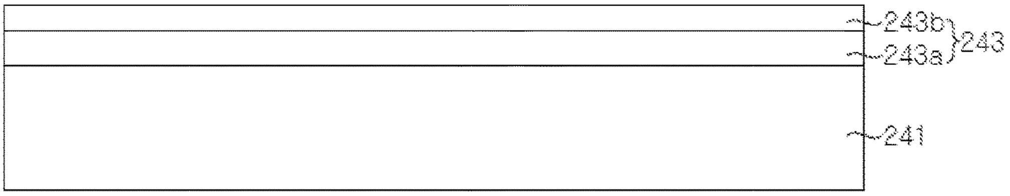


FIG. 22B

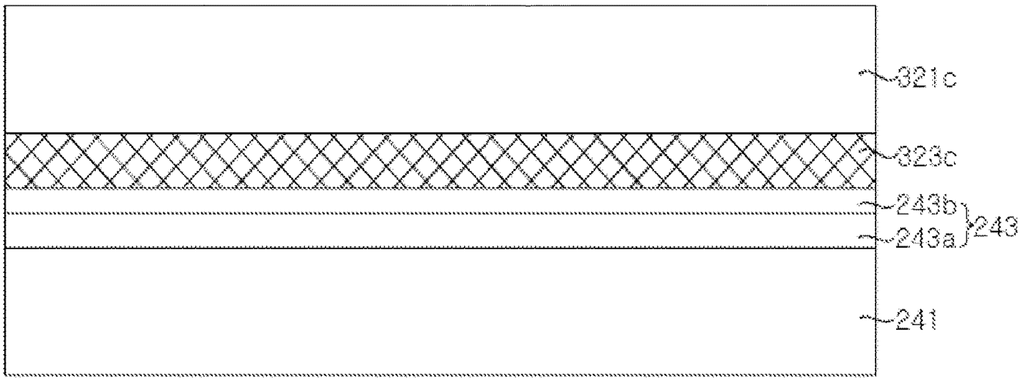


FIG. 22C

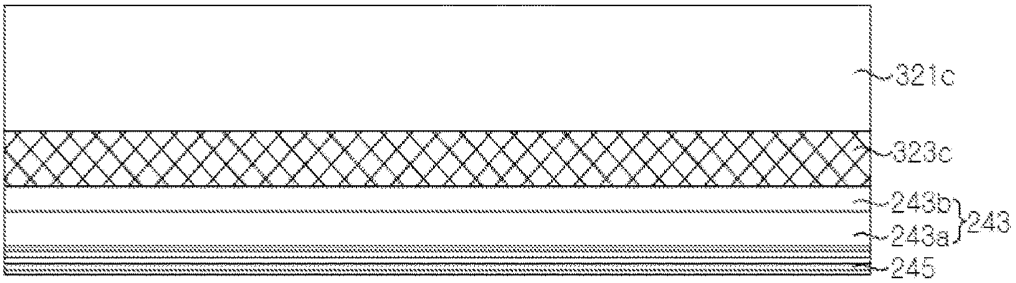


FIG. 23A

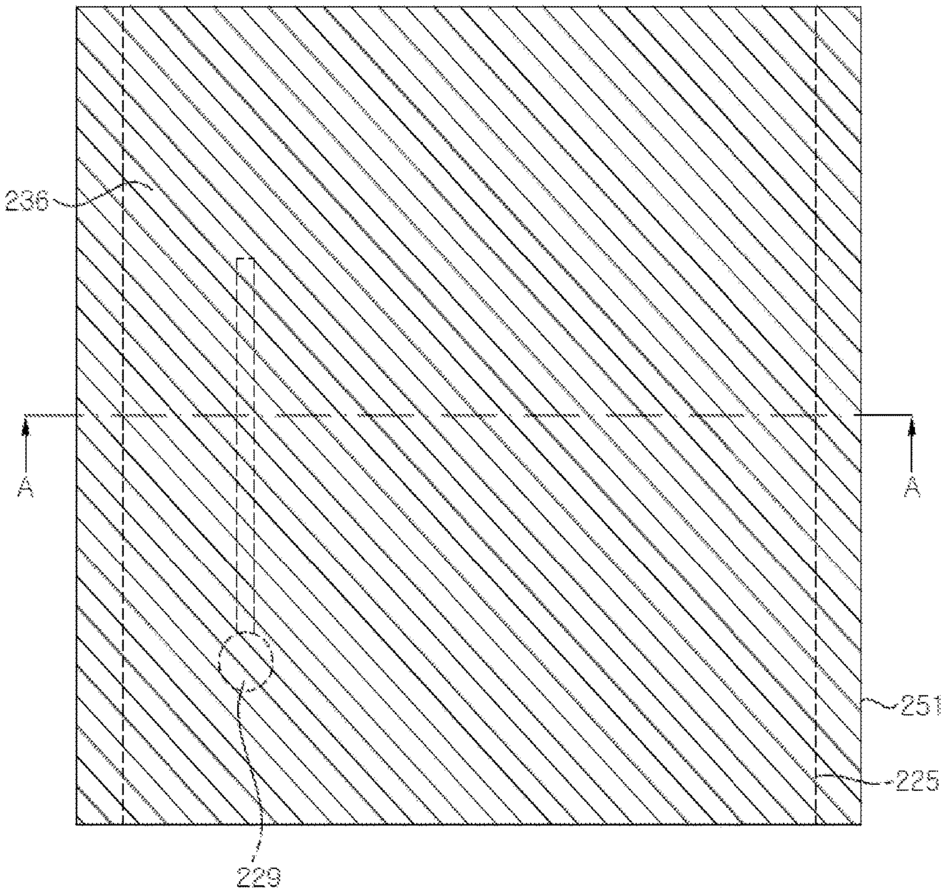


FIG. 23B

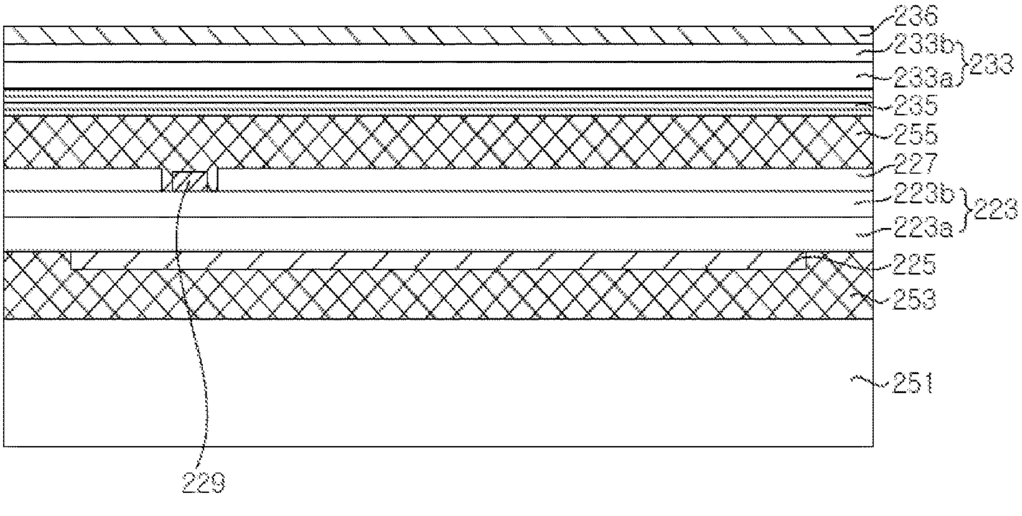


FIG. 24A

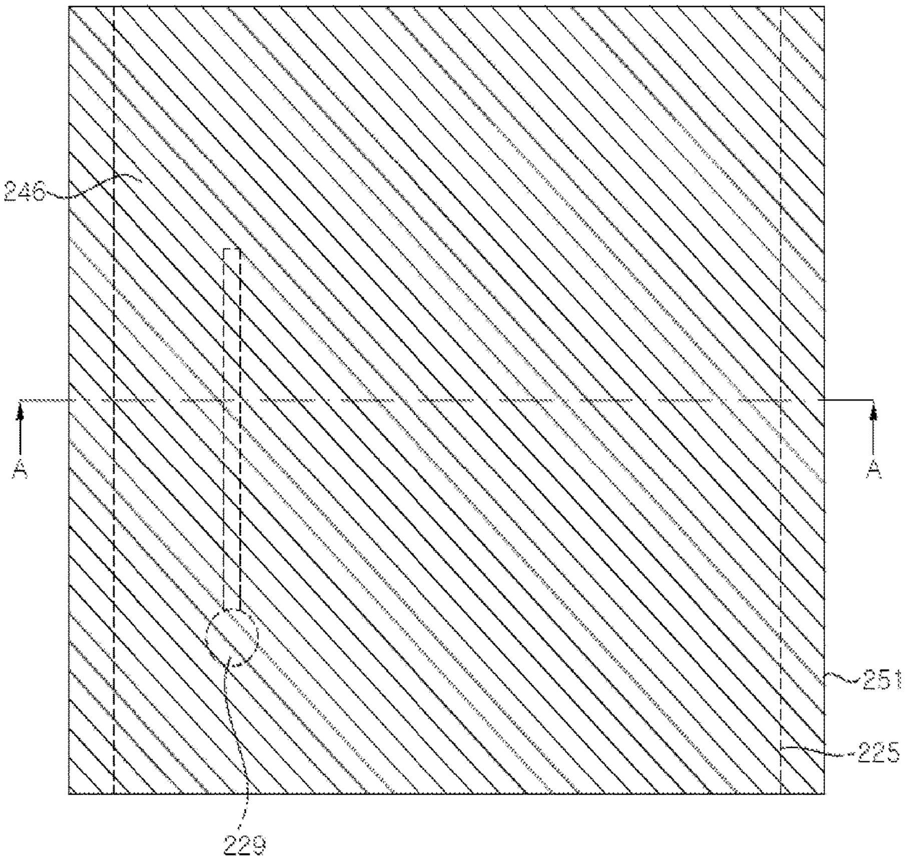


FIG. 24B

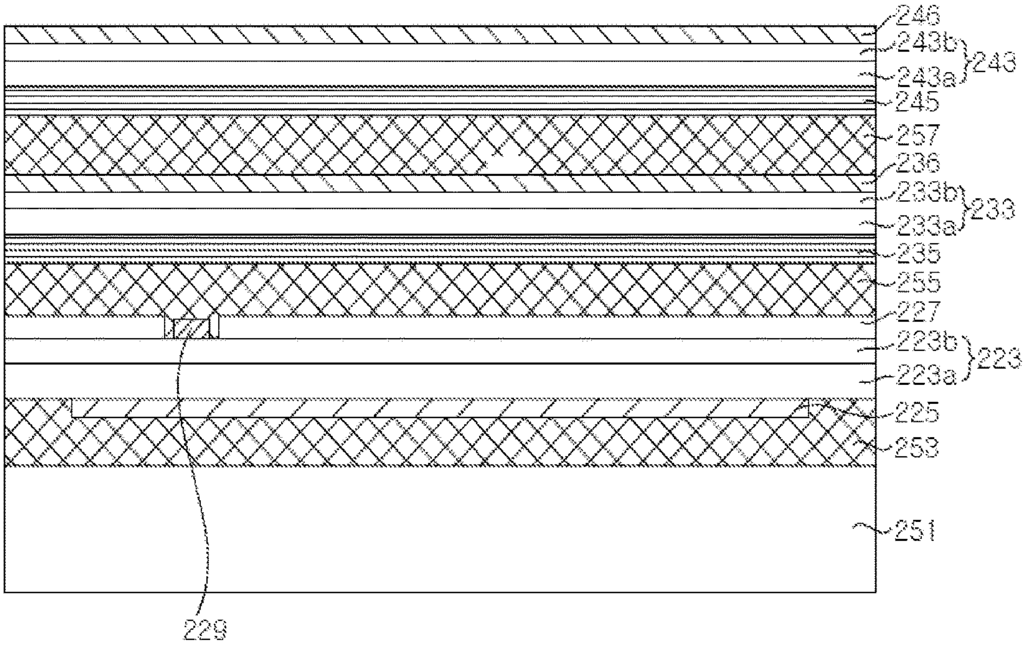


FIG. 25A

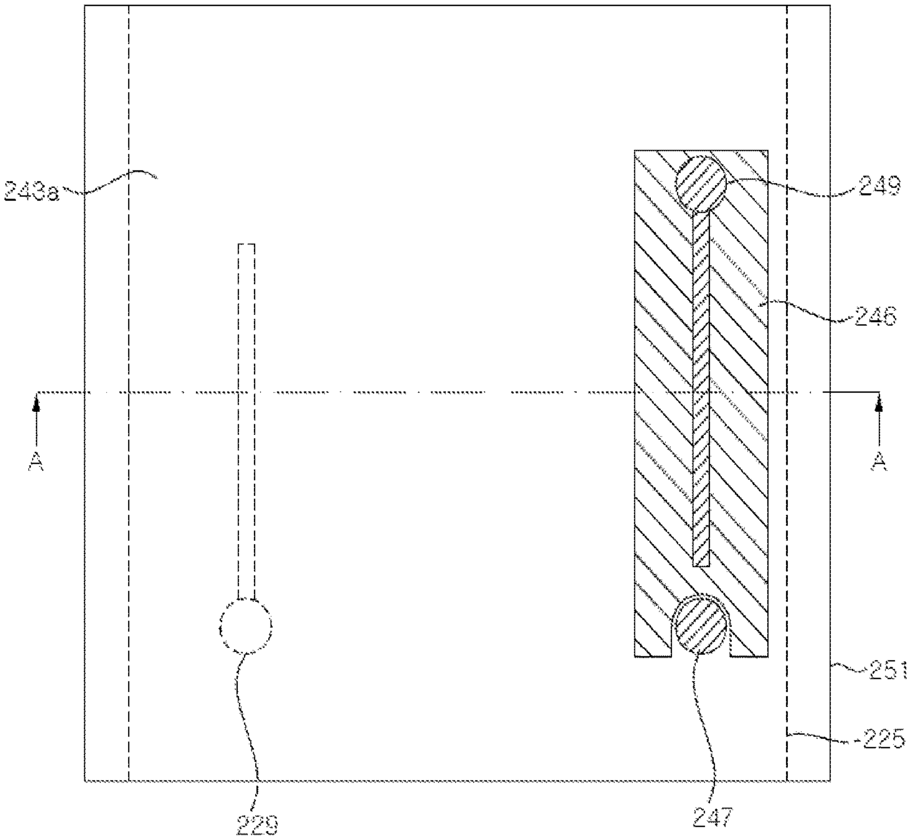


FIG. 25B

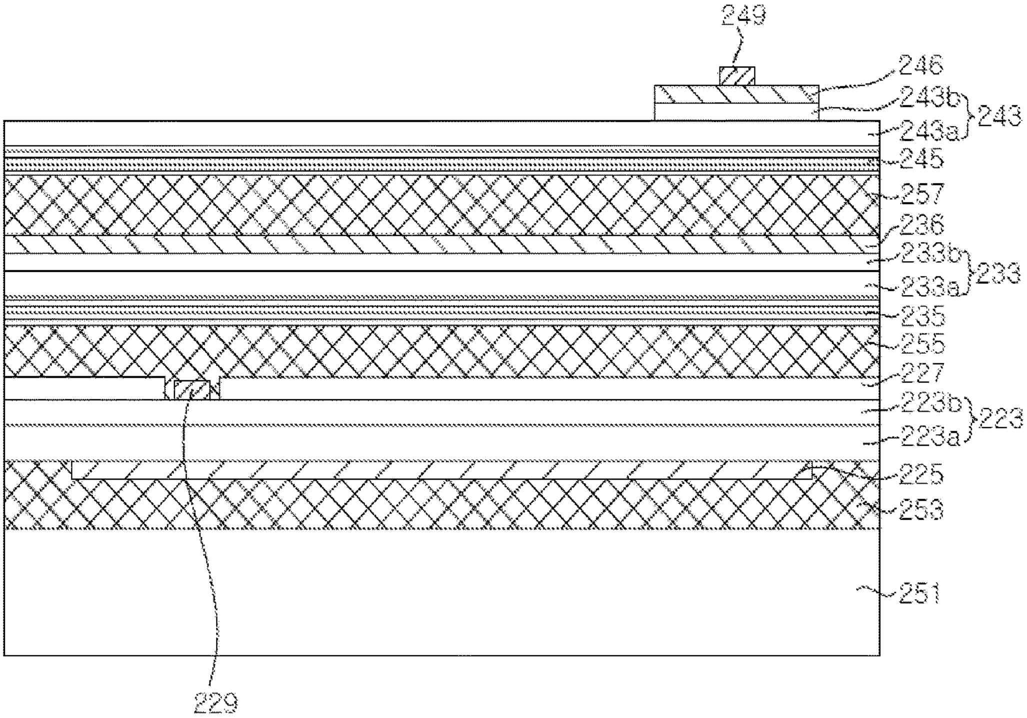


FIG. 26A

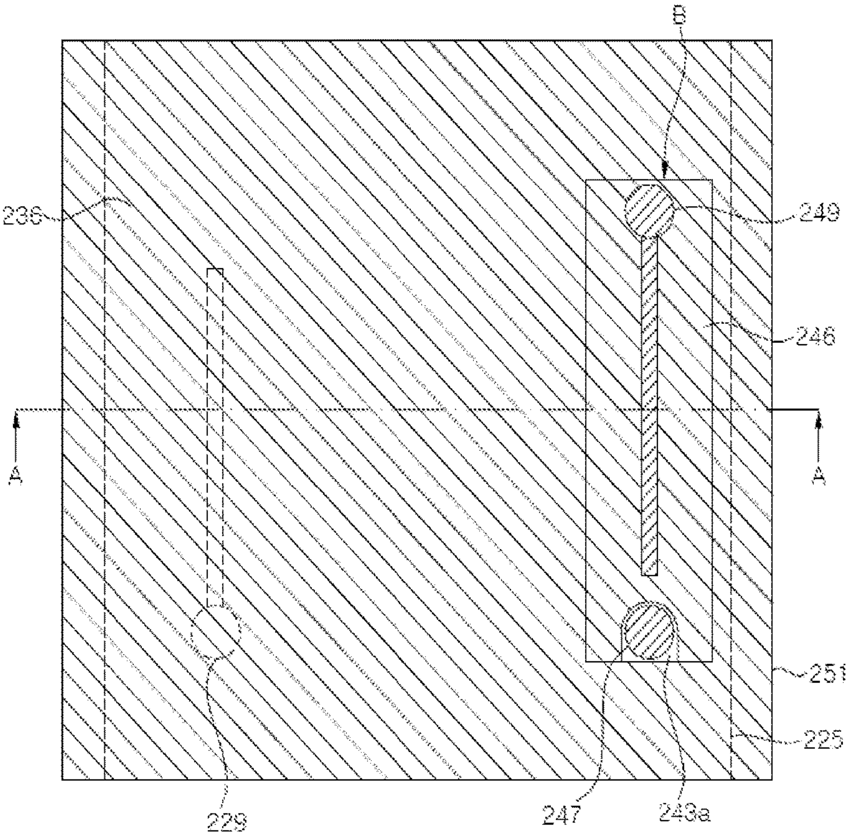


FIG. 26B

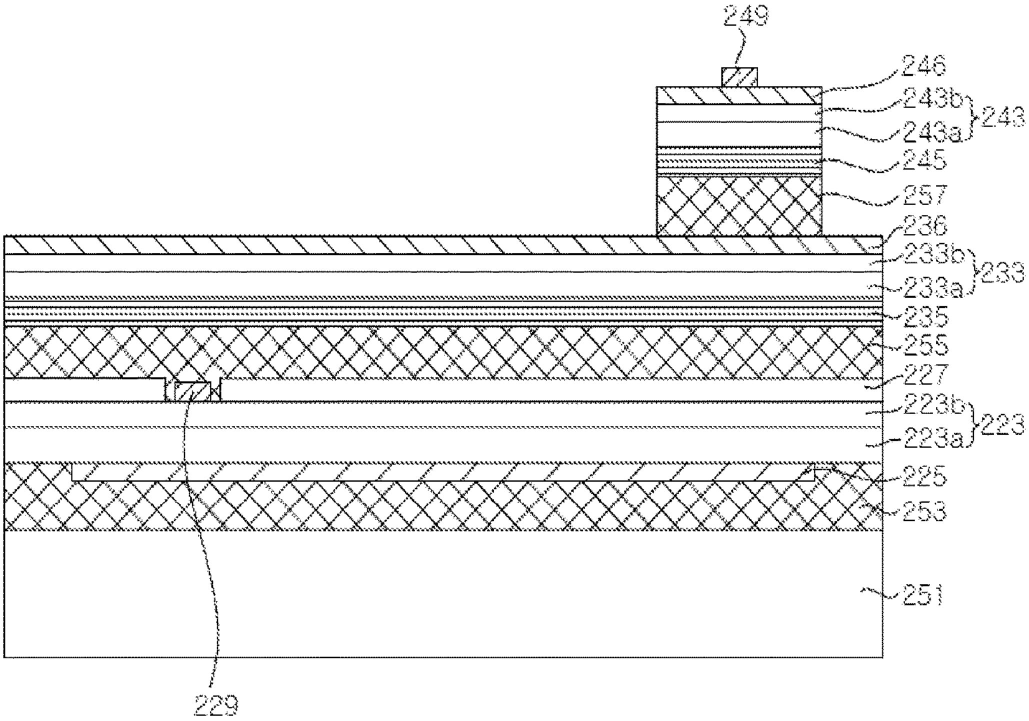


FIG. 27A

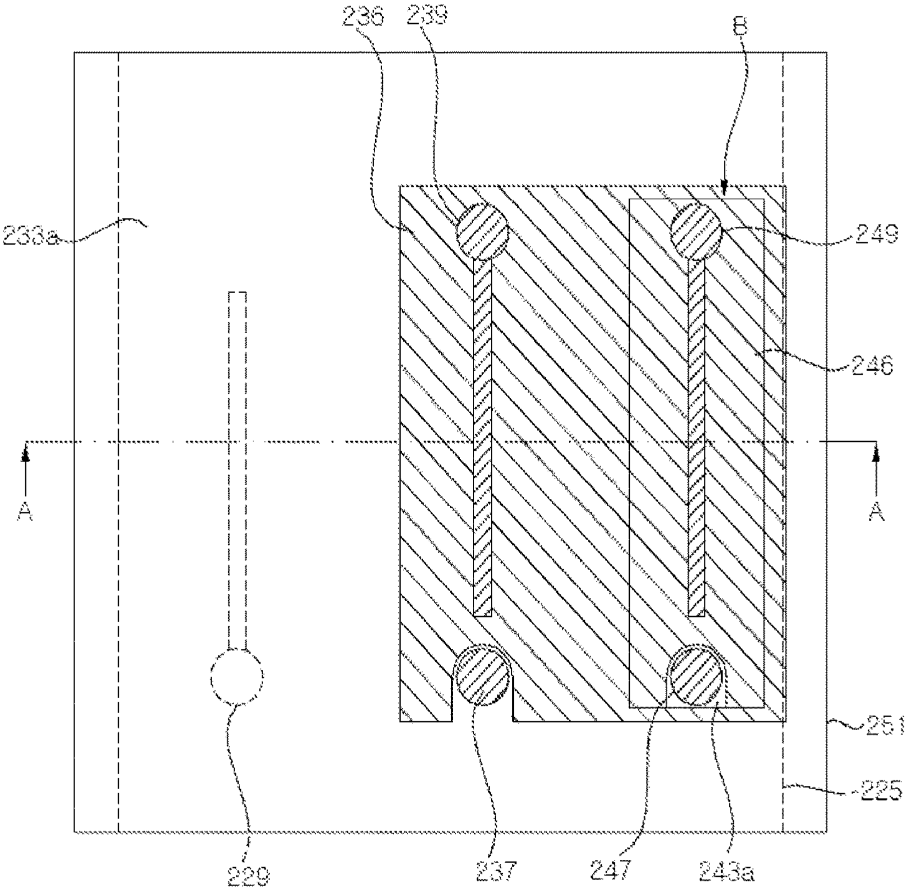


FIG. 27B

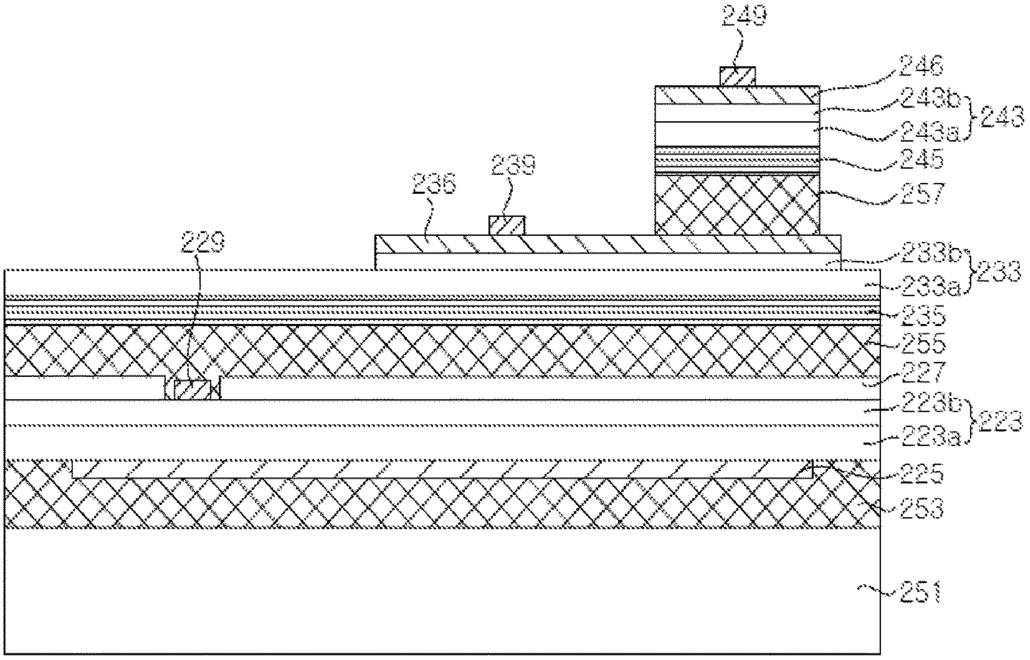


FIG. 28A

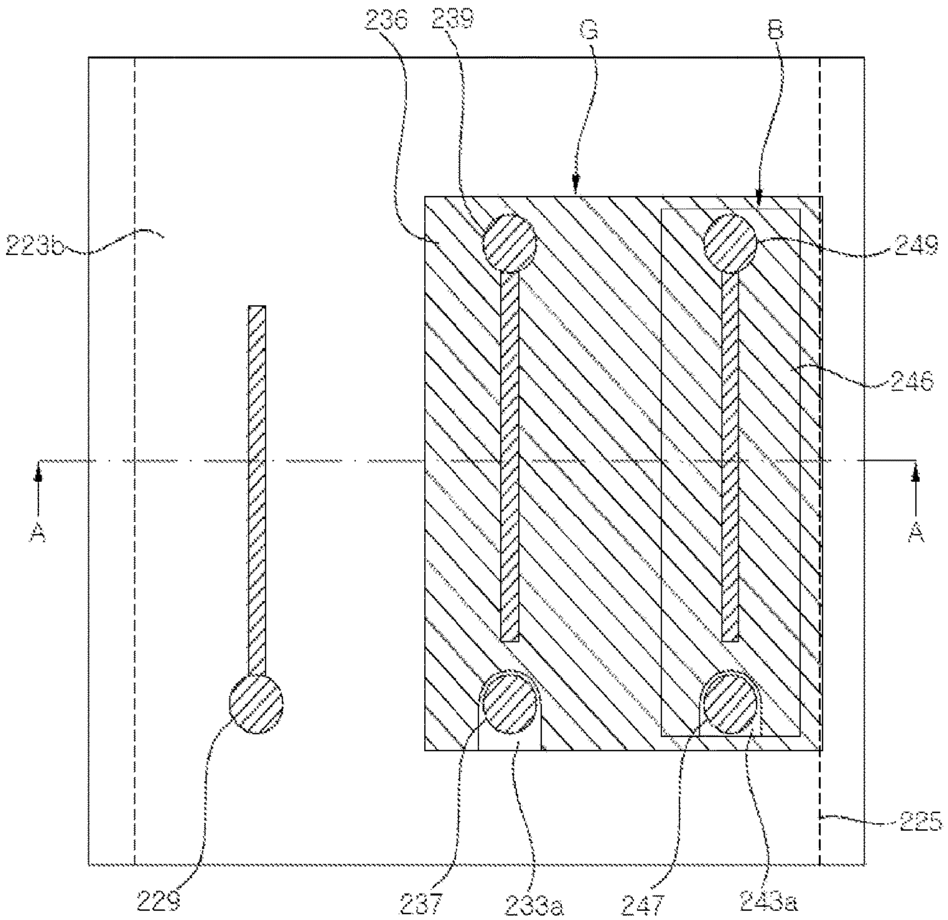


FIG. 28B

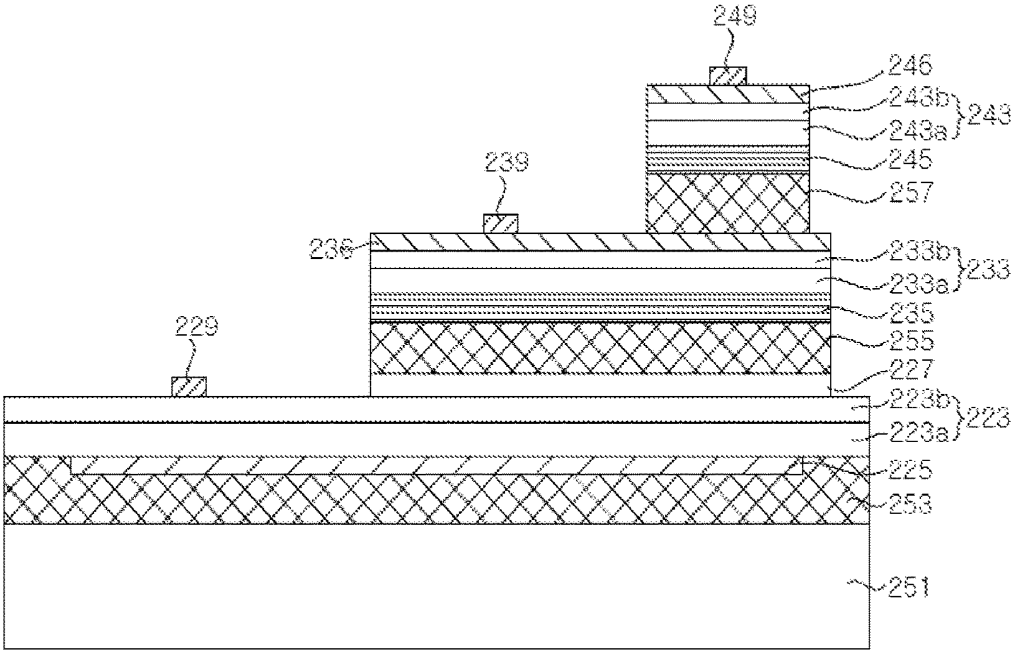


FIG. 29A

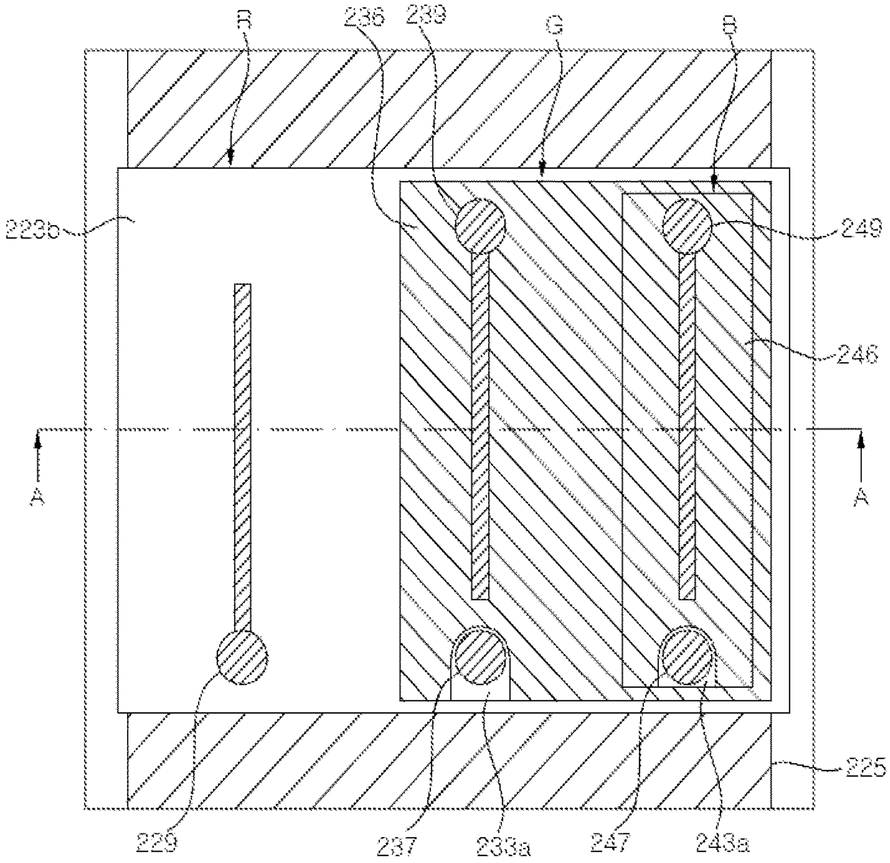


FIG. 29B

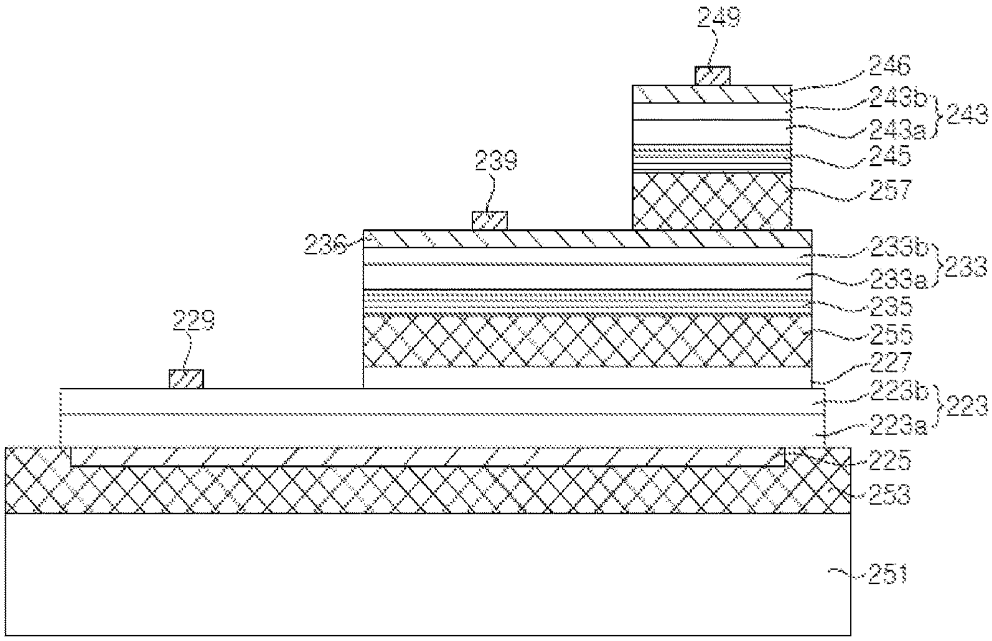


FIG. 30A

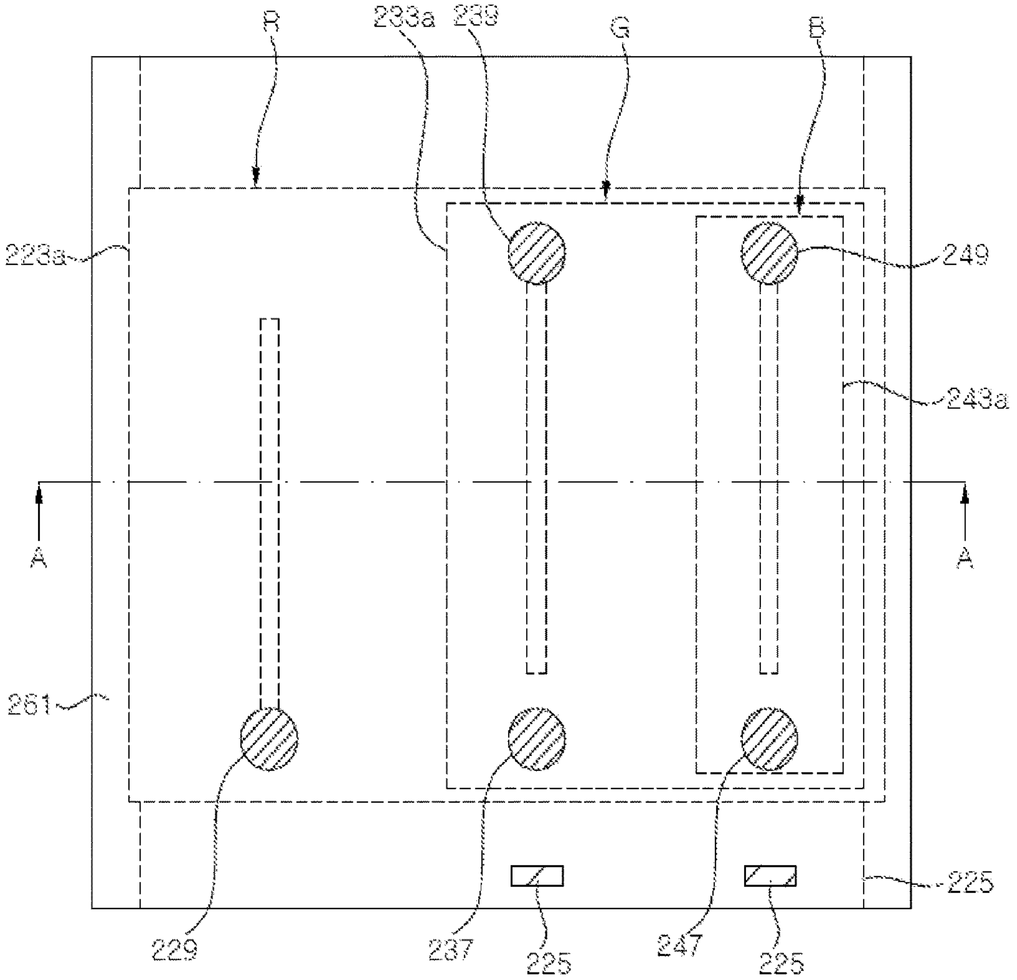


FIG. 30B

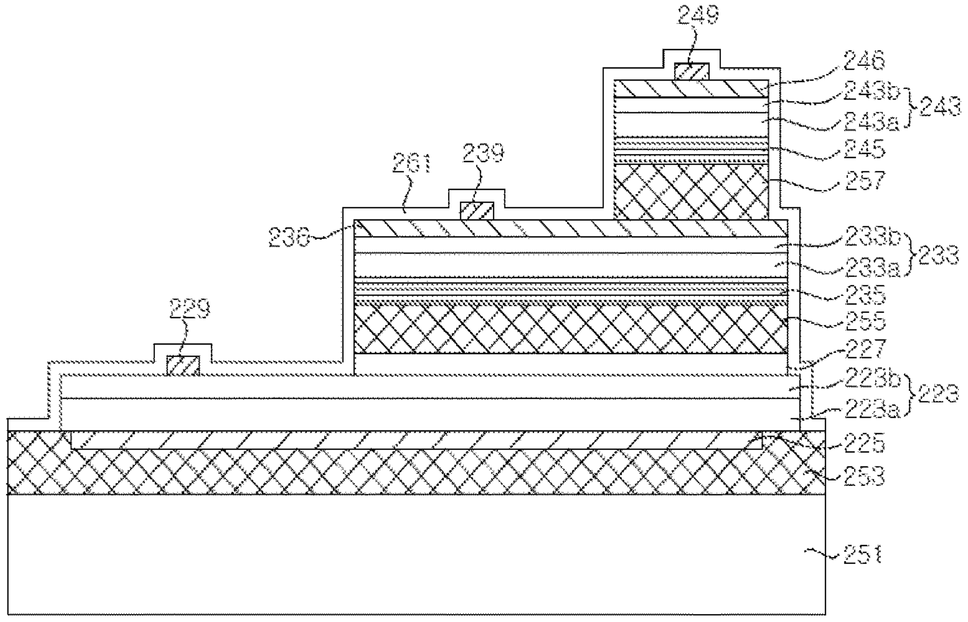


FIG. 31

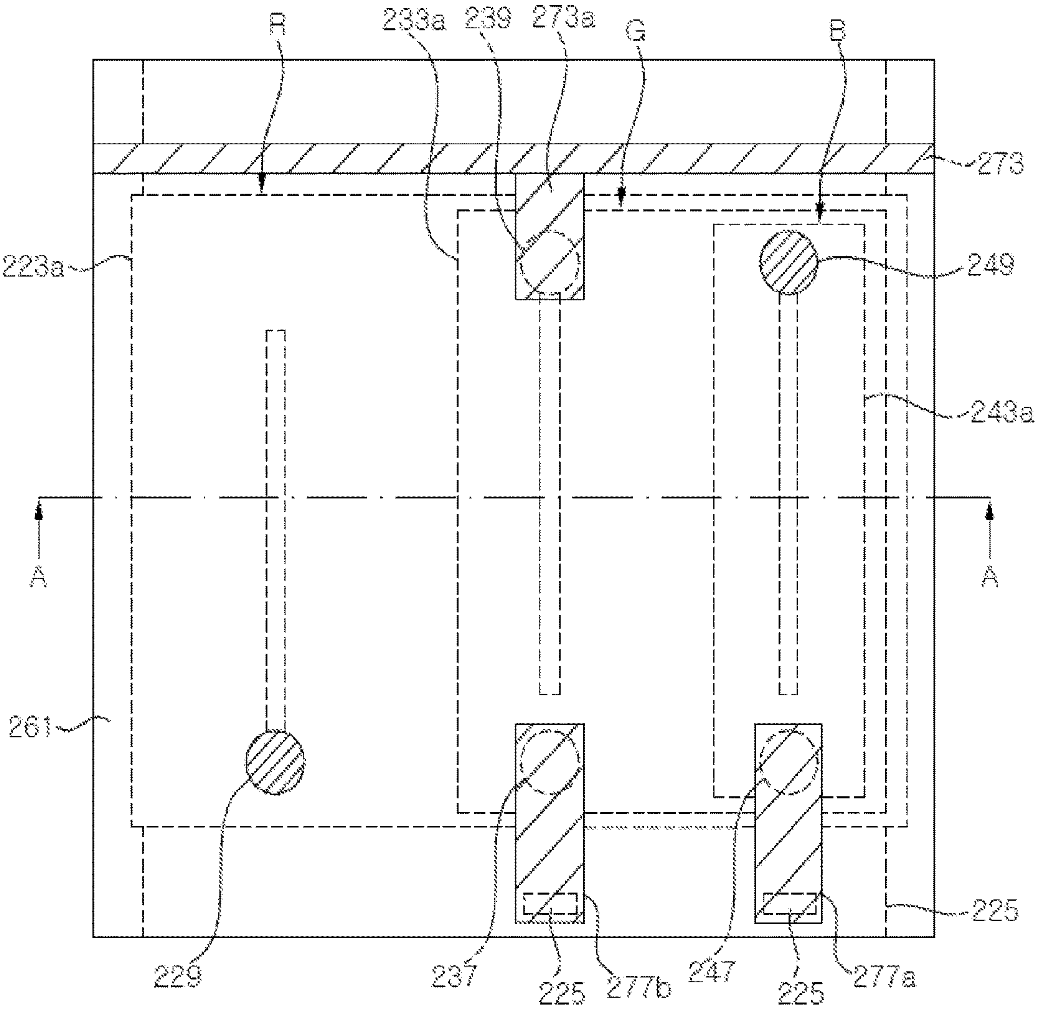

R
233a
239
273a
G
B
273
223a
249
243a
A
A
261
225
229
237
225
277b
247
225
277a

FIG. 32A

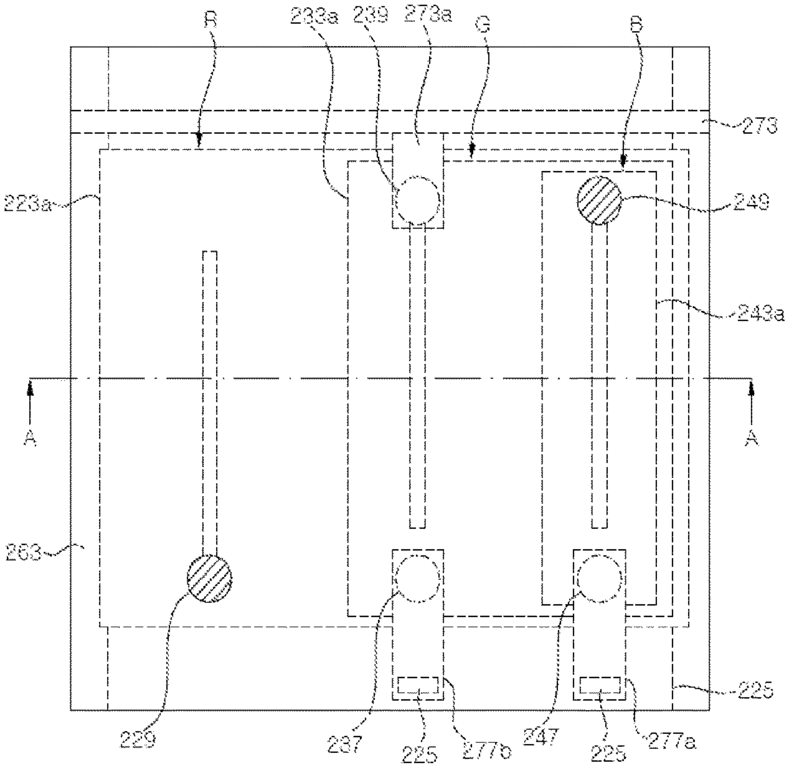


FIG. 32B

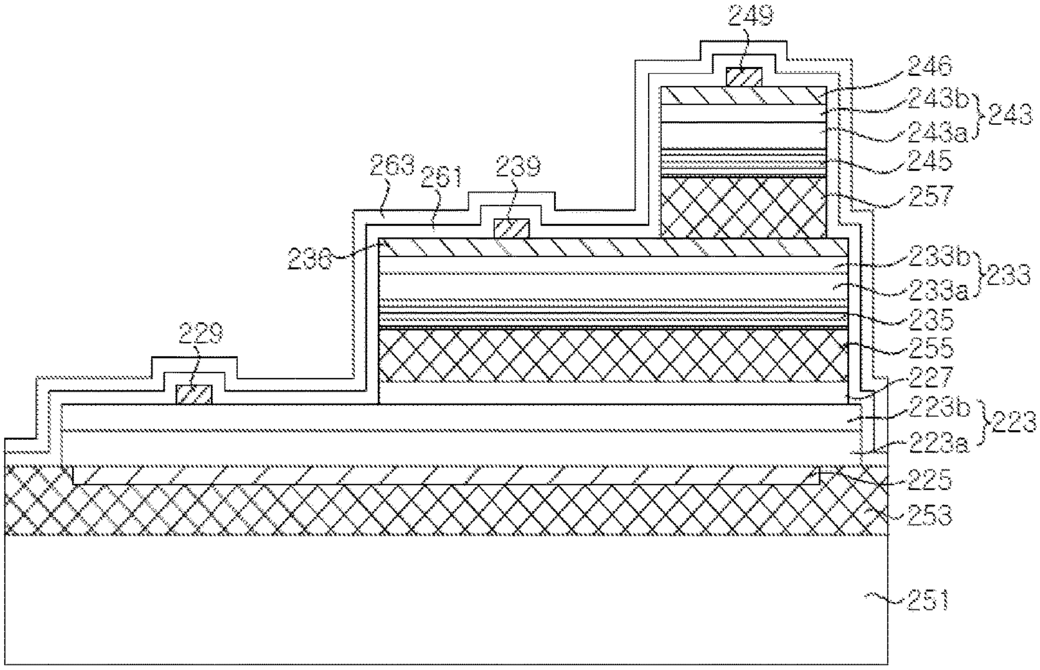


FIG. 33

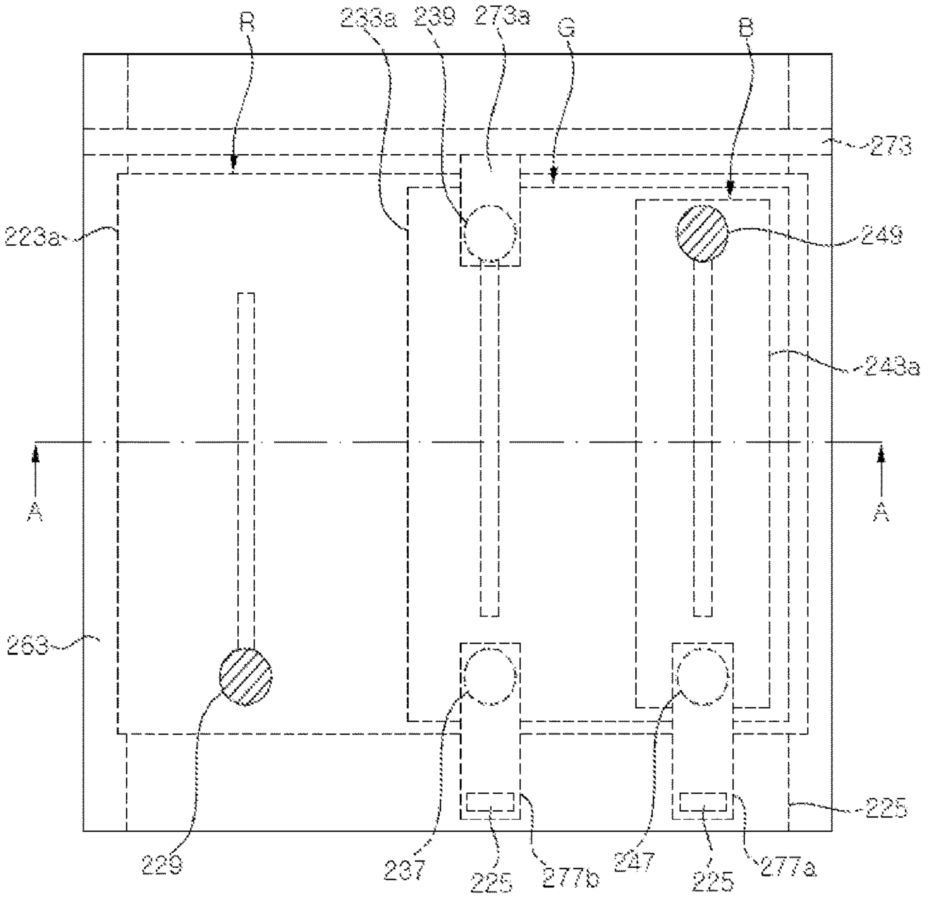

R
233a
239
273a
G
B
273
223a
249
243a
A
A
263
225
229
237
225
277b
247
225
277a

FIG. 34

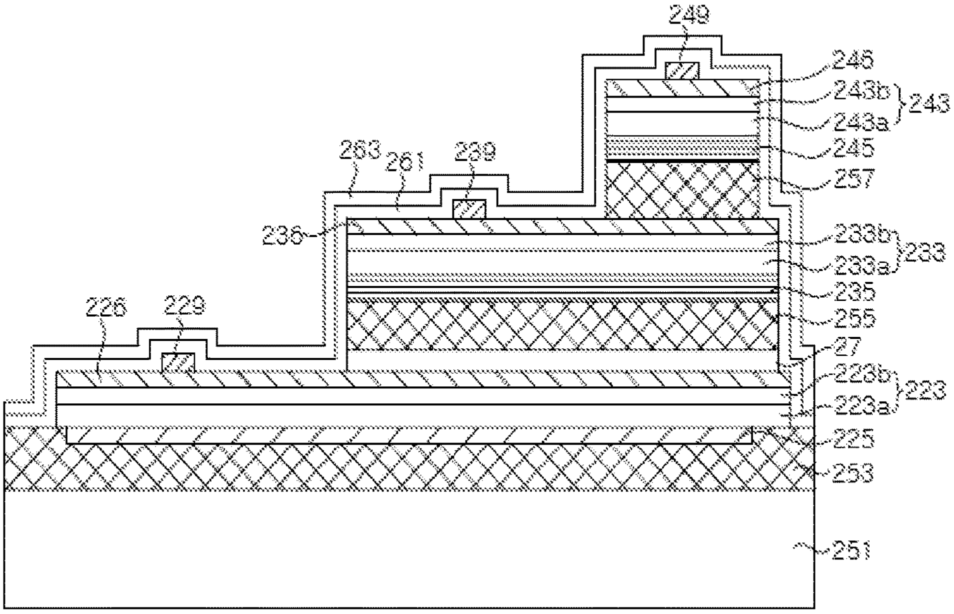

249
246
243b
243
243a
245
257
263
261
239
236
233b
233
233a
235
255
226
229
27
223b
223
223a
225
253
251

FIG. 35

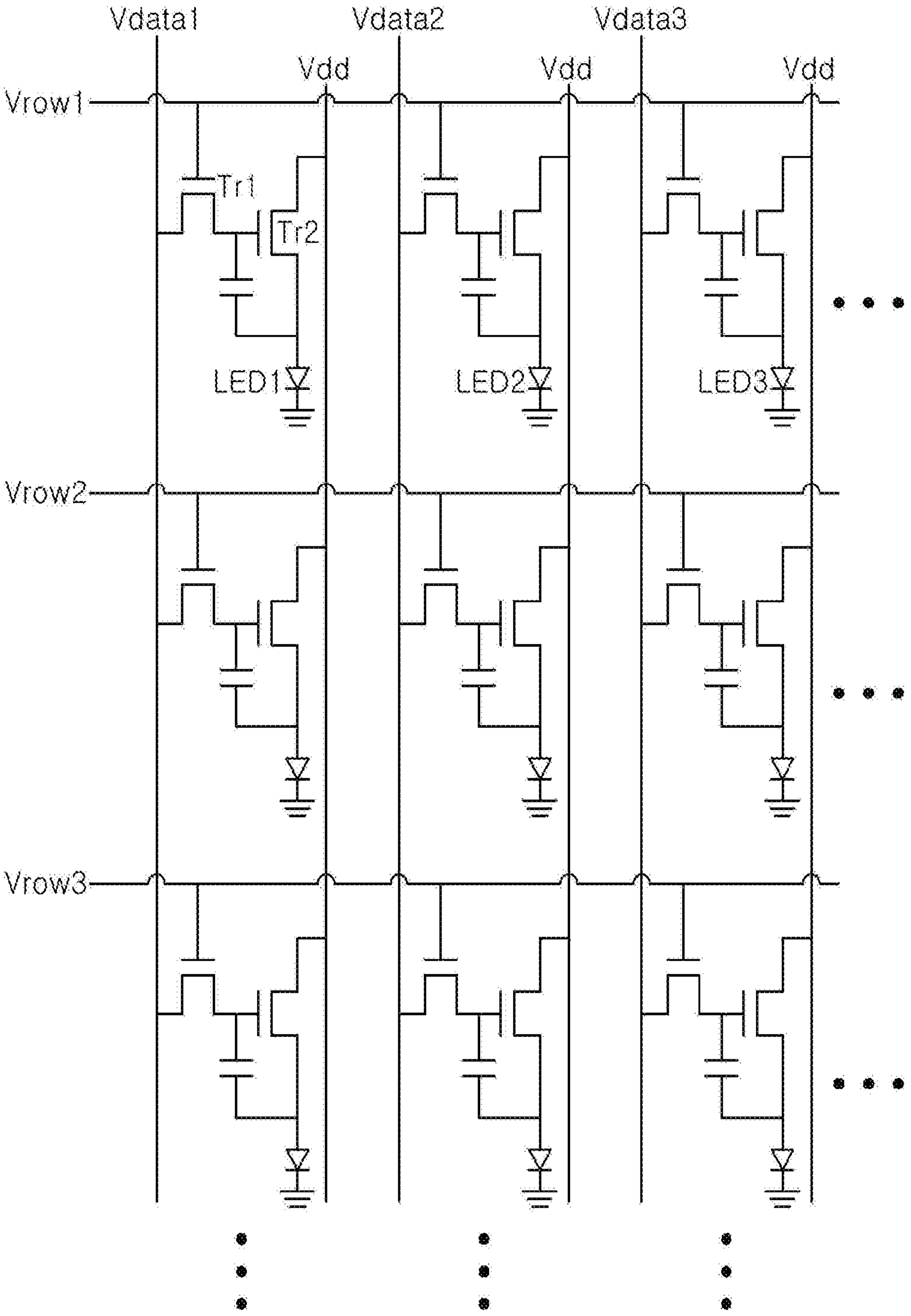

Vdata1
Vdata2
Vdata3
Vdd
Vdd
Vdd
Vrow1
Tr1
Tr2
LED1
LED2
LED3
Vrow2
Vrow3

FIG. 36

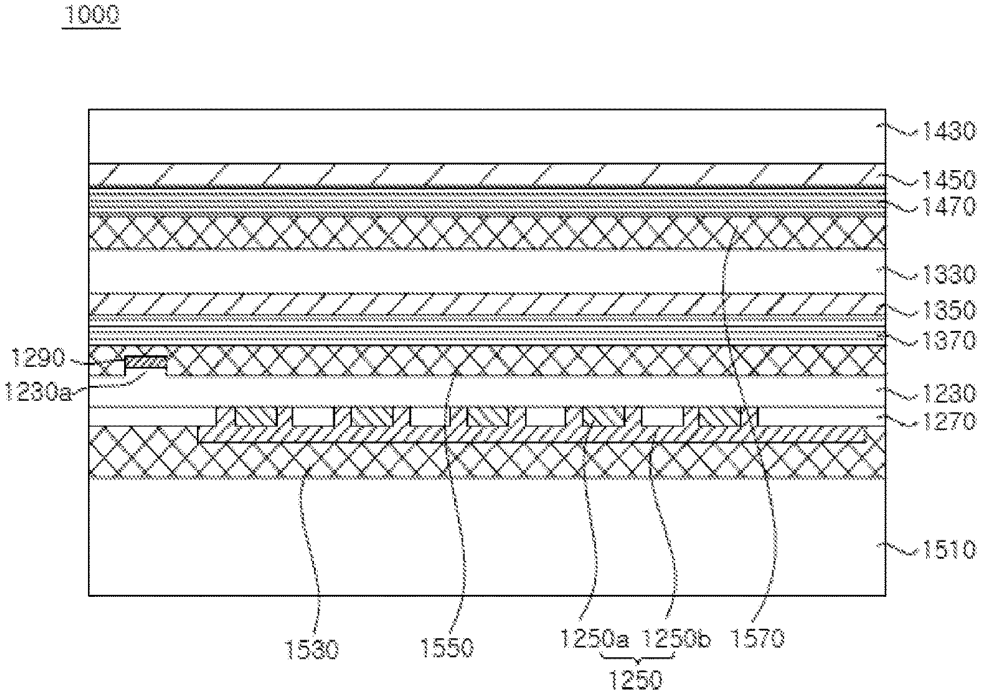


FIG. 37A

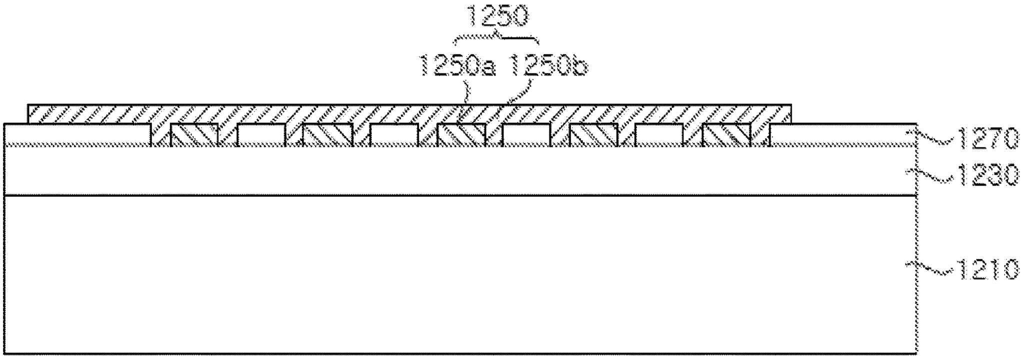


FIG. 37B

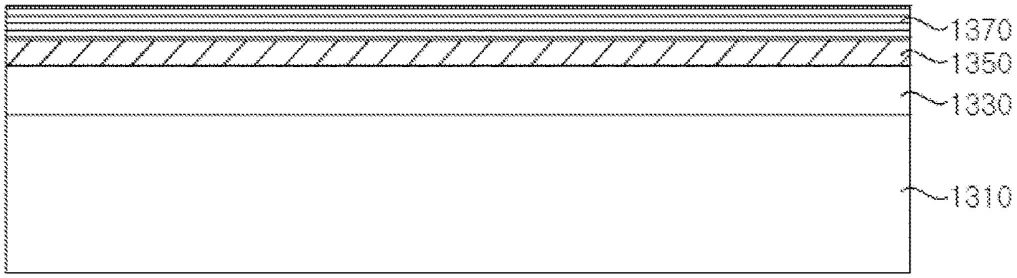


FIG. 37C

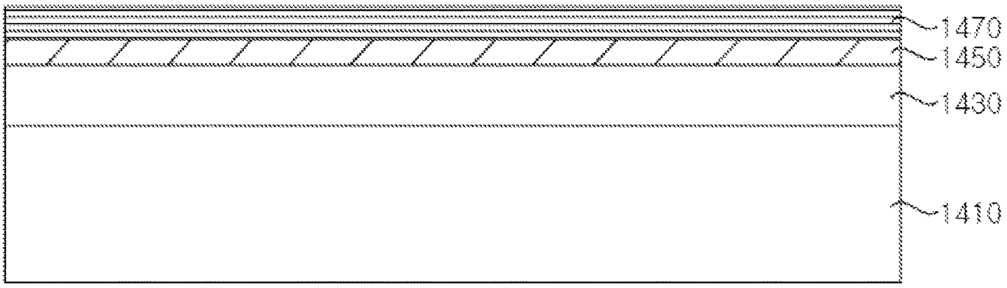


FIG. 37D

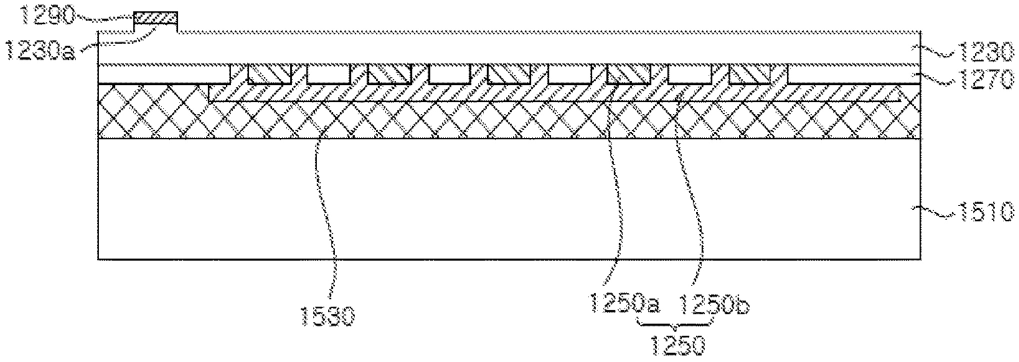


FIG. 37E

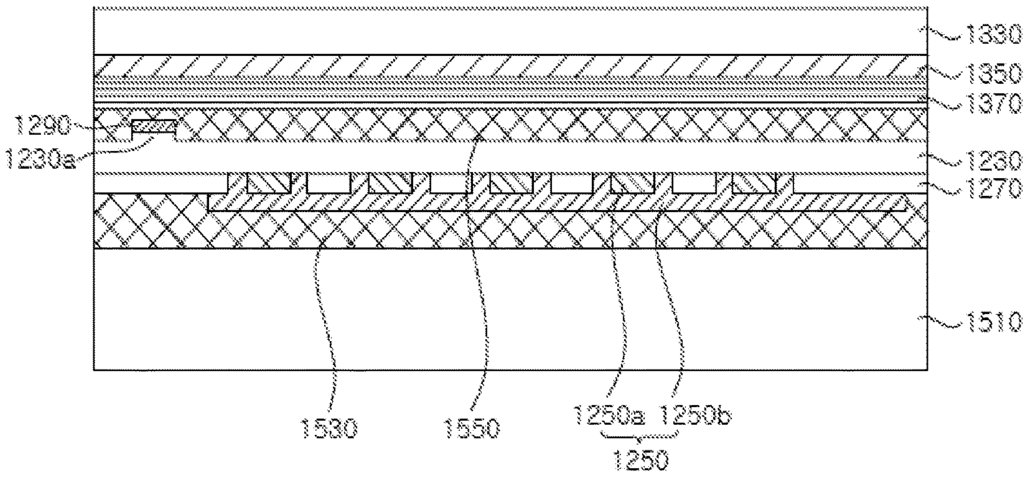


FIG. 38

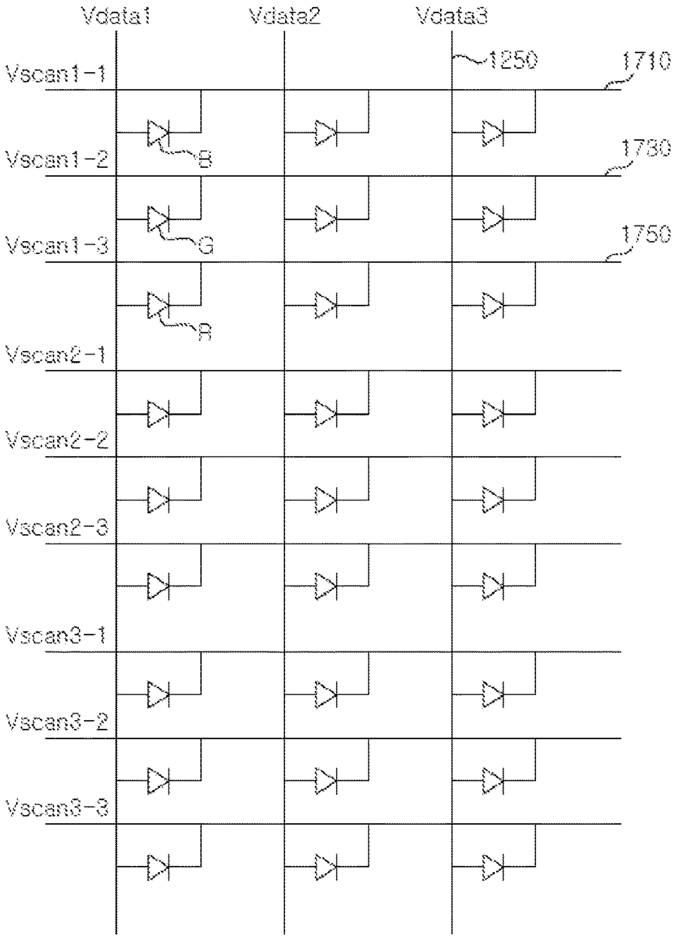


FIG. 39

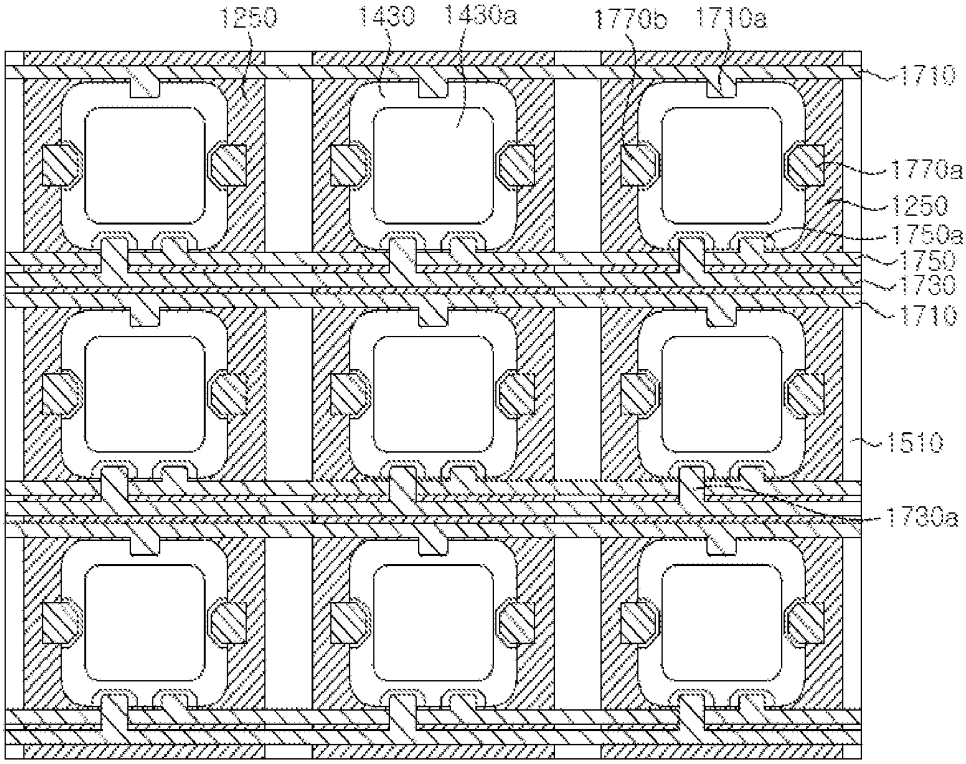

1250
1430
1430a
1770b
1710a
1710
1770a
1250
1750a
1750
1730
1710
1510
1730a

FIG. 40

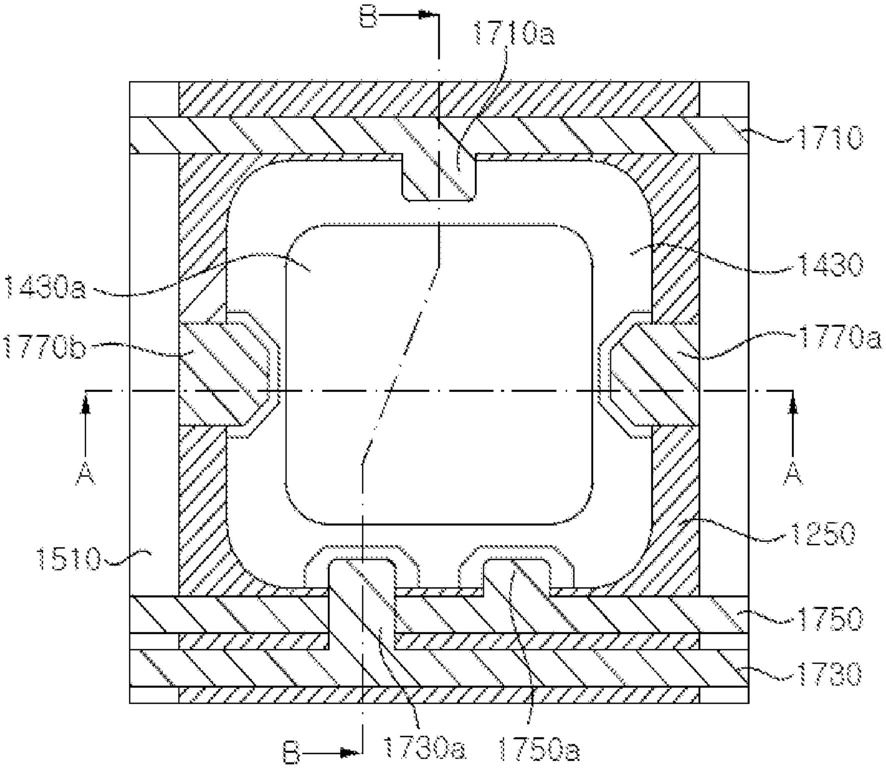

B
1710a
1710
1430a
1430
1770b
1770a
A
A
1510
1250
1750
1730
B
1730a
1750a

FIG. 41

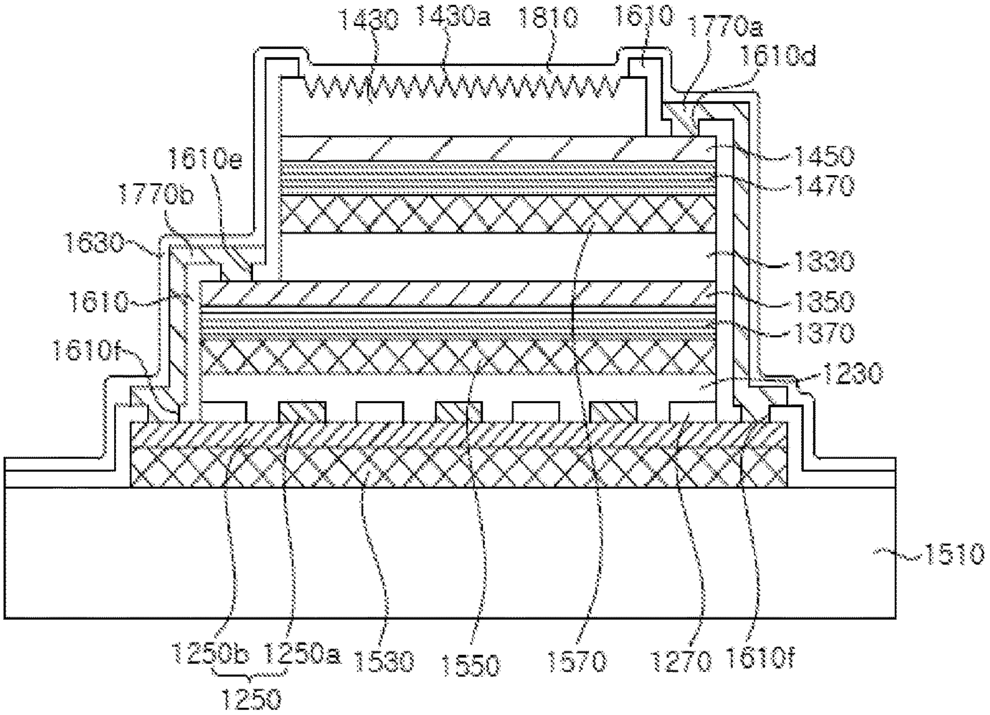

1430
1430a
1810
1610
1770a
1610d
1610e
1770b
1630
1610
1610f
1450
1470
1330
1350
1370
1230
1510
1250b
1250a
1250
1530
1550
1570
1270
1610f

FIG. 42

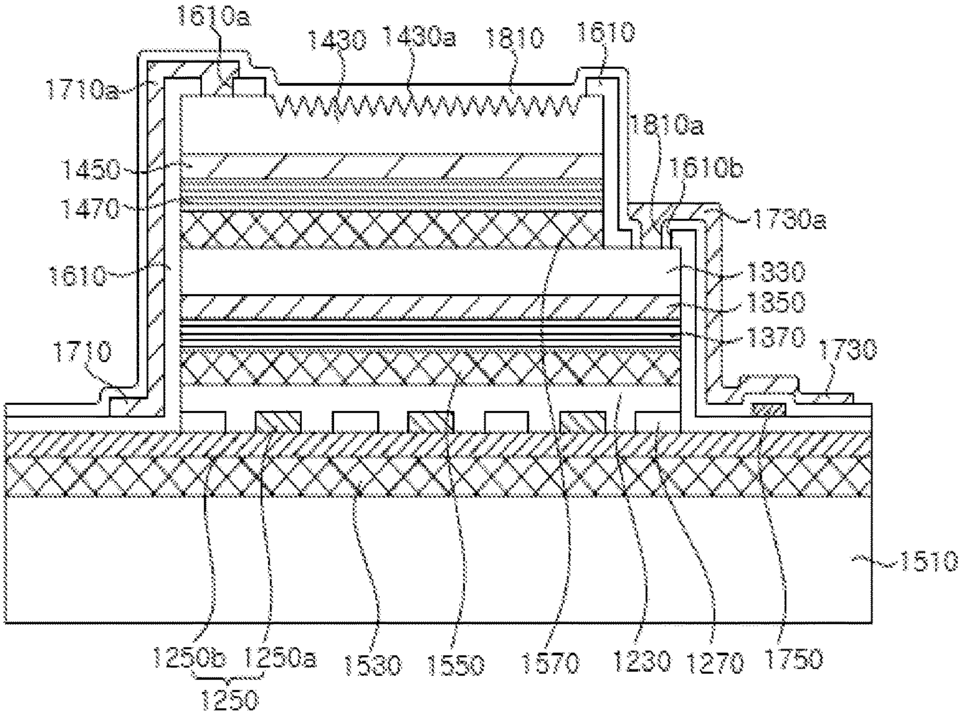

1610a
1430
1430a
1810
1610
1710a
1450
1470
1610
1810a
1610b
1730a
1330
1350
1370
1730
1710
1510
1250b
1250a
1250
1530
1550
1570
1230
1270
1750

FIG. 43A

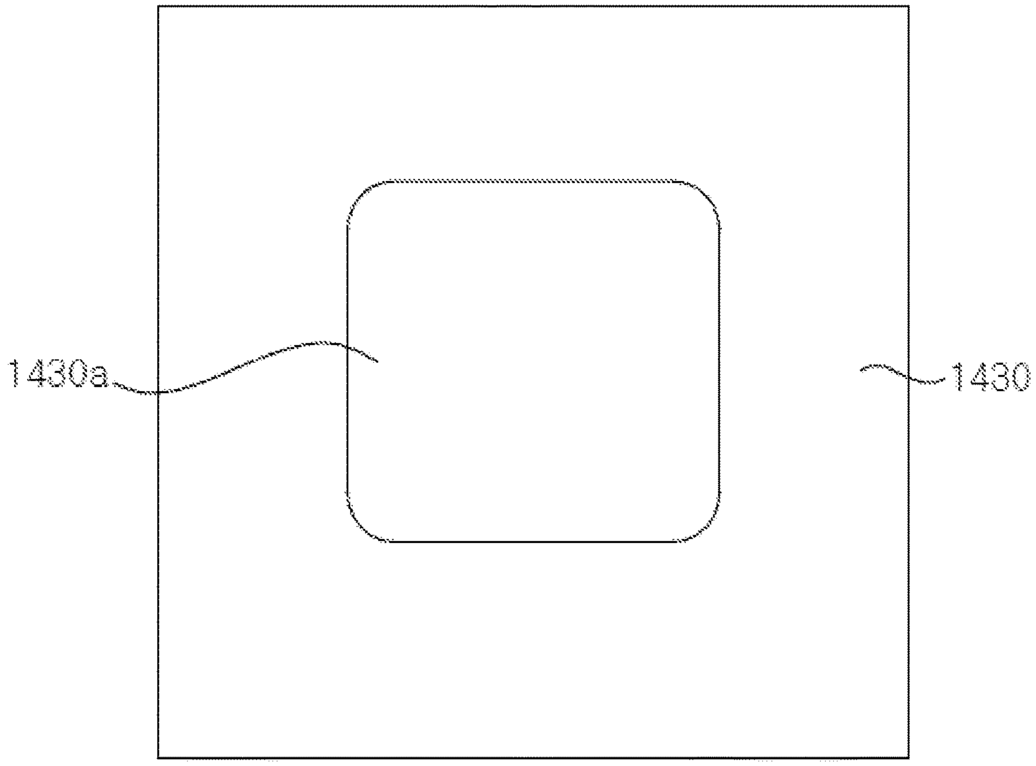


FIG. 43B

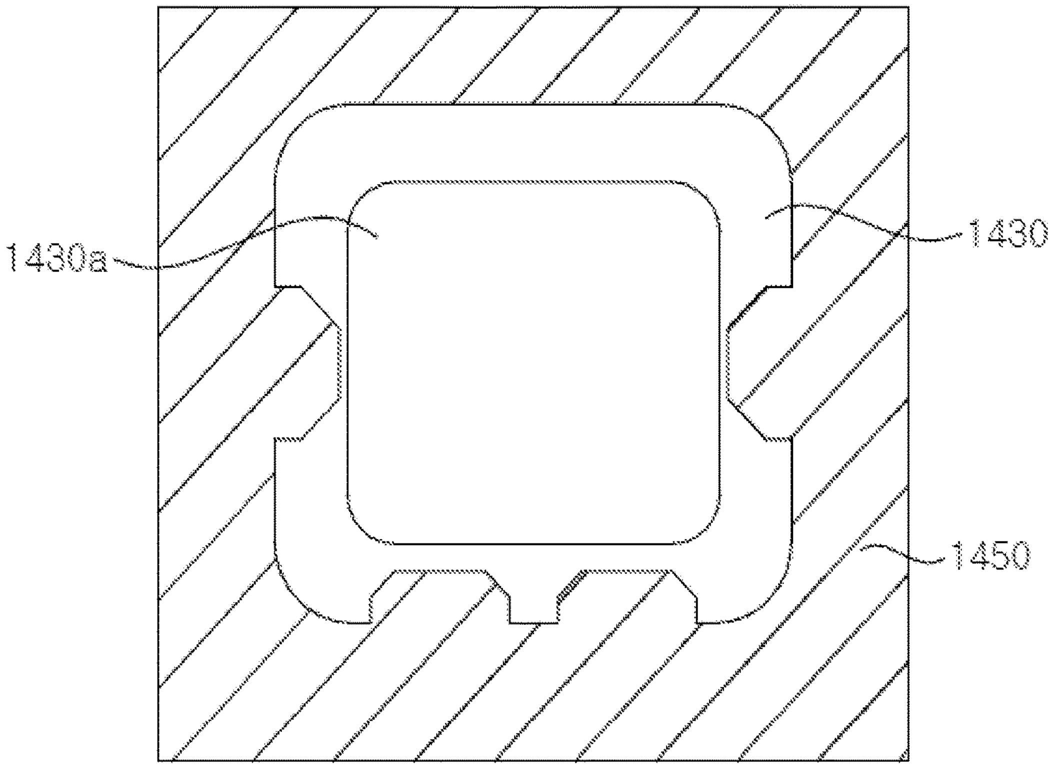


FIG. 43C

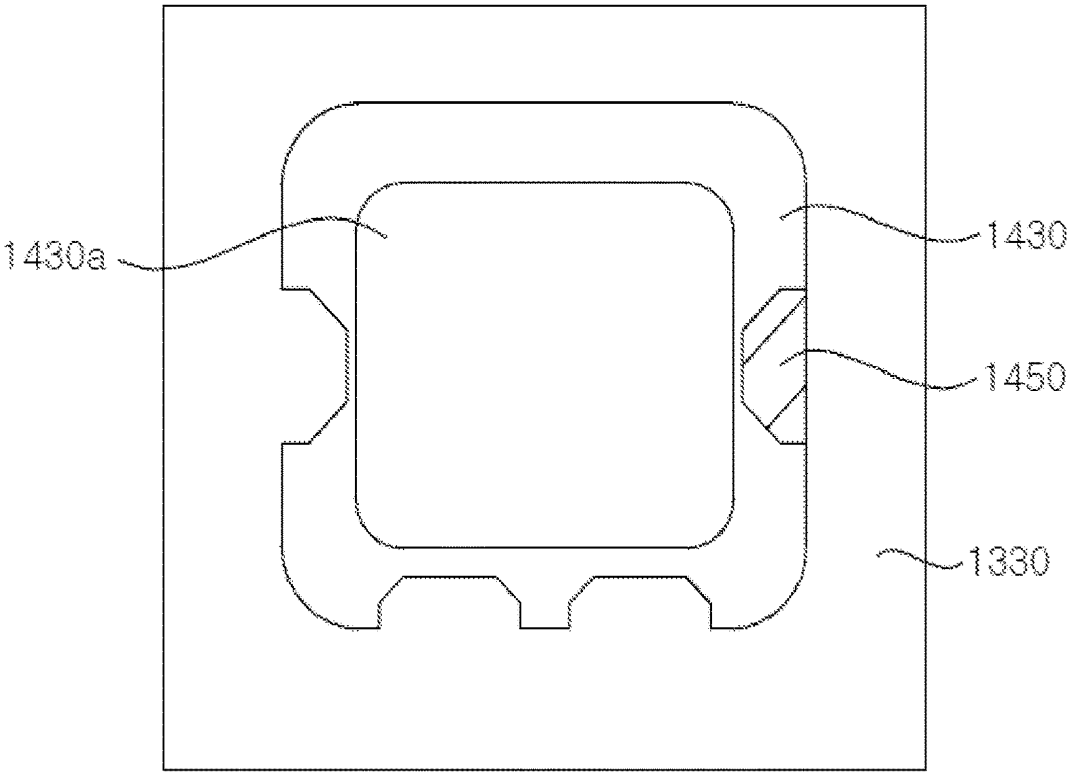


FIG. 43D

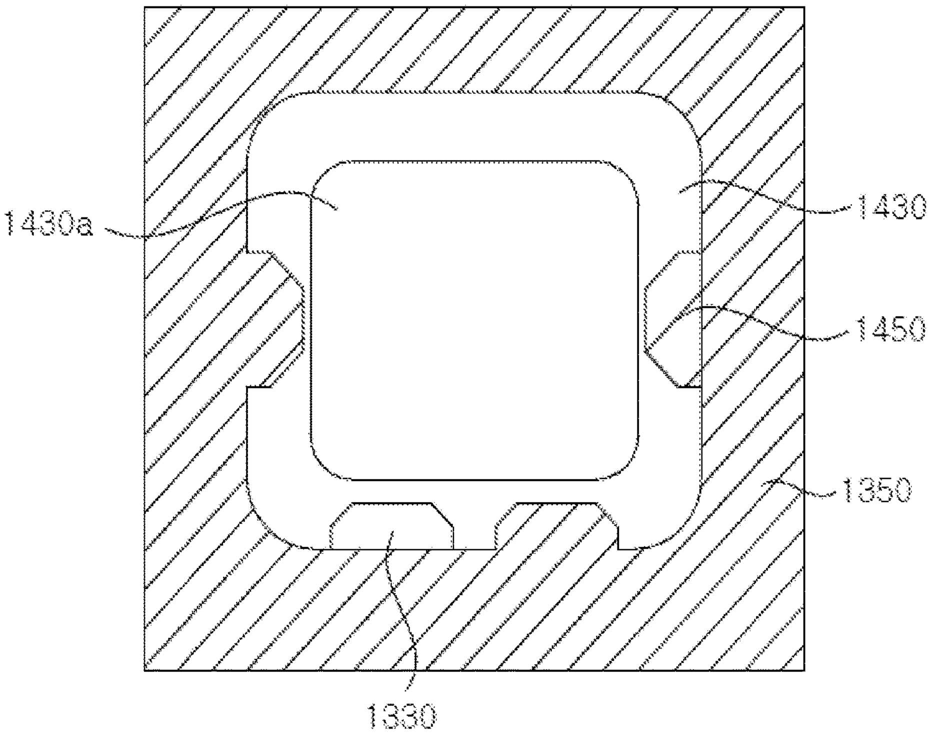


FIG. 43E

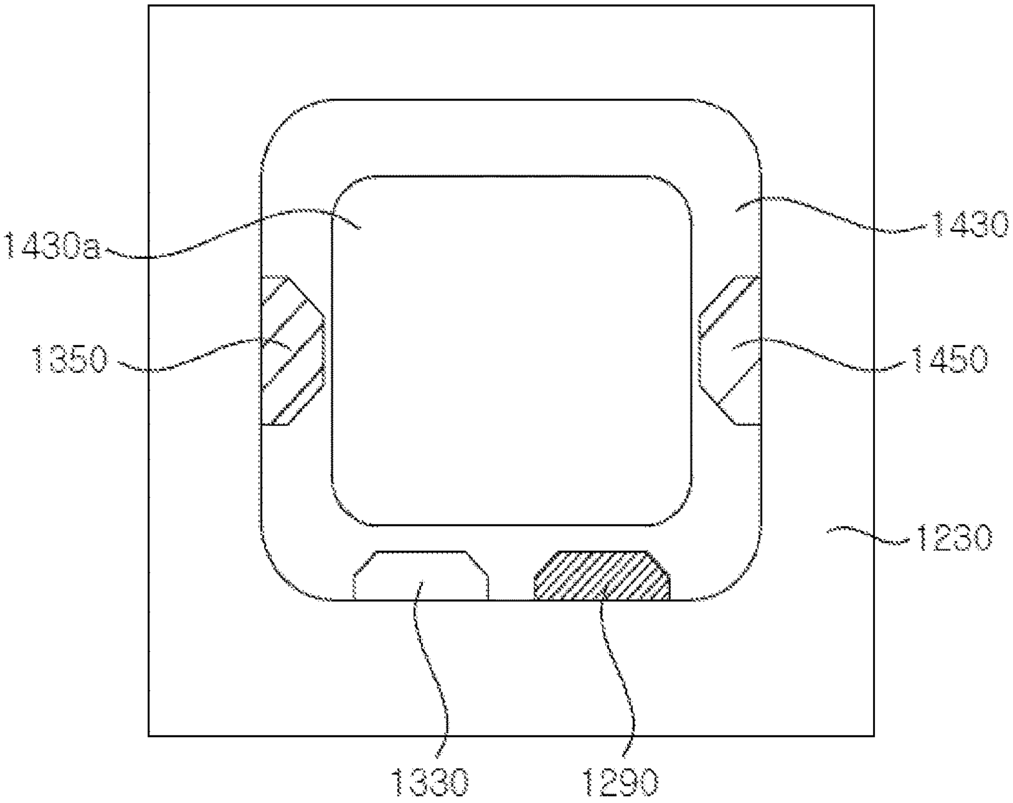


FIG. 43F

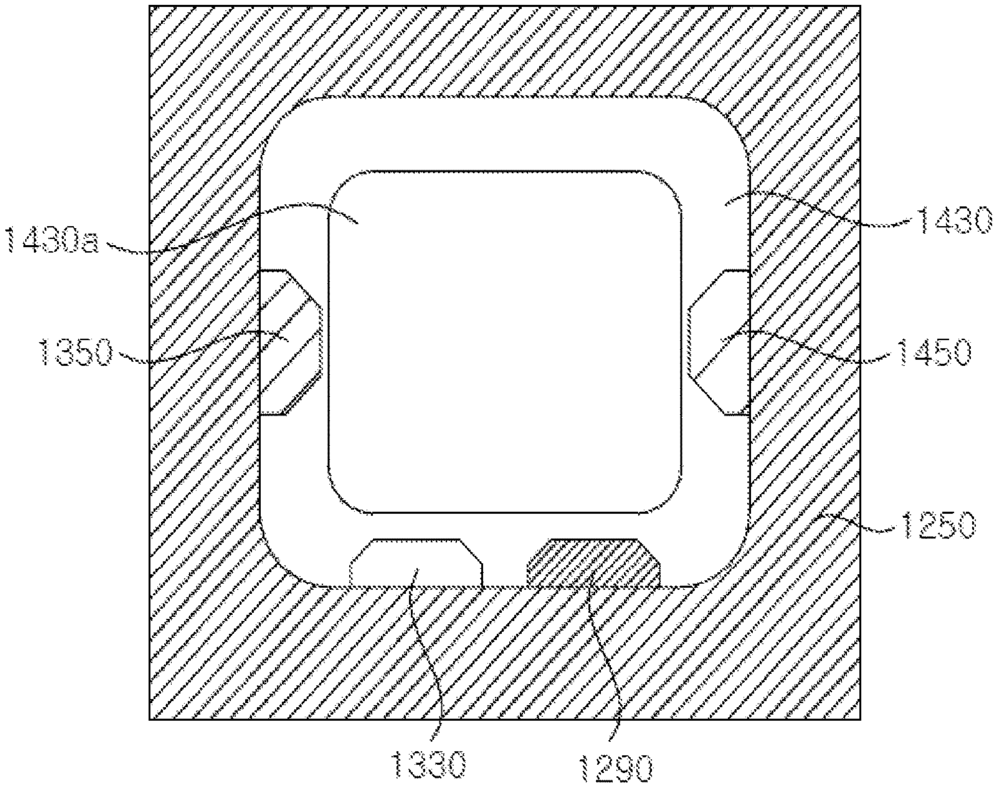


FIG. 43G

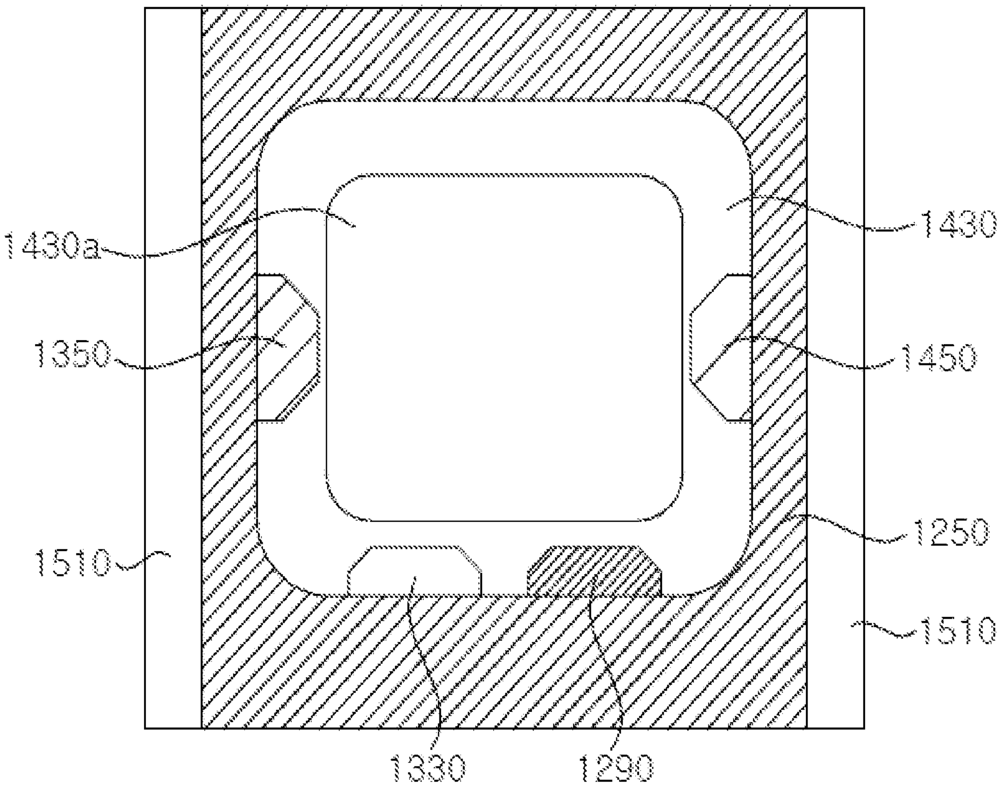


FIG. 43H

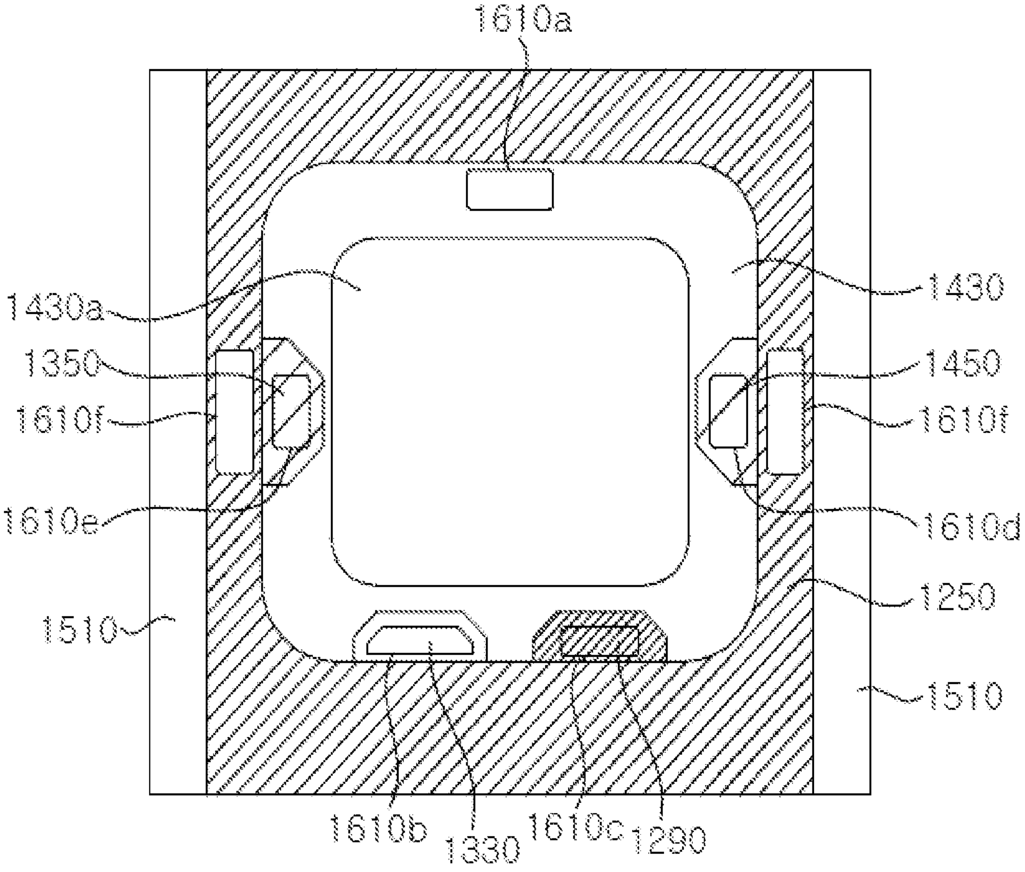


FIG. 43I

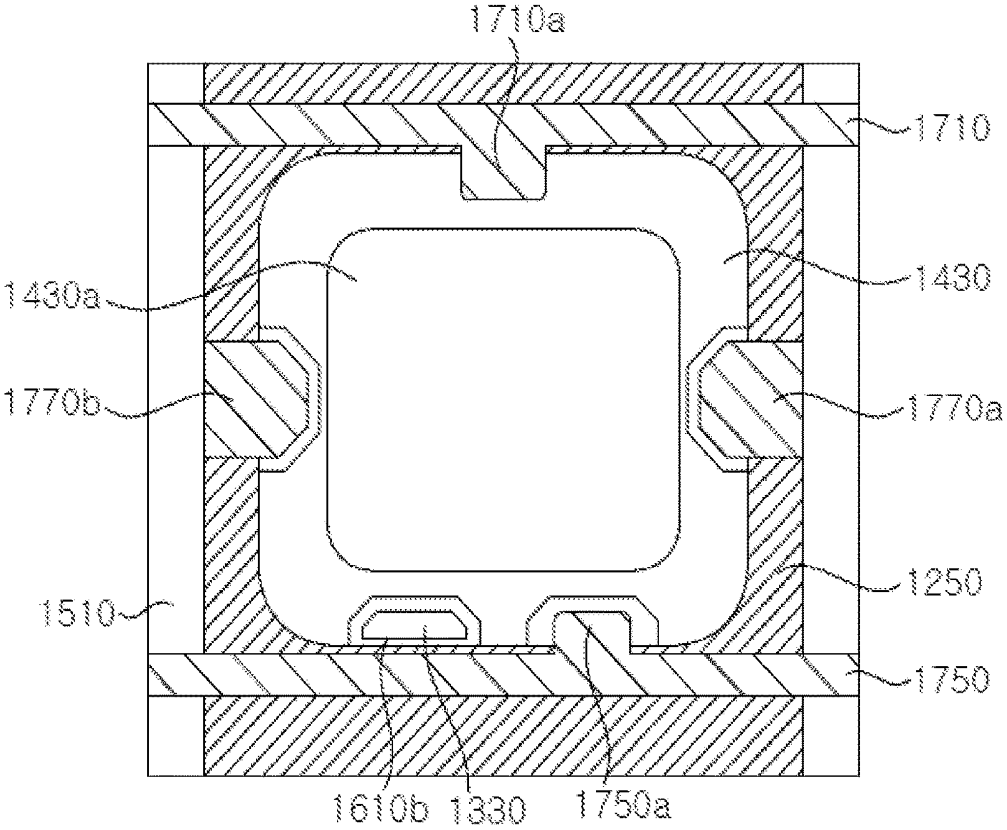


FIG. 43J

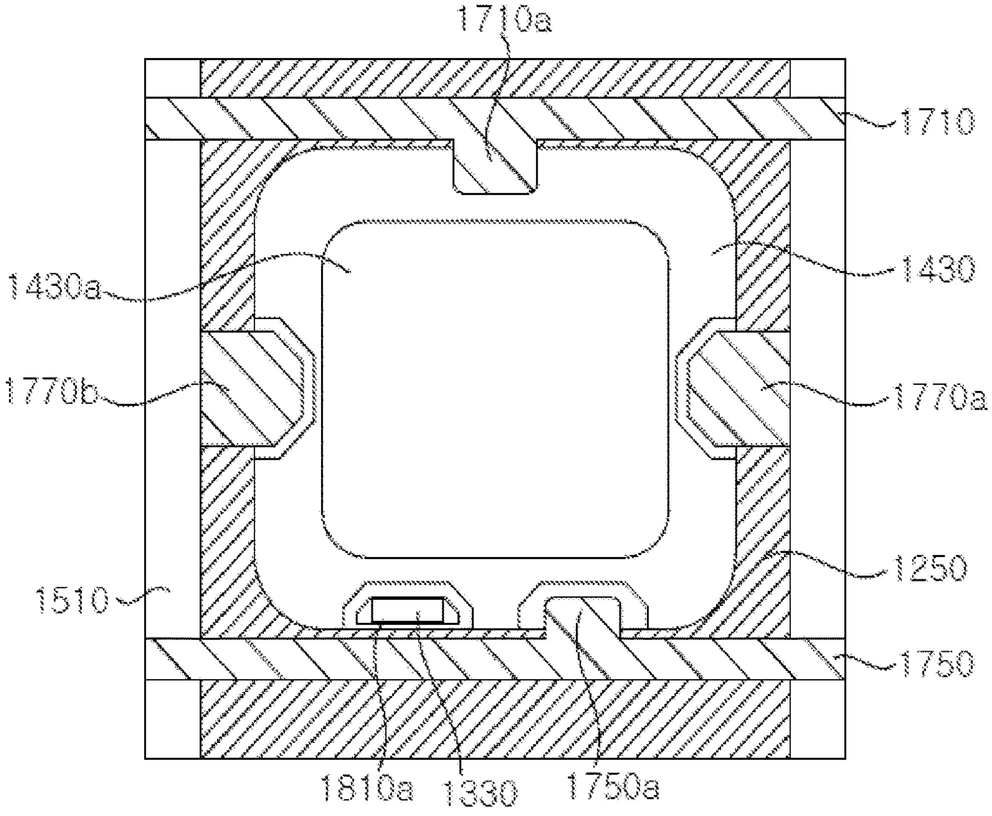


FIG. 43K

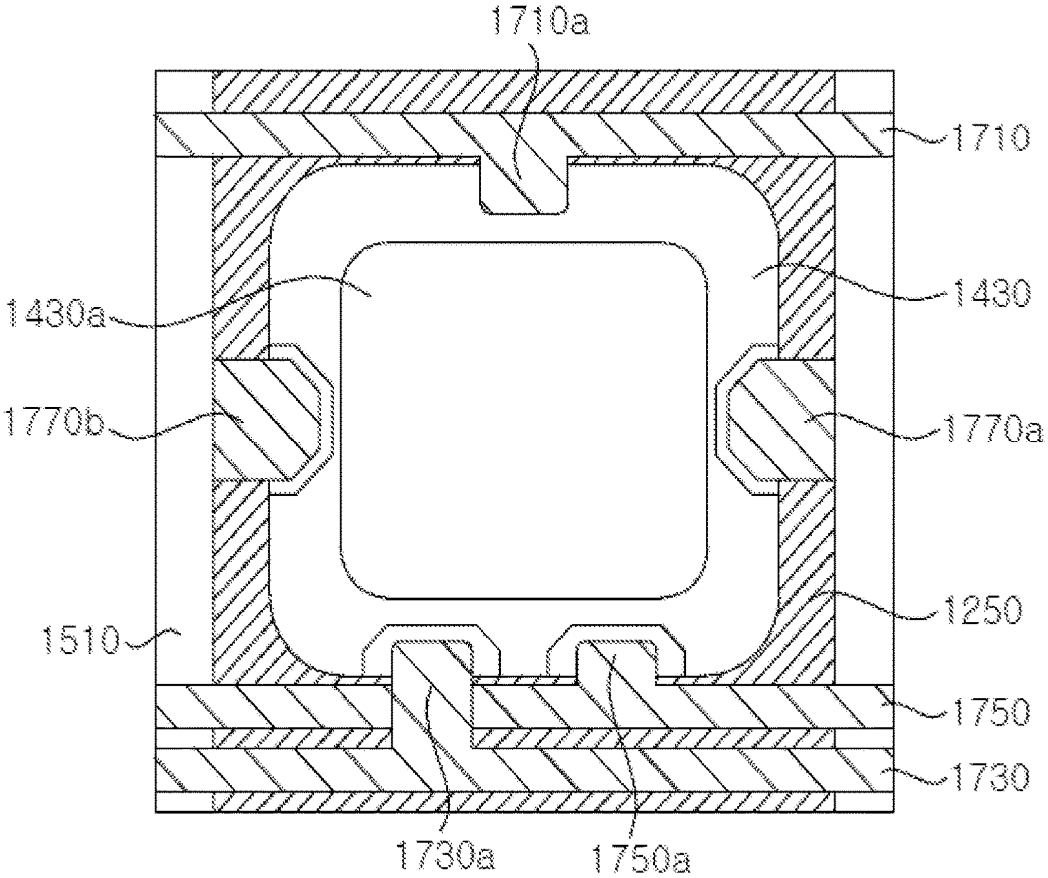

1710a
1710
1430a
1430
1770b
1770a
1250
1510
1750
1730
1730a
1750a

FIG. 44

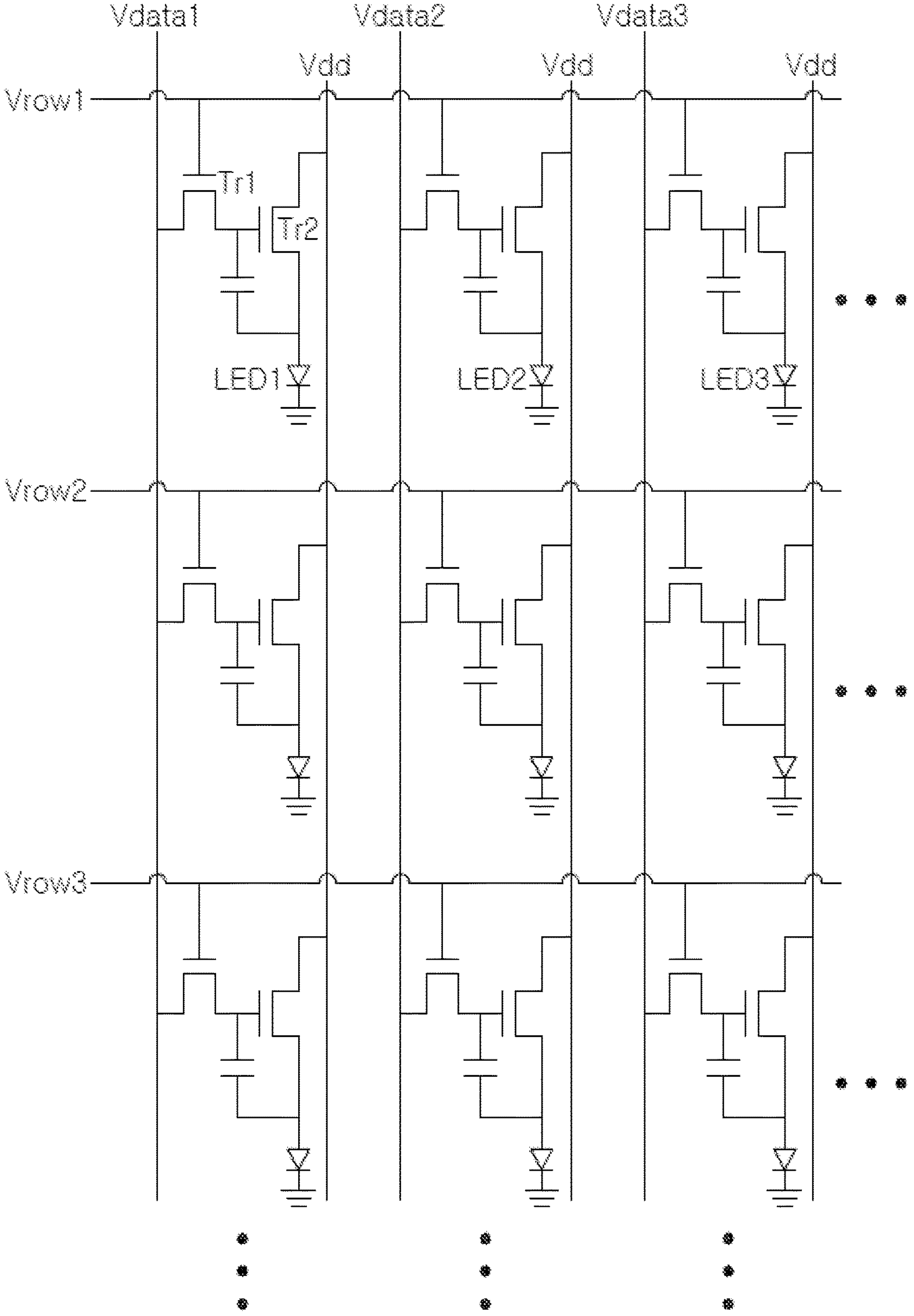

Vdata1
Vdata2
Vdata3
Vdd
Vdd
Vdd
Vrow1
Tr1
Tr2
LED1
LED2
LED3
Vrow2
Vrow3

FIG. 45

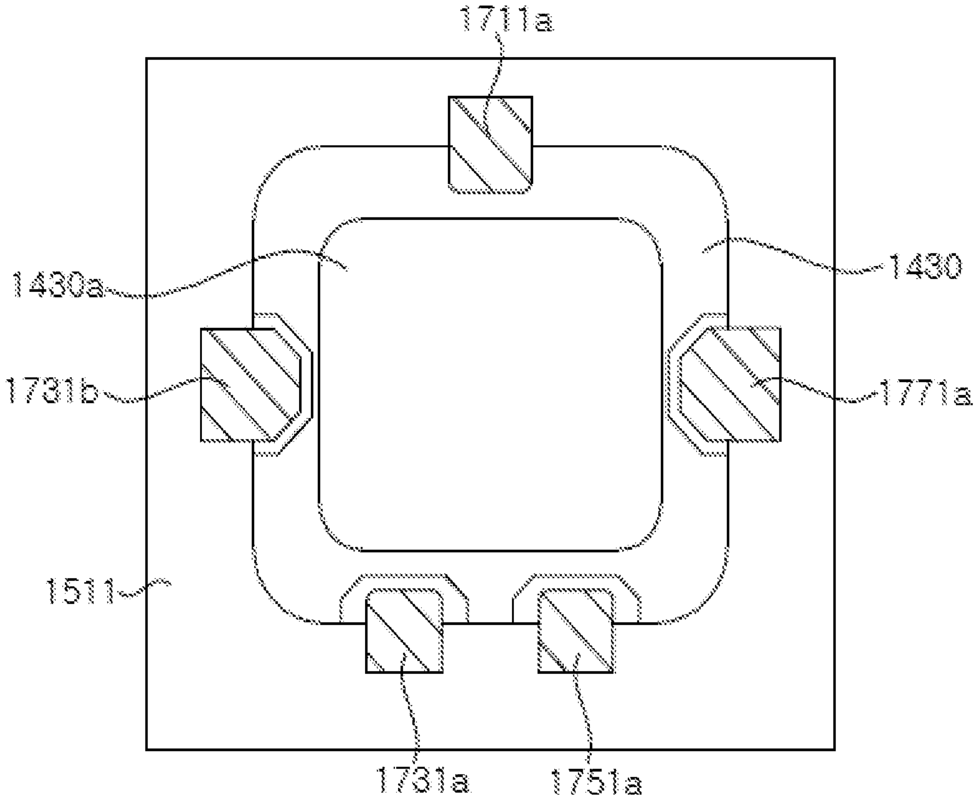


FIG. 46

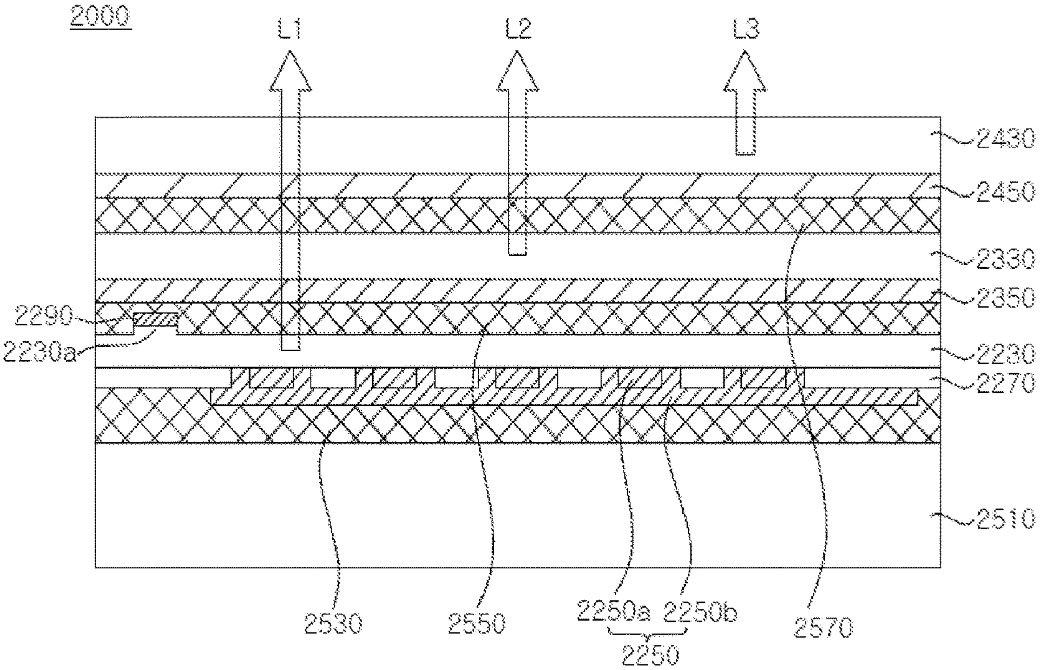


FIG. 47A

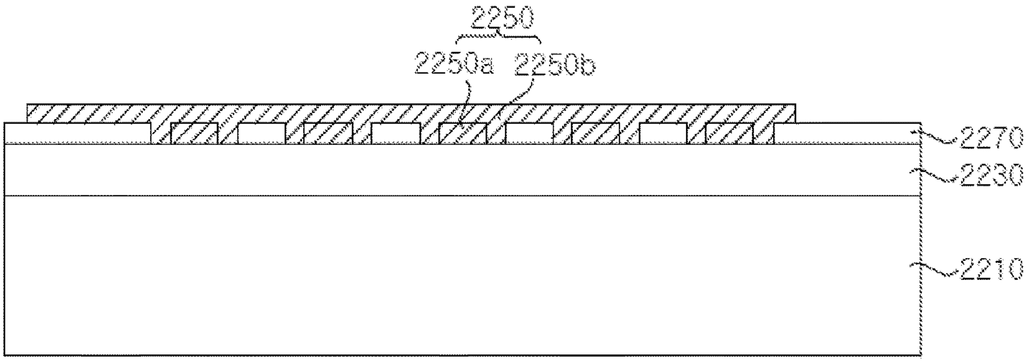


FIG. 47B

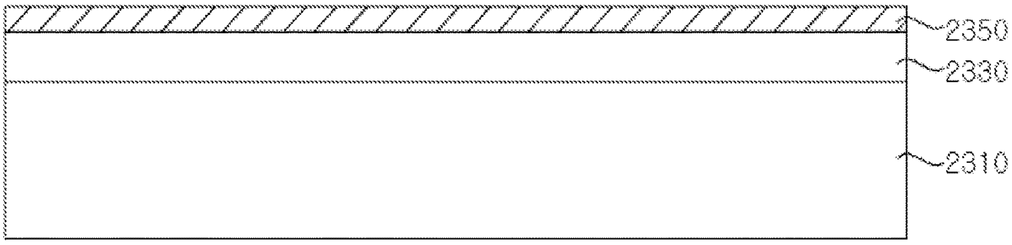


FIG. 47C

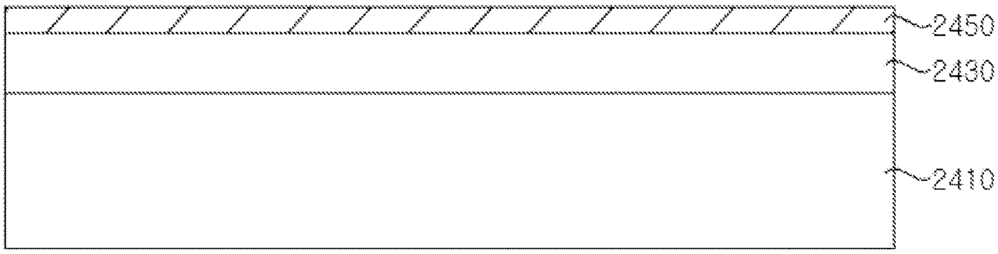


FIG. 47D

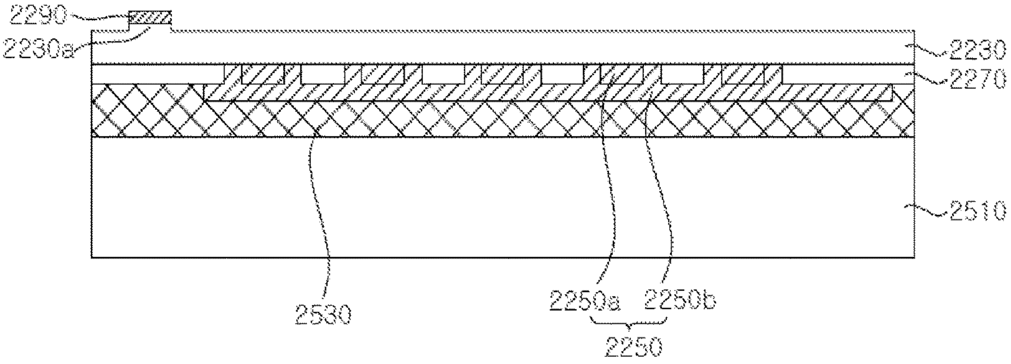


FIG. 47E

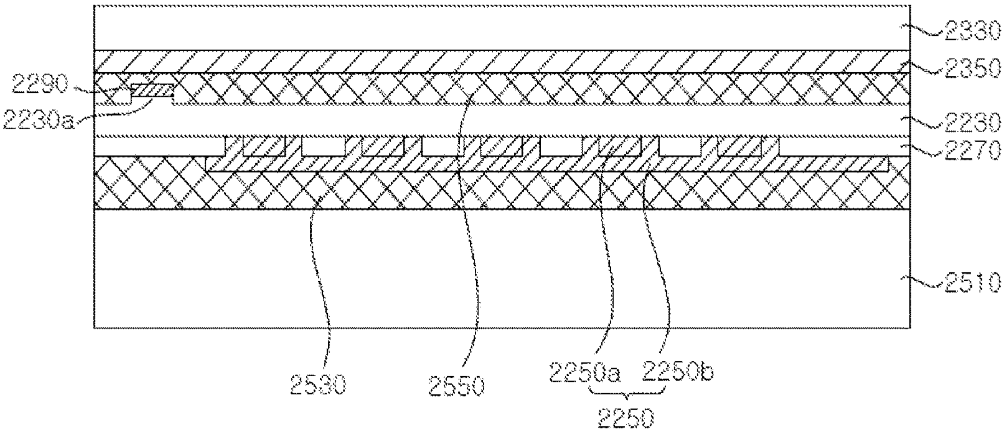


FIG. 48

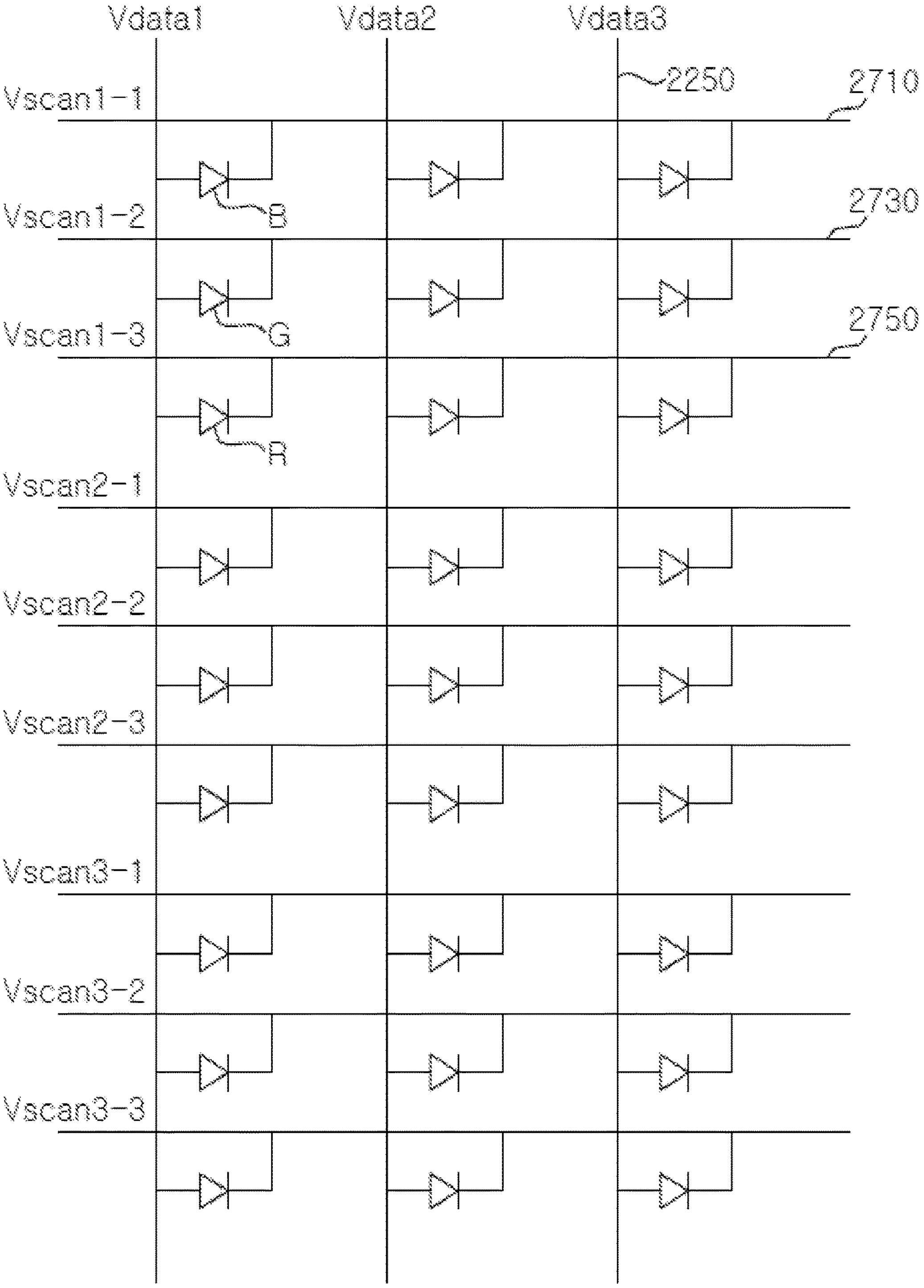

Vdata1
Vdata2
Vdata3
2250
2710
Vscan1-1
Vscan1-2
B
2730
Vscan1-3
G
2750
R
Vscan2-1
Vscan2-2
Vscan2-3
Vscan3-1
Vscan3-2
Vscan3-3

FIG. 49

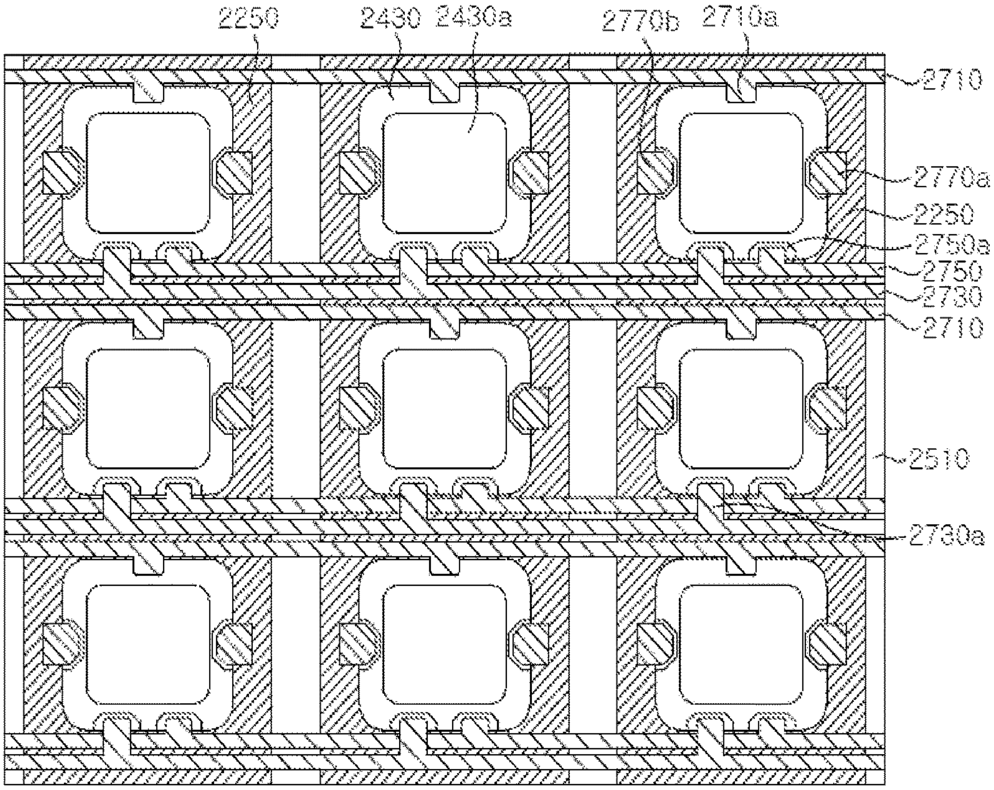

2250
2430
2430a
2770b
2710a
2710
2770a
2250
2750a
2750
2730
2710
2510
2730a

FIG. 50

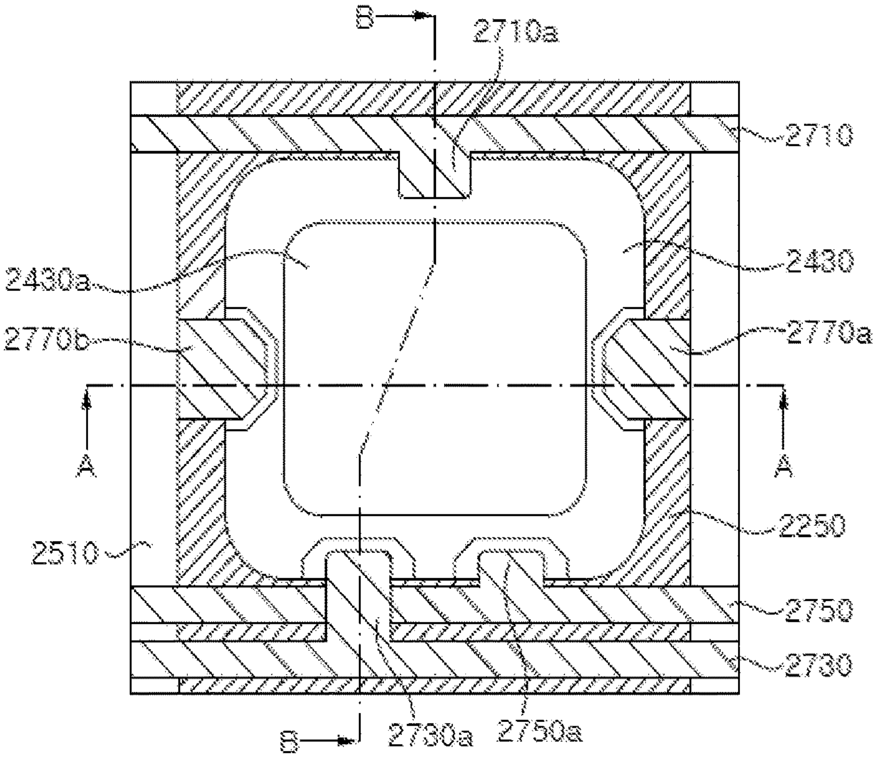

B
2710a
2710
2430a
2430
2770b
2770a
A
A
2510
2250
2750
2730
B
2730a
2750a

FIG. 51

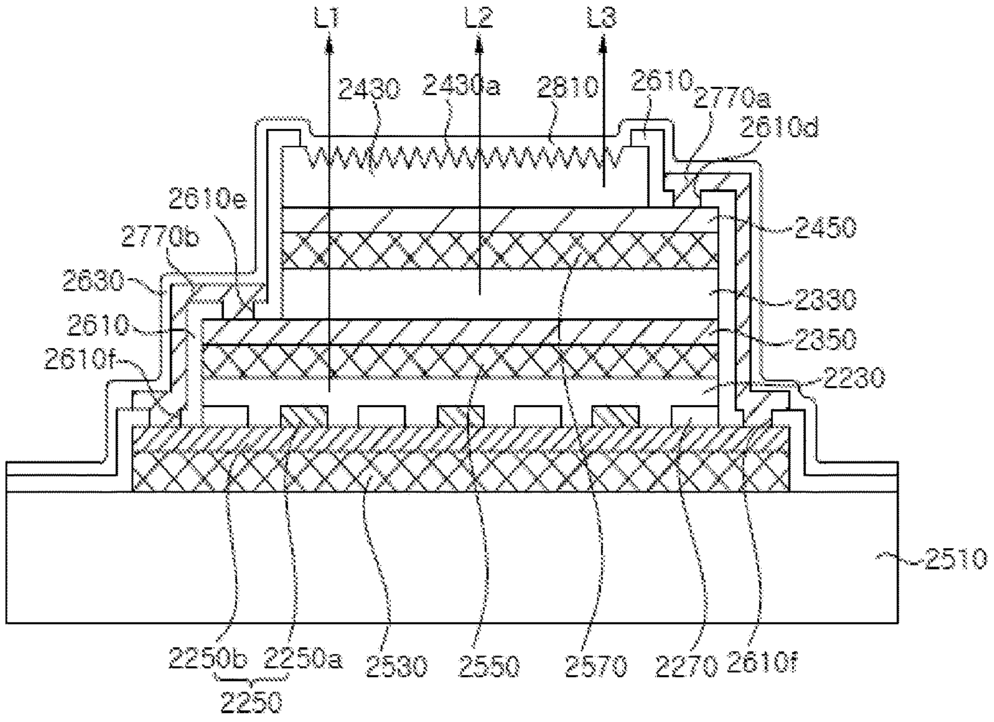

L1
L2
L3
2430
2430a
2810
2610
2770a
2610d
2610e
2450
2770b
2630
2330
2610
2350
2610f
2230
2510
2250b
2250a
2250
2530
2550
2570
2270
2610f

FIG. 52

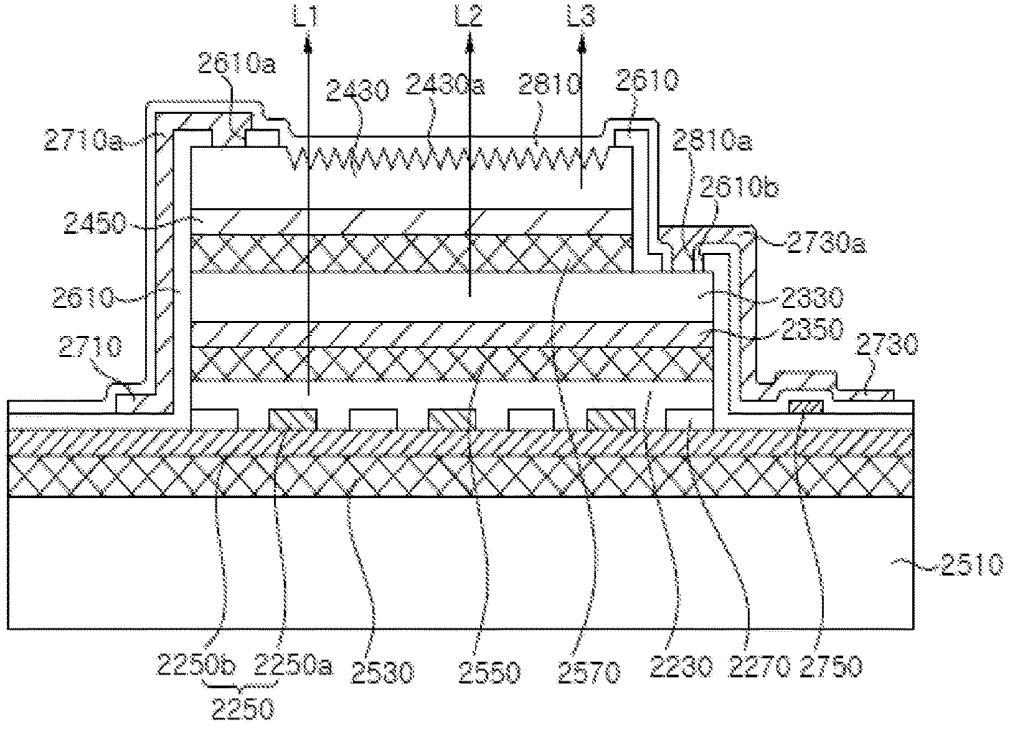

L1
L2
L3
2610a
2430
2430a
2810
2610
2710a
2810a
2610b
2450
2730a
2610
2330
2350
2710
2730
2510
2250b
2250a
2250
2530
2550
2570
2230
2270
2750

FIG. 53A

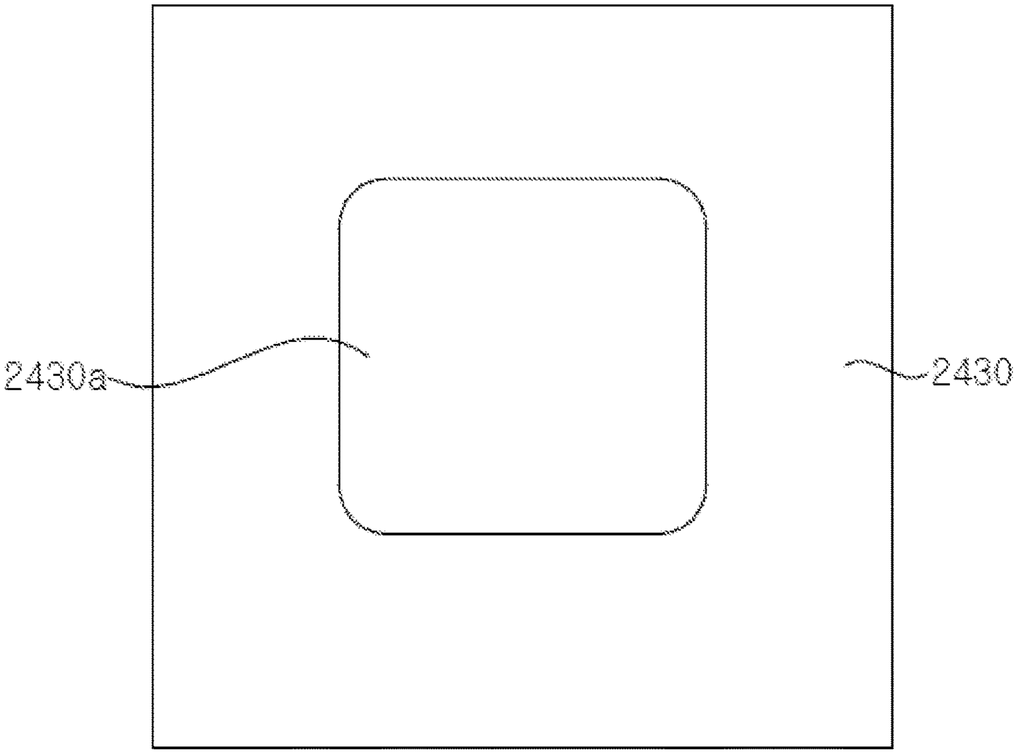


FIG. 53B

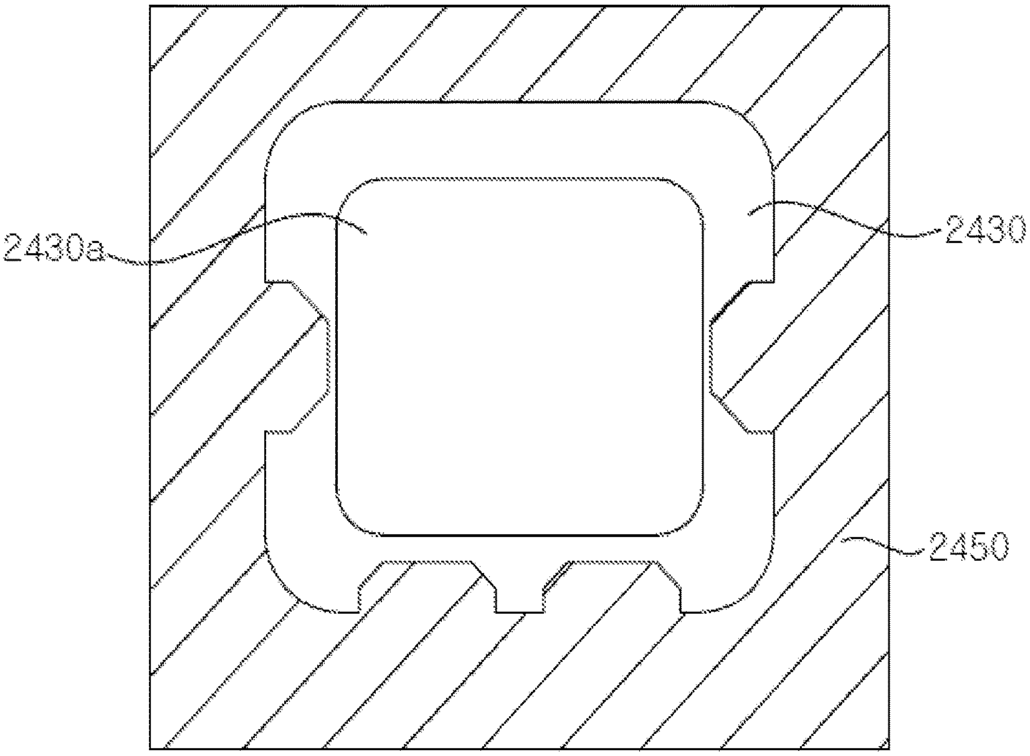


FIG. 53C

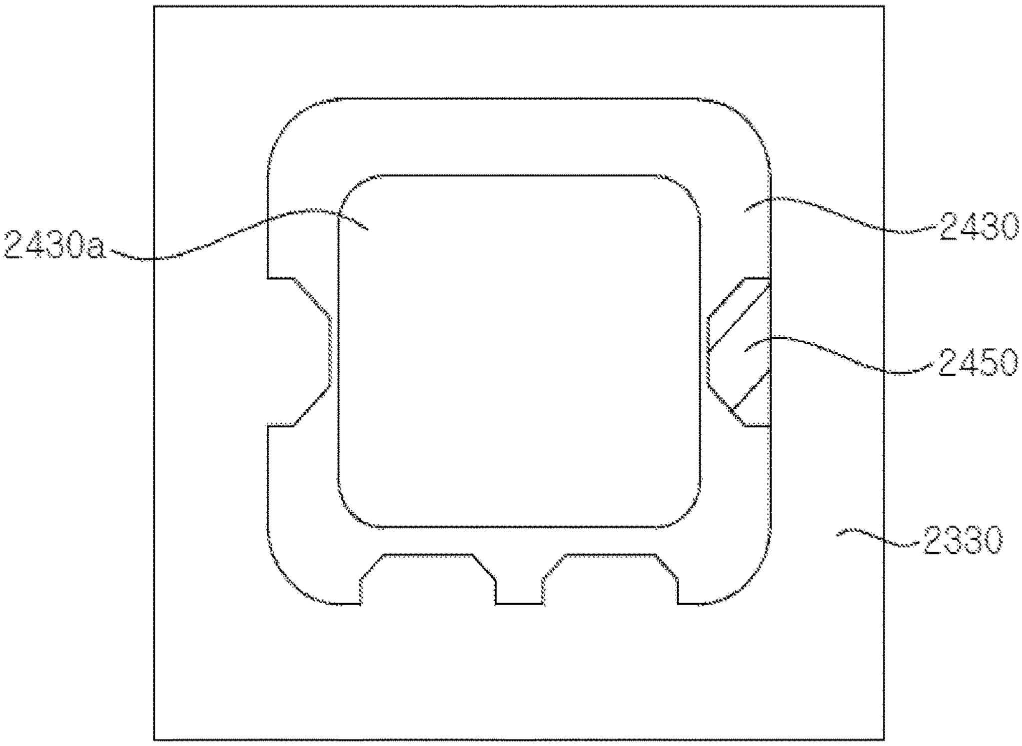


FIG. 53D

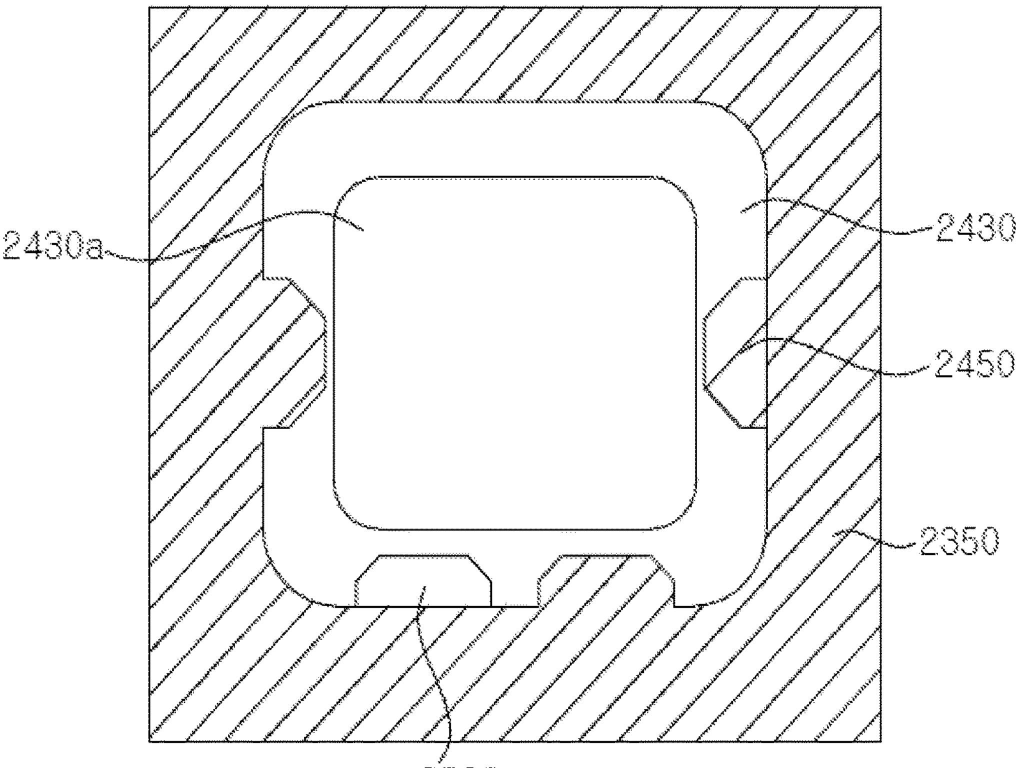


FIG. 53E

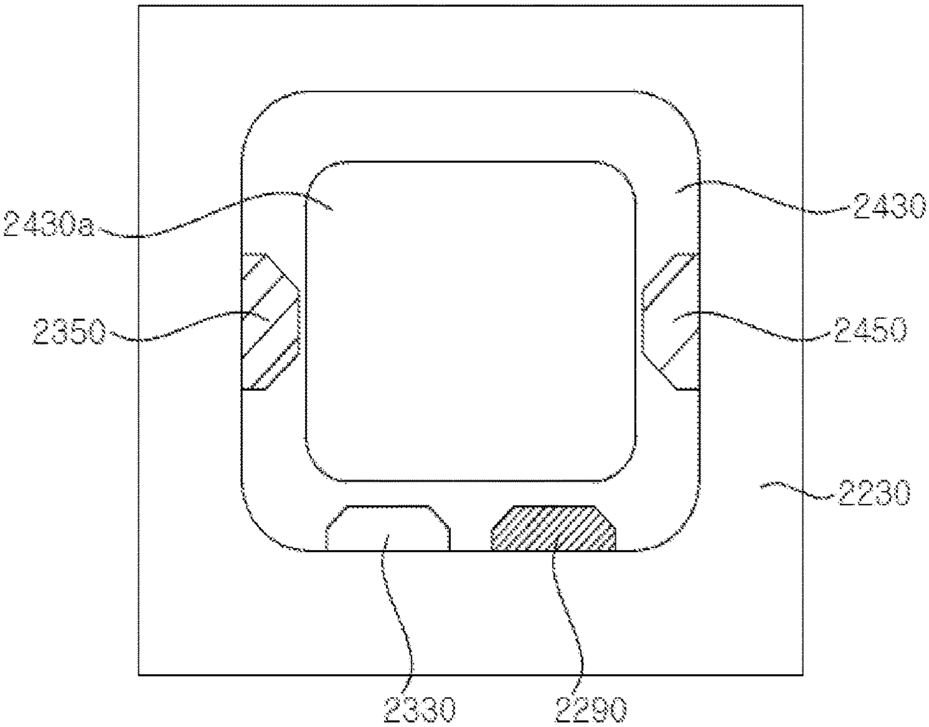


FIG. 53F

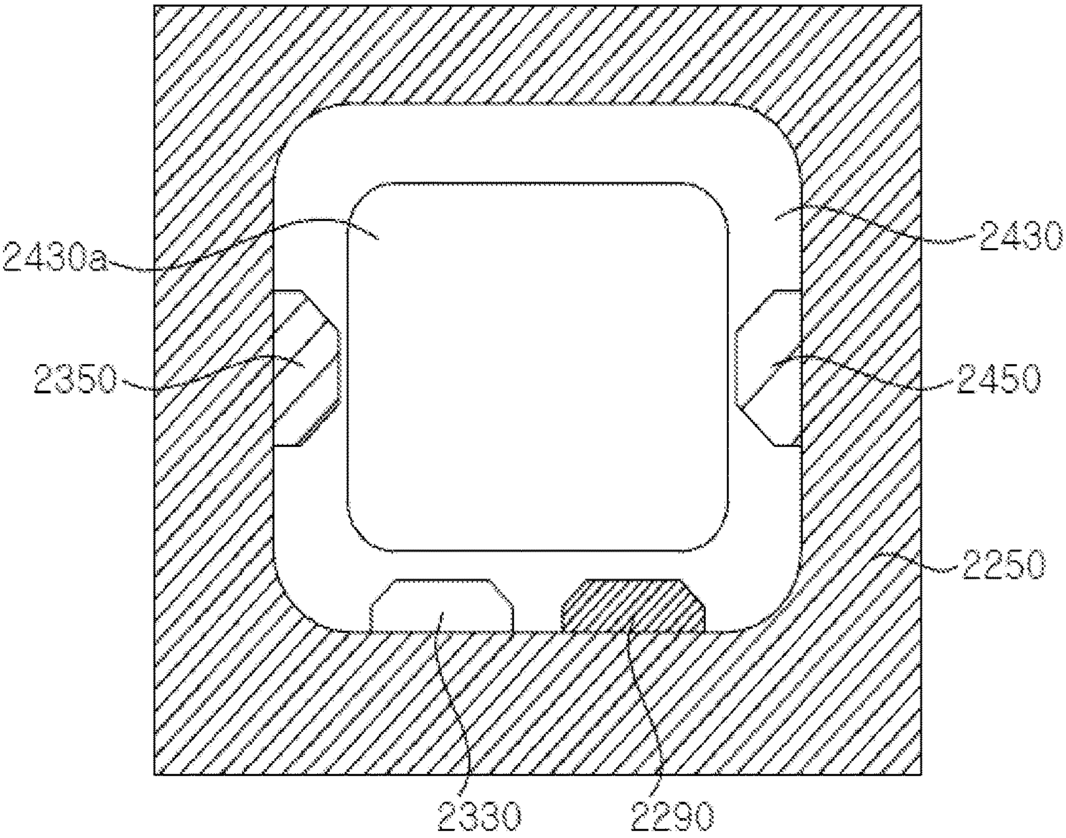


FIG. 53G

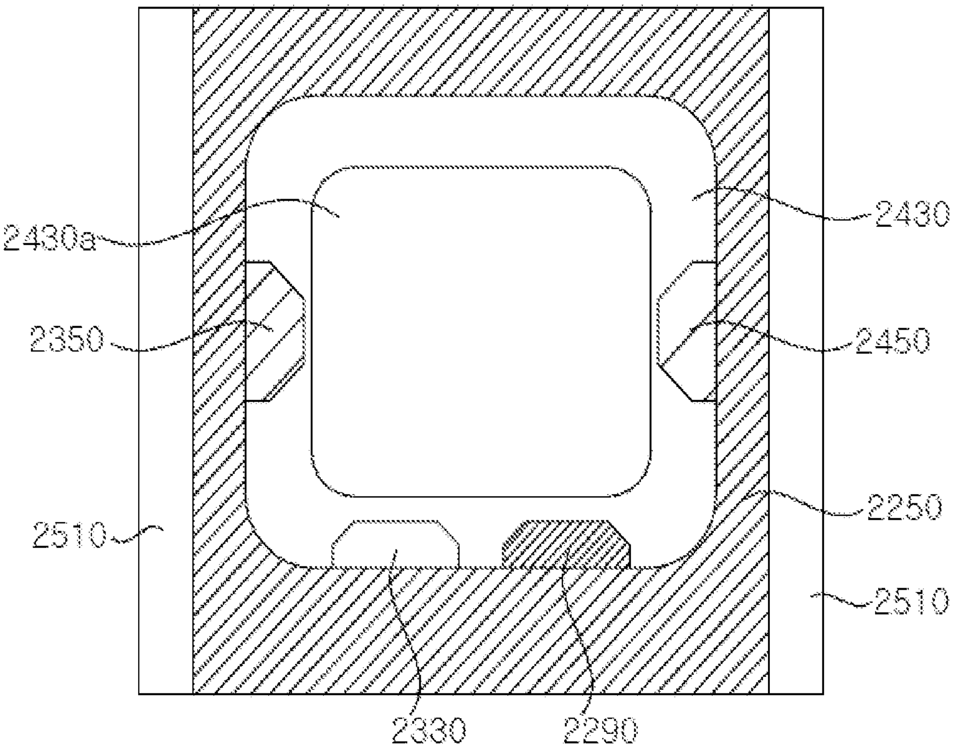


FIG. 53H

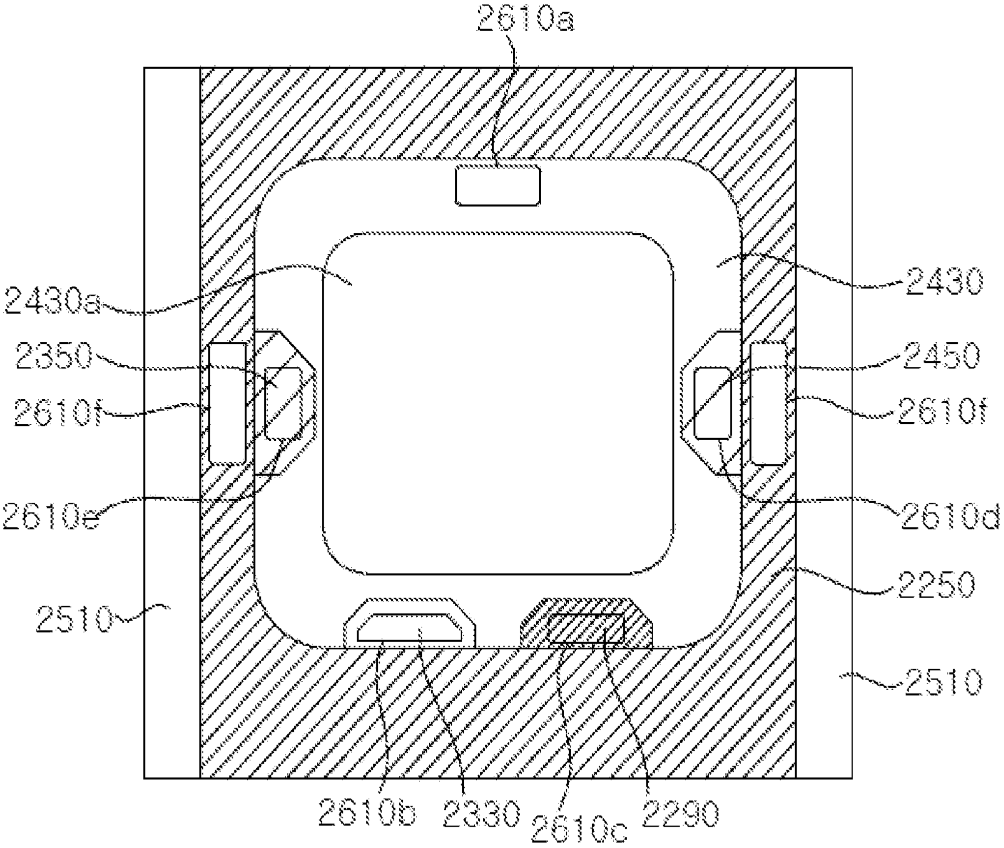


FIG. 53I

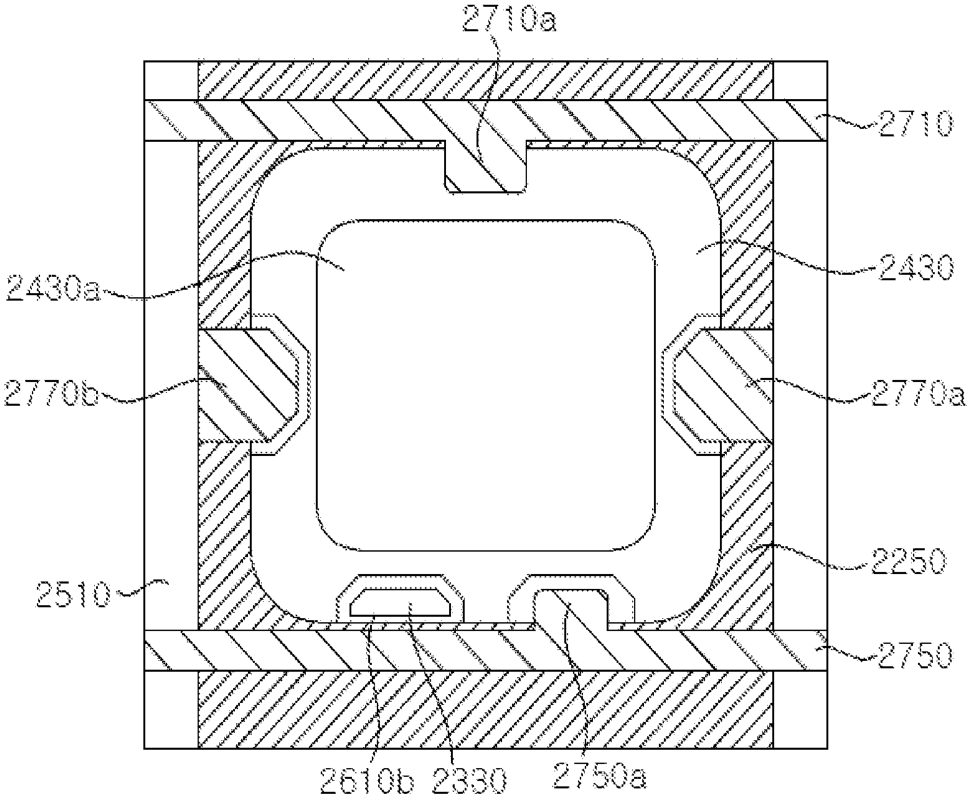


FIG. 53J

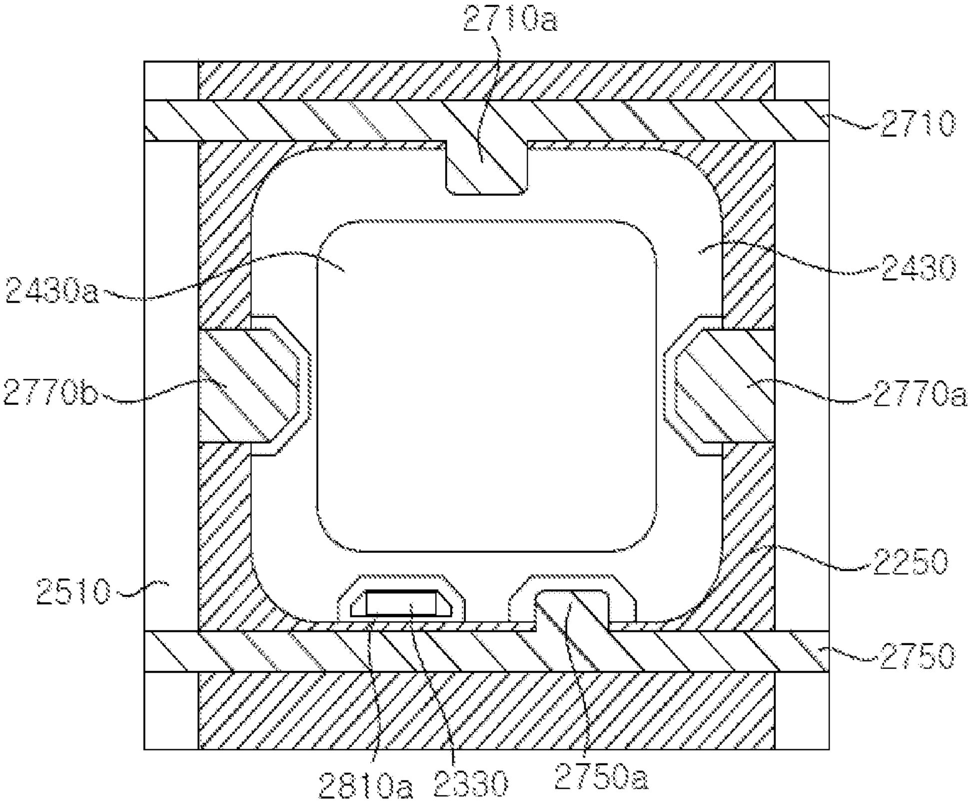


FIG. 53K

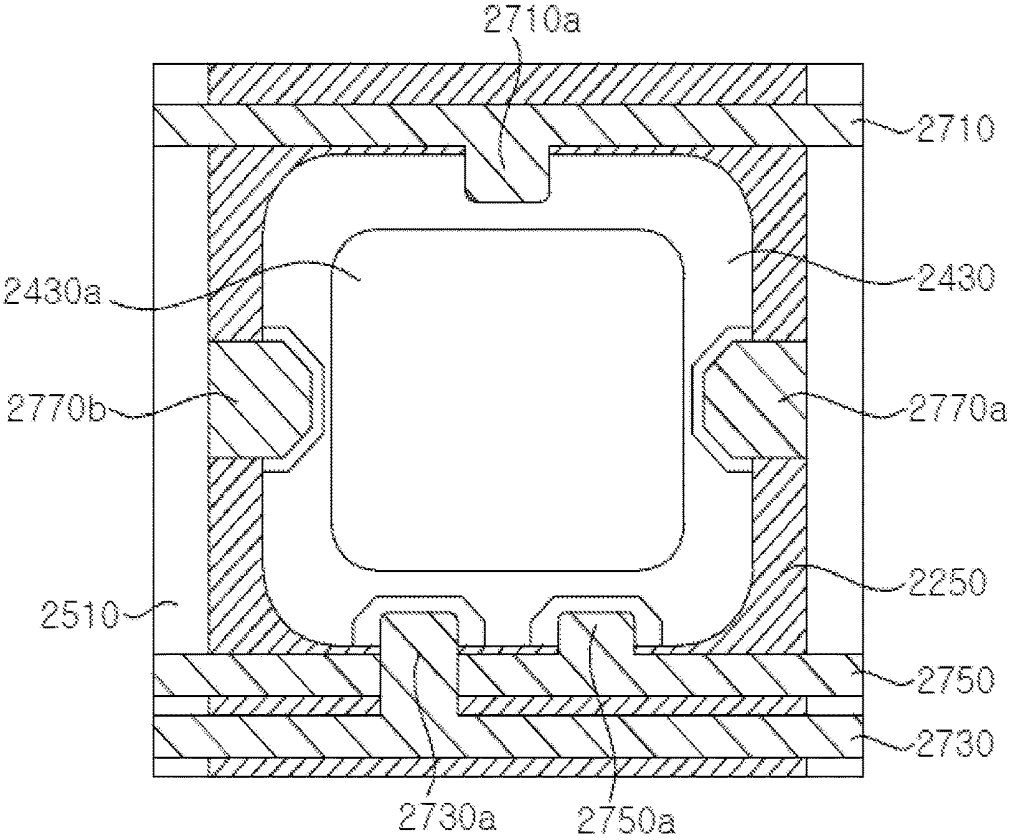

2710a
2710
2430a
2430
2770b
2770a
2250
2510
2750
2730
2730a
2750a

FIG. 54

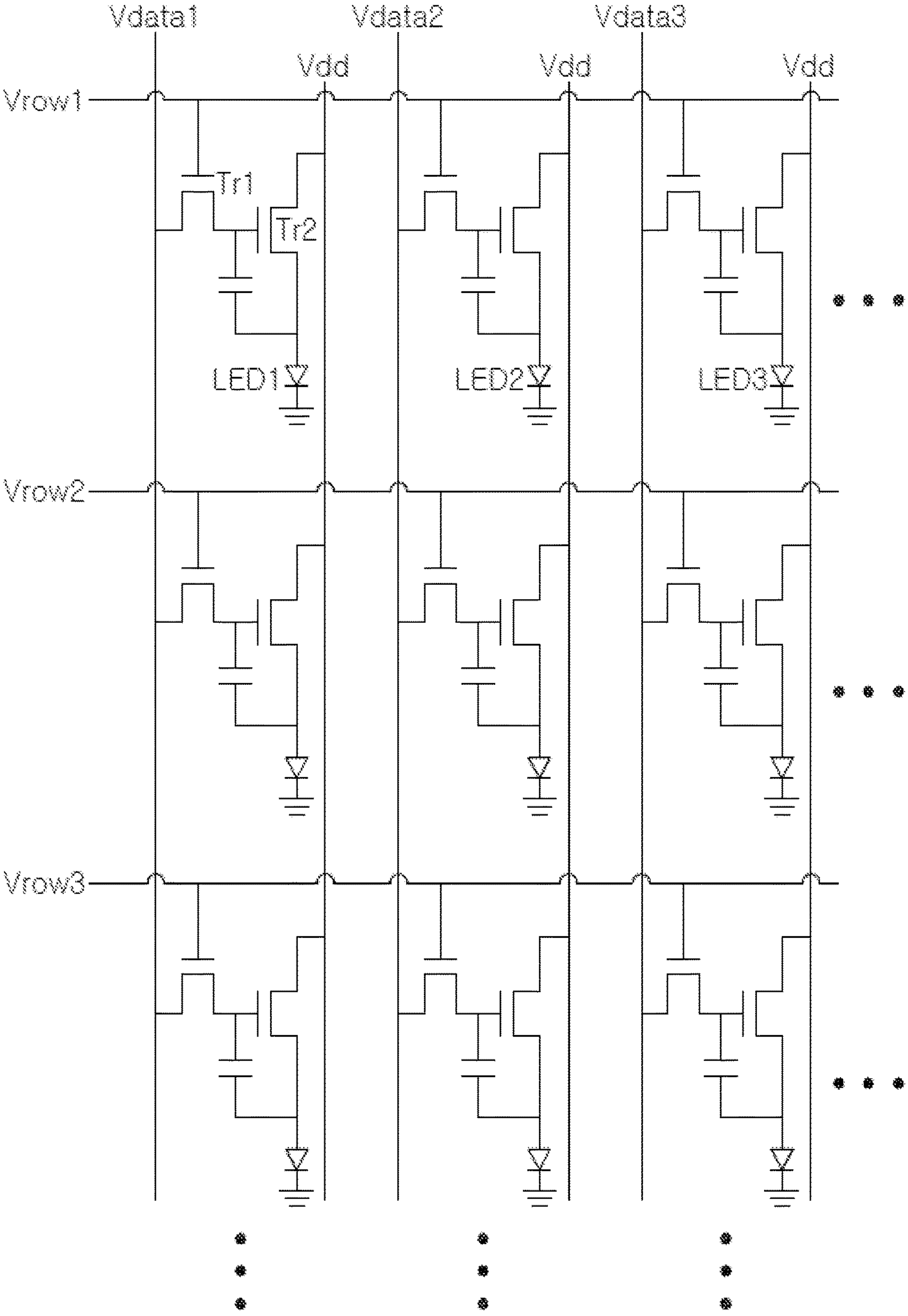

Vdata1
Vdata2
Vdata3
Vdd
Vdd
Vdd
Vrow1
Tr1
Tr2
LED1
LED2
LED3
Vrow2
Vrow3

FIG. 55

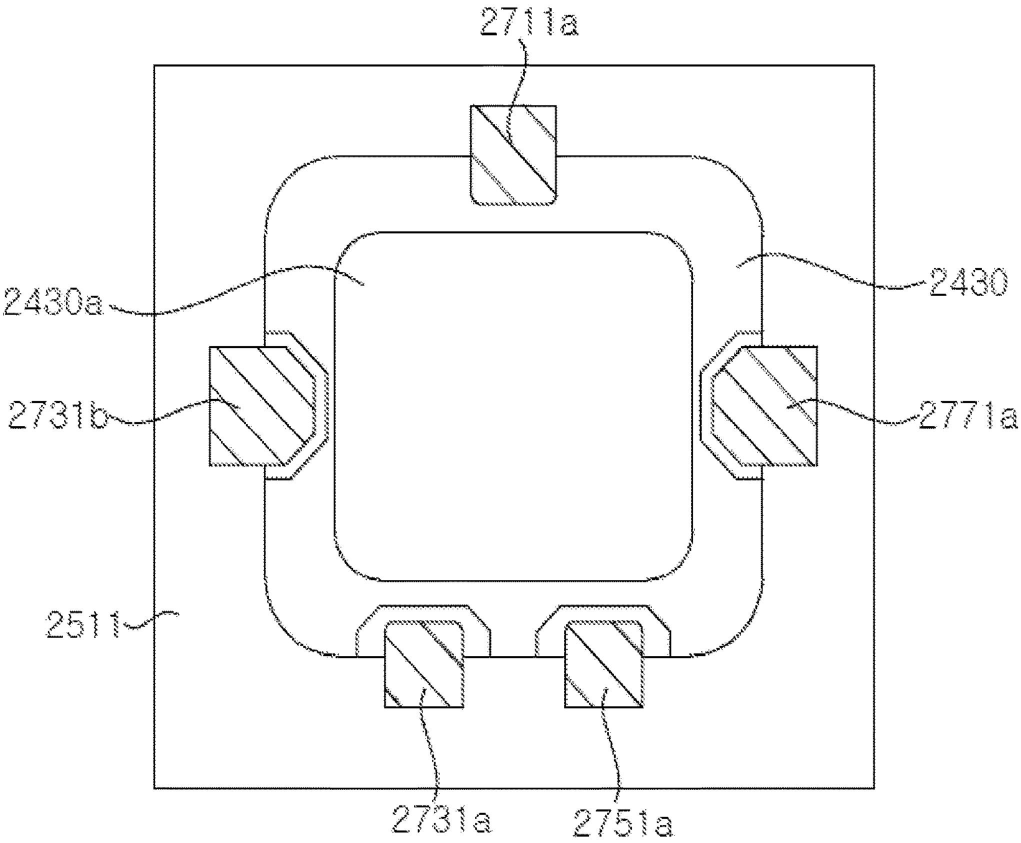


FIG. 56

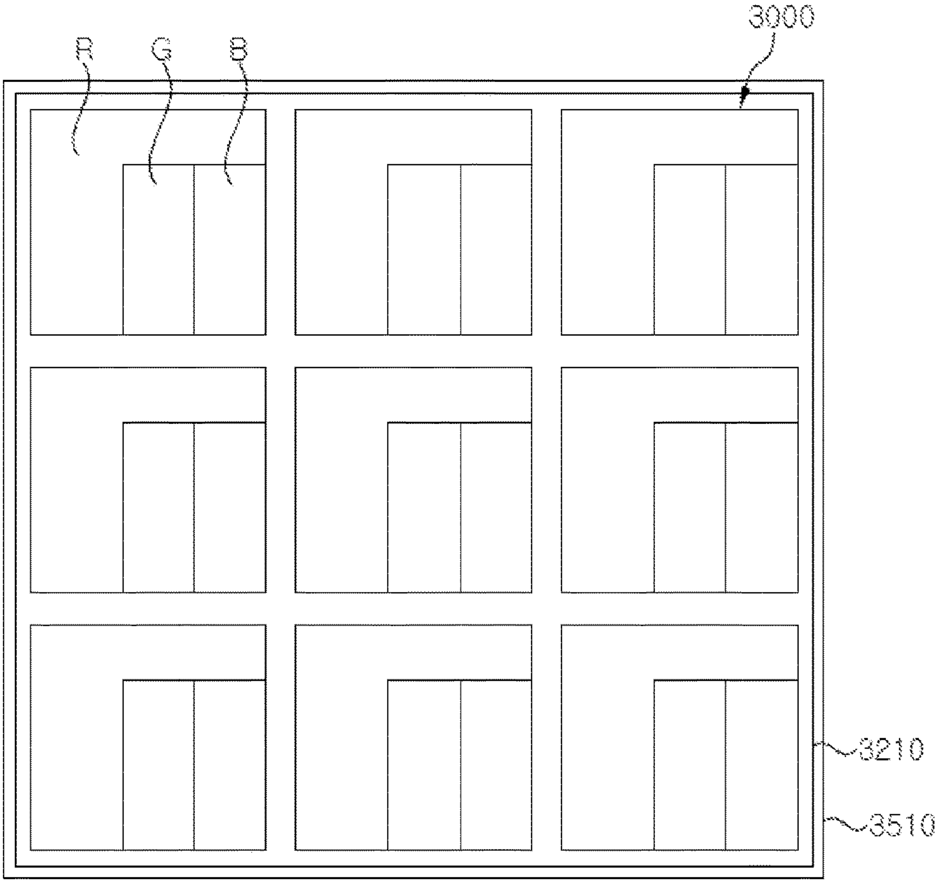


FIG. 57

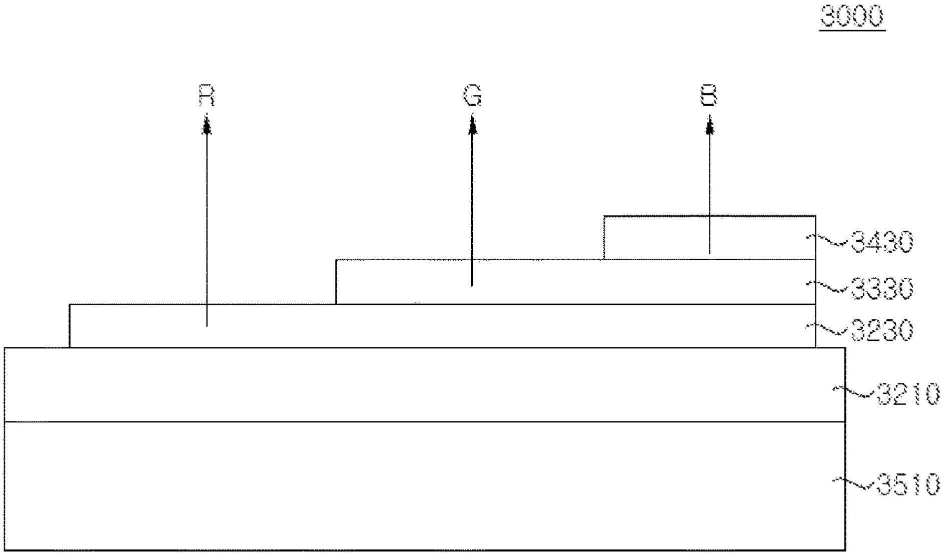


FIG. 58

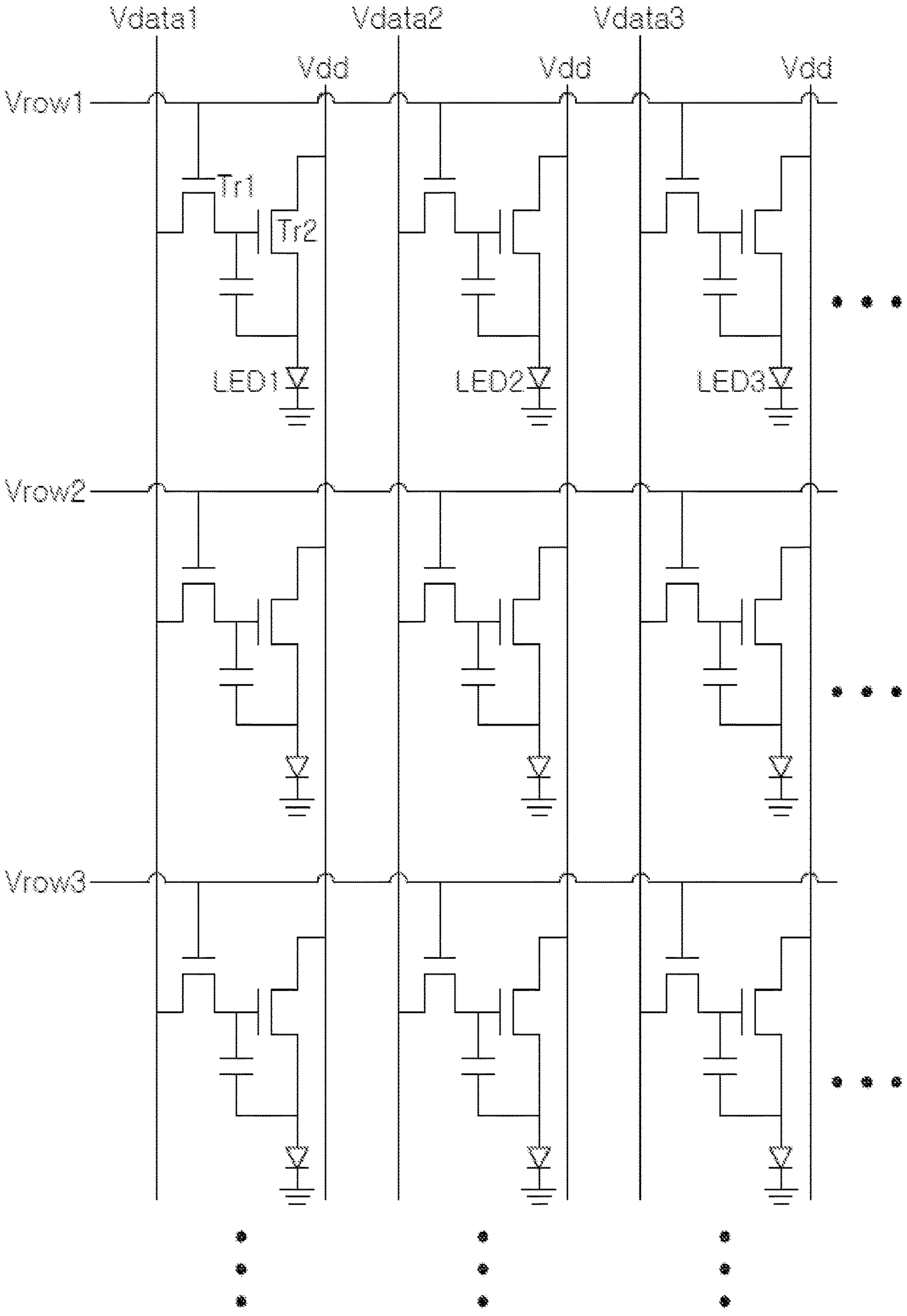

Vdata1
Vdata2
Vdata3
Vdd
Vdd
Vdd
Vrow1
Tr1
Tr2
LED1
LED2
LED3
Vrow2
Vrow3

FIG. 59A

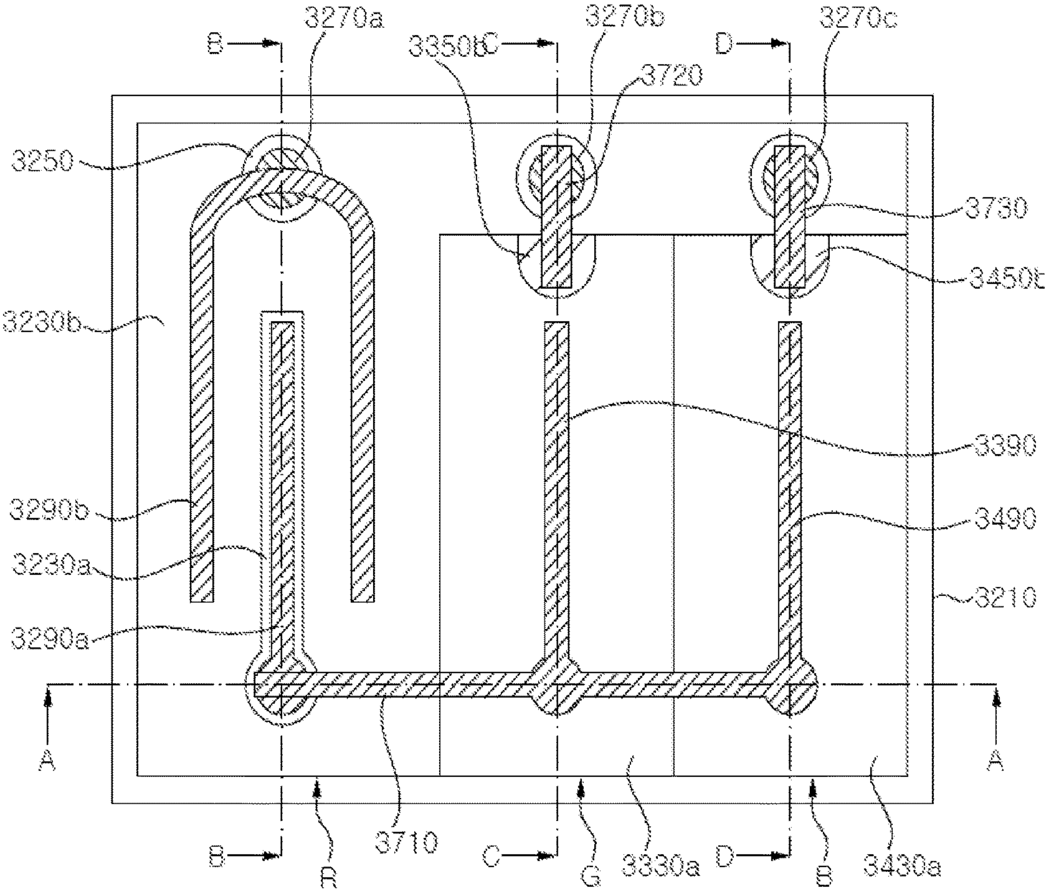

3270a
B
B
3350b
C
C
3270b
3720
D
D
3270c
3250
3730
3450b
3230b
3390
3290b
3490
3230a
3210
3290a
A
A
B
B
3710
R
C
C
G
3330a
D
D
B
3430a

FIG. 59B

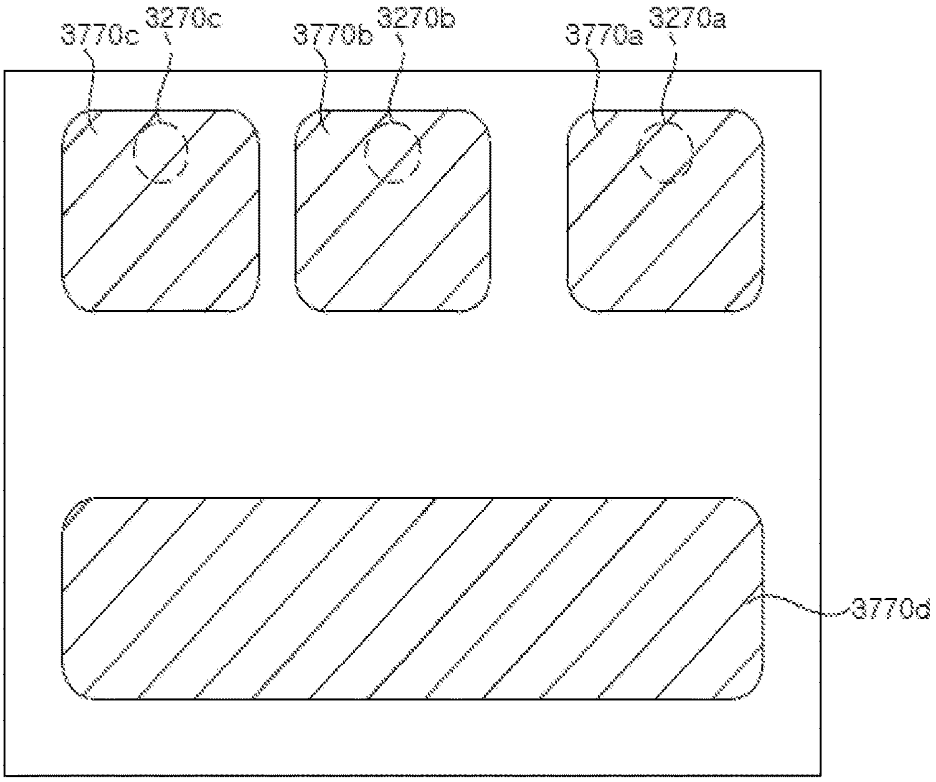


FIG. 60A

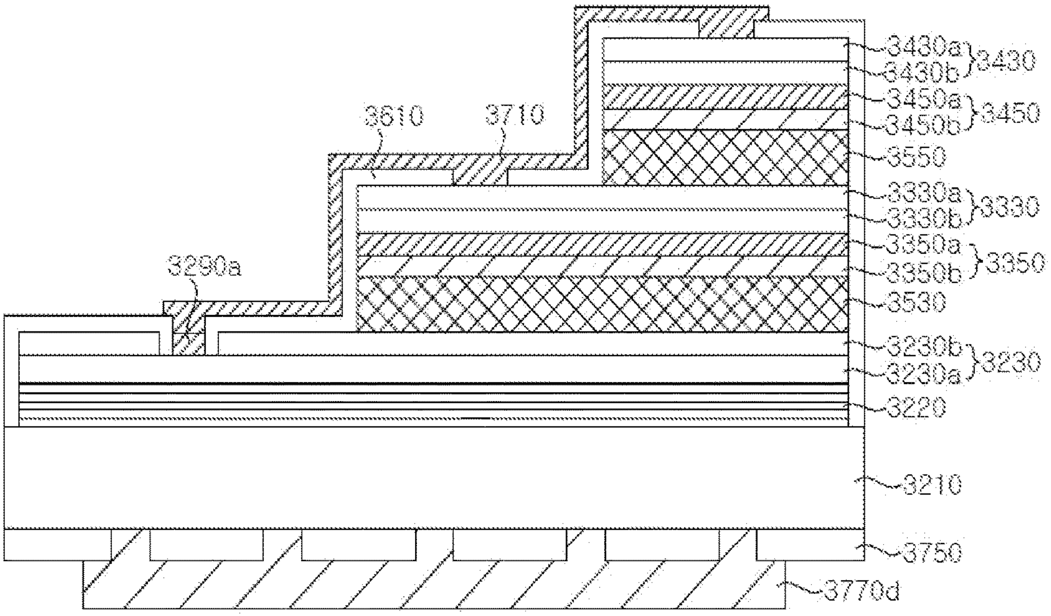


FIG. 60B

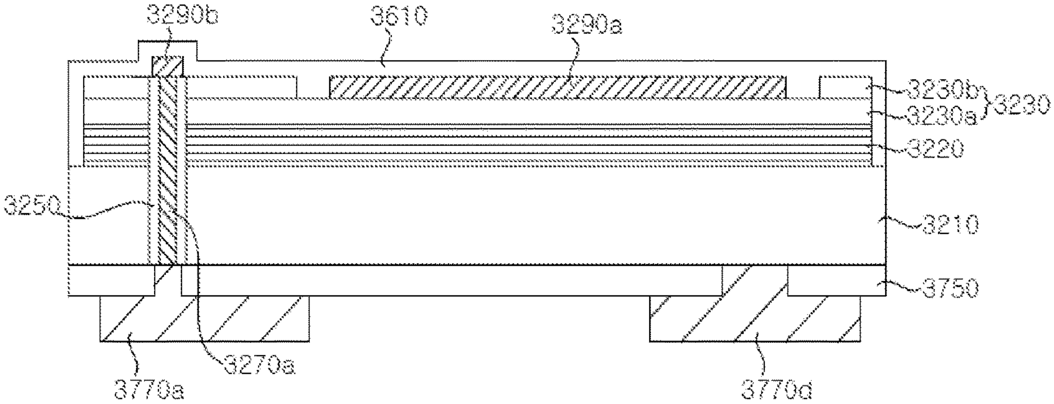


FIG. 60C

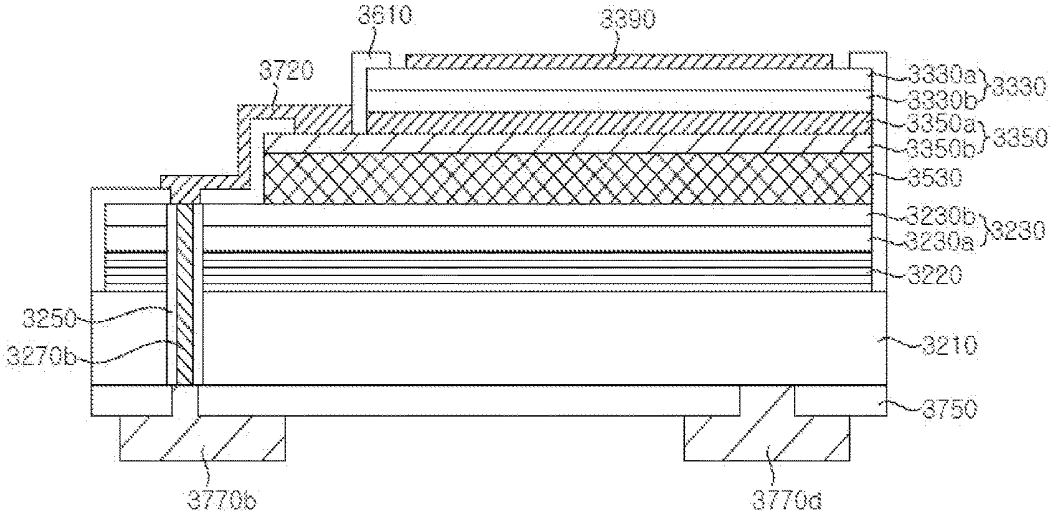


FIG. 60D

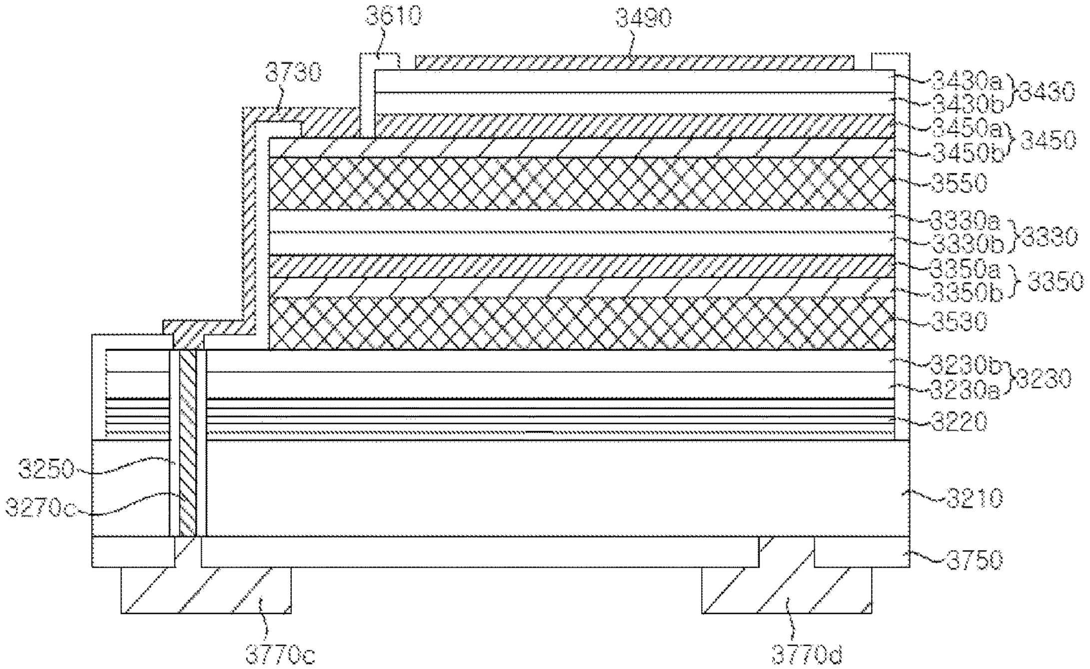


FIG. 61A

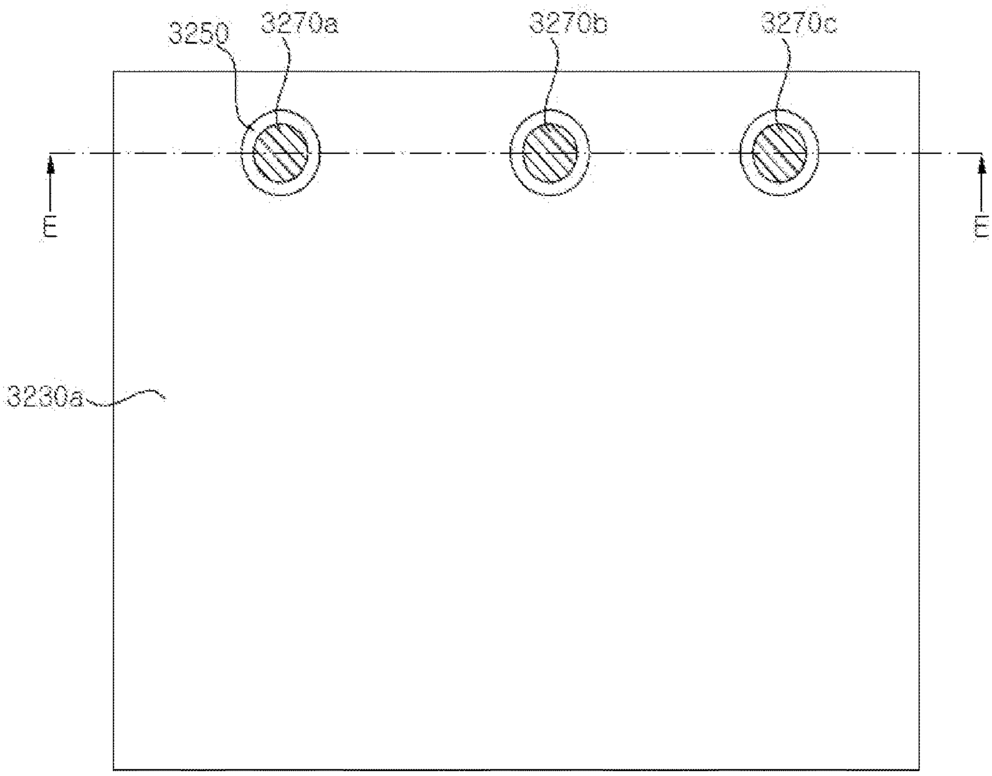


FIG. 61B

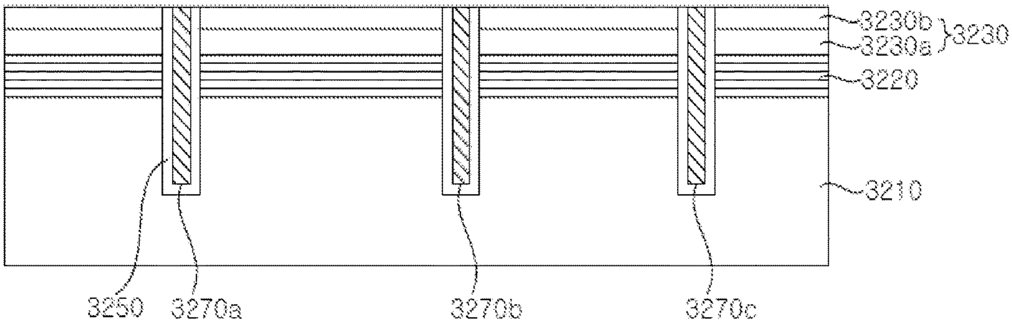


FIG. 62A

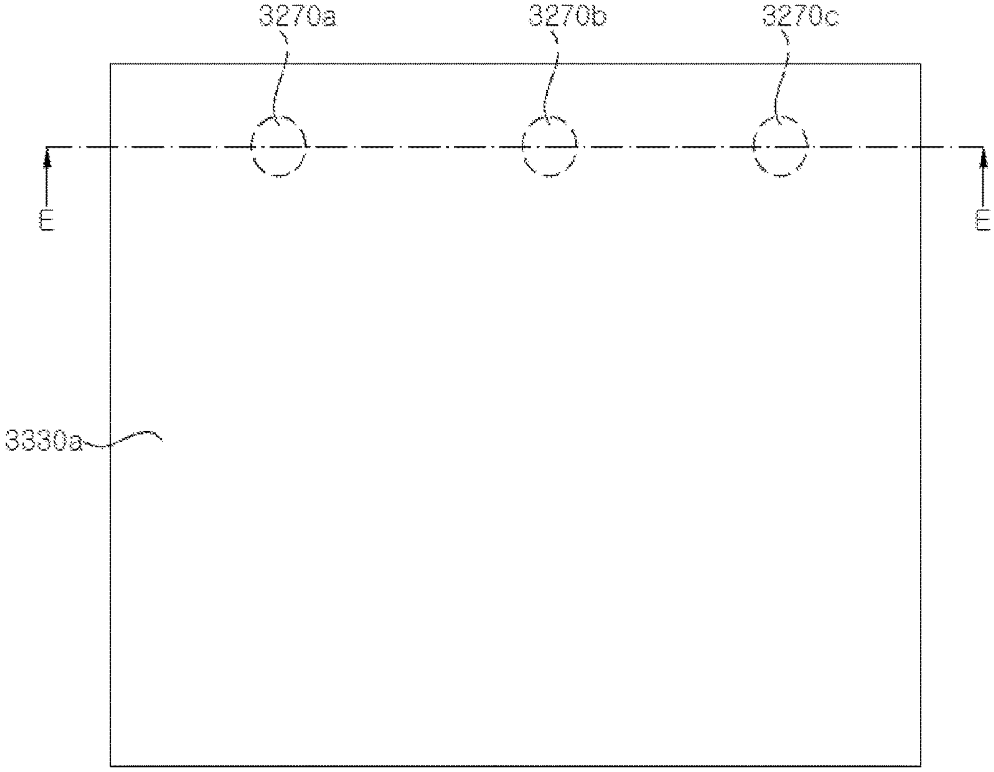


FIG. 62B

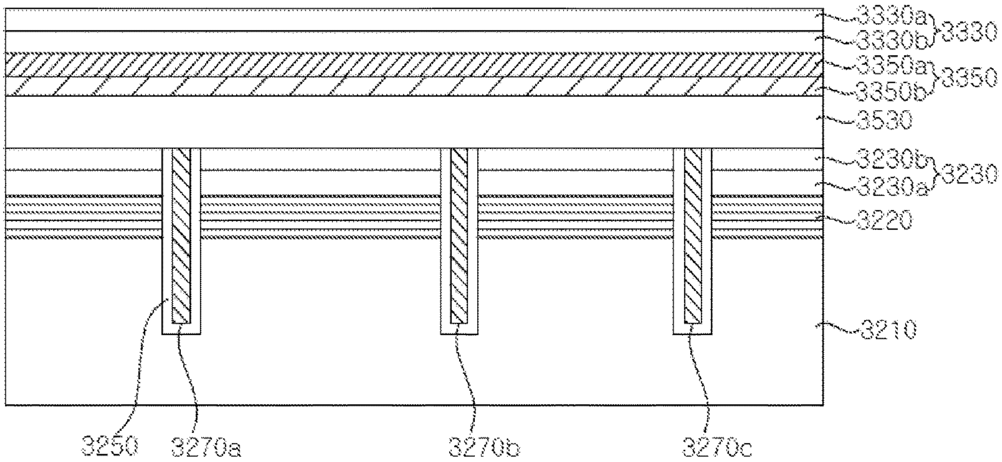


FIG. 63A

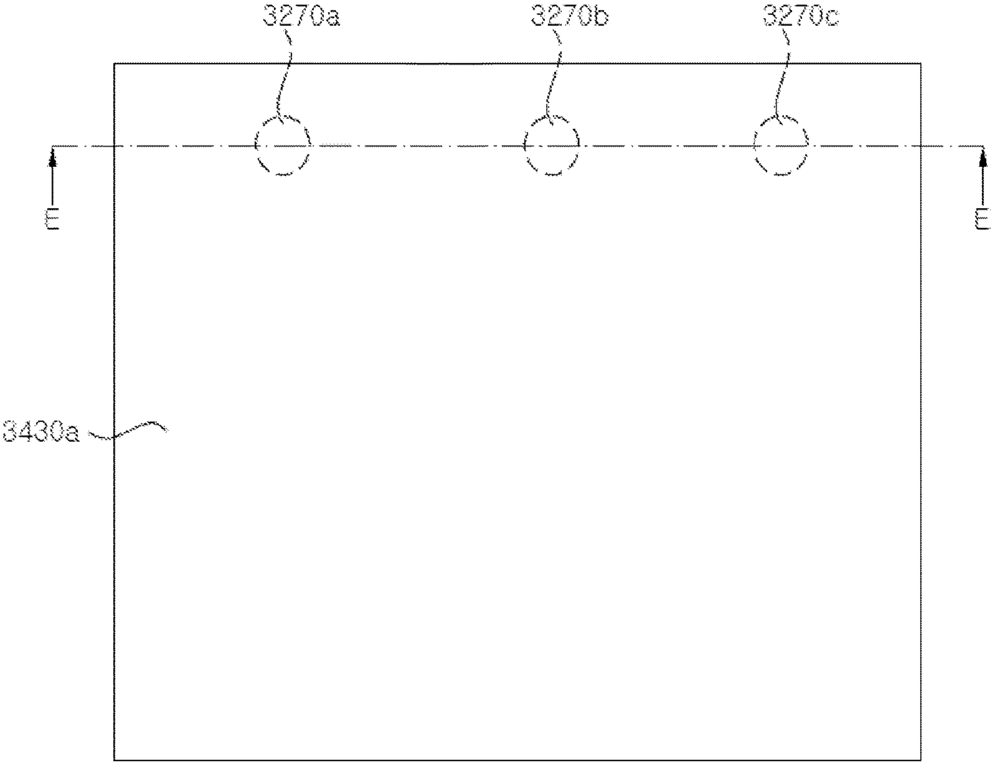


FIG. 63B

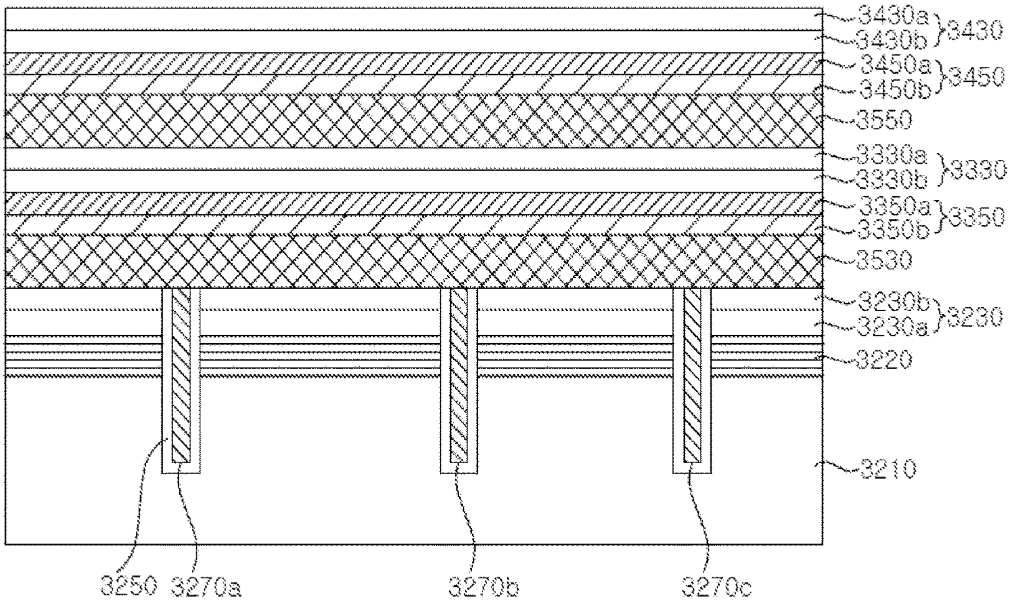


FIG. 64A

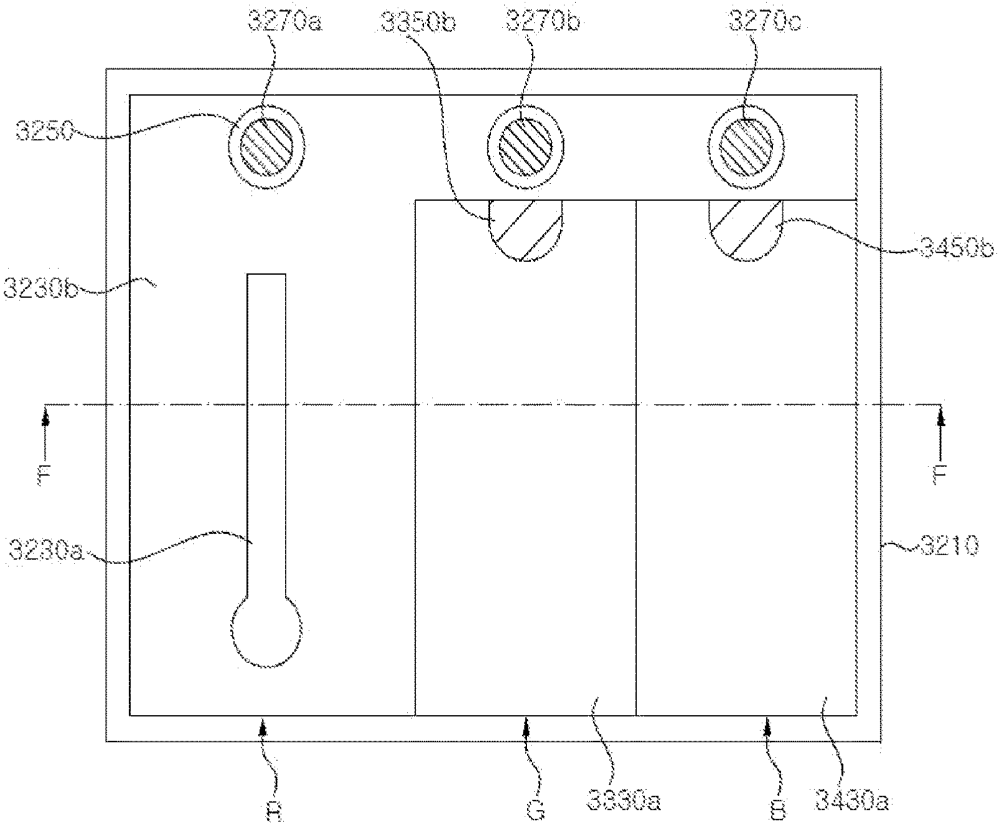


FIG. 64B

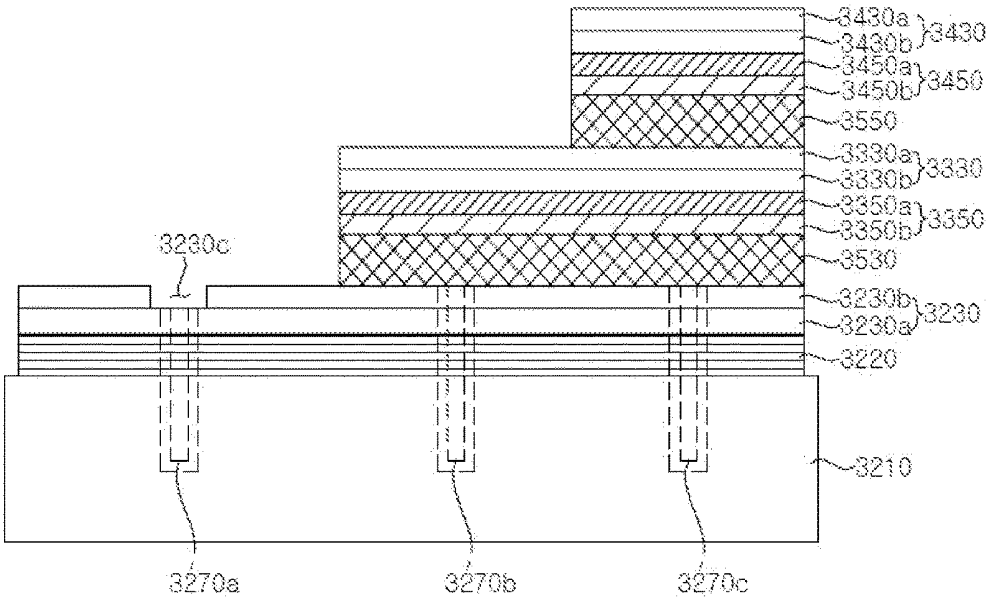


FIG. 65A

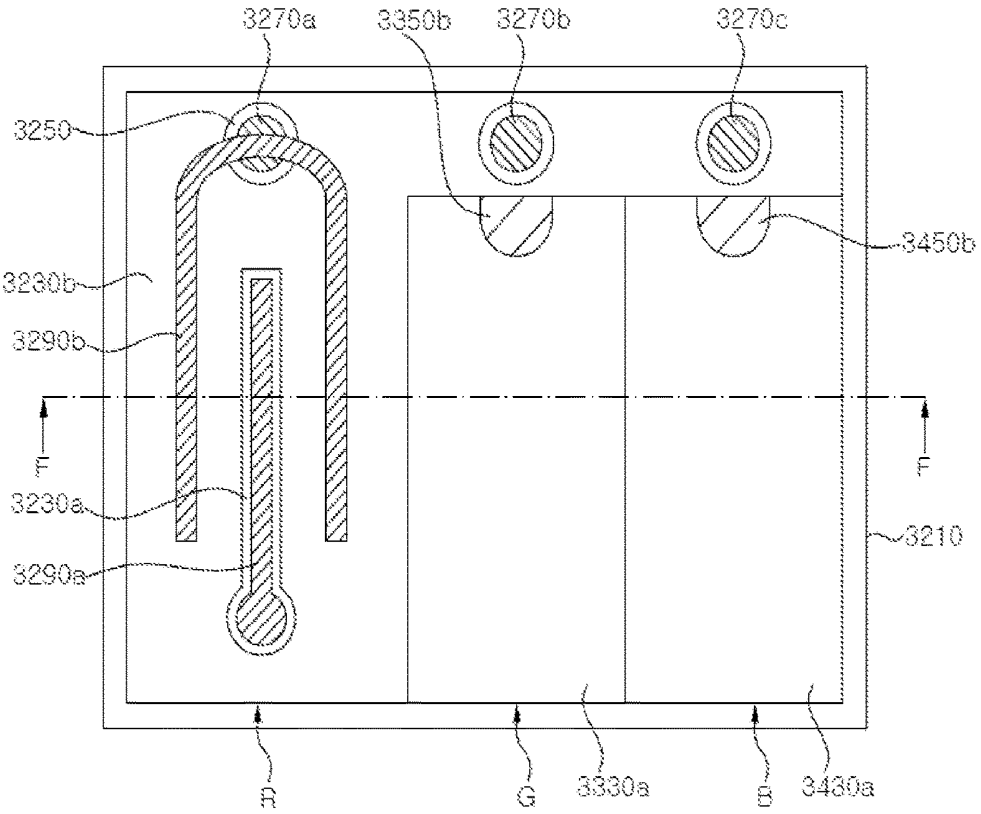


FIG. 65B

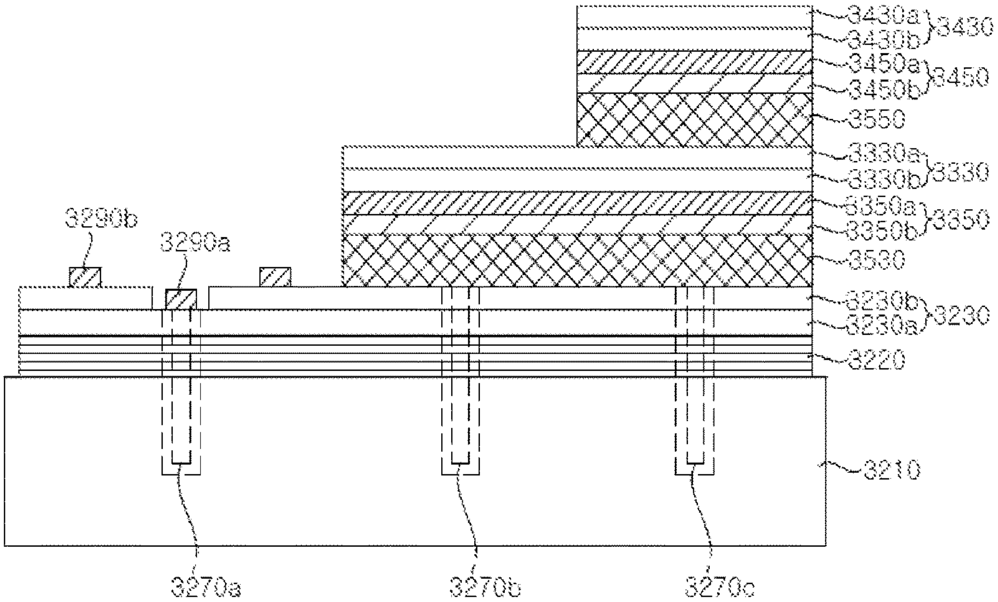


FIG. 66A

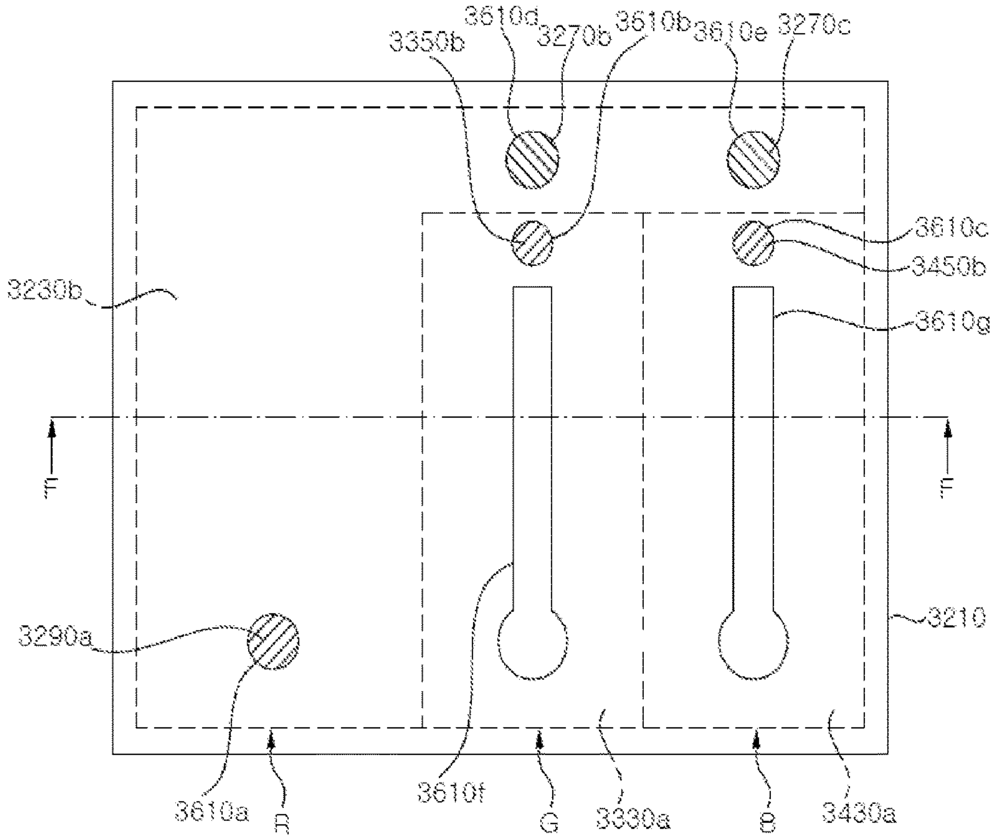


FIG. 66B

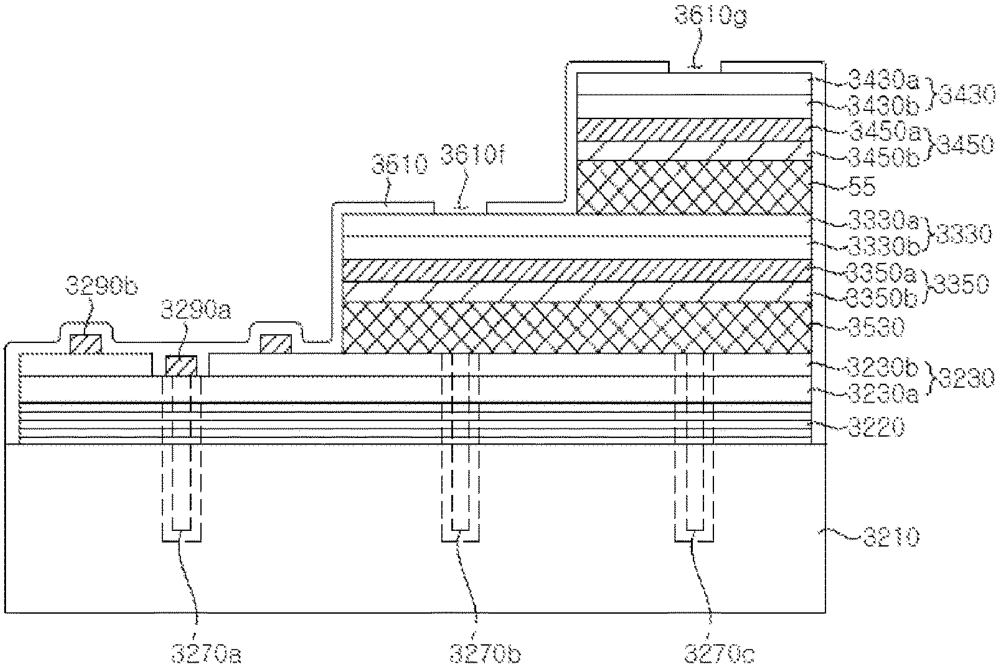


FIG. 67A

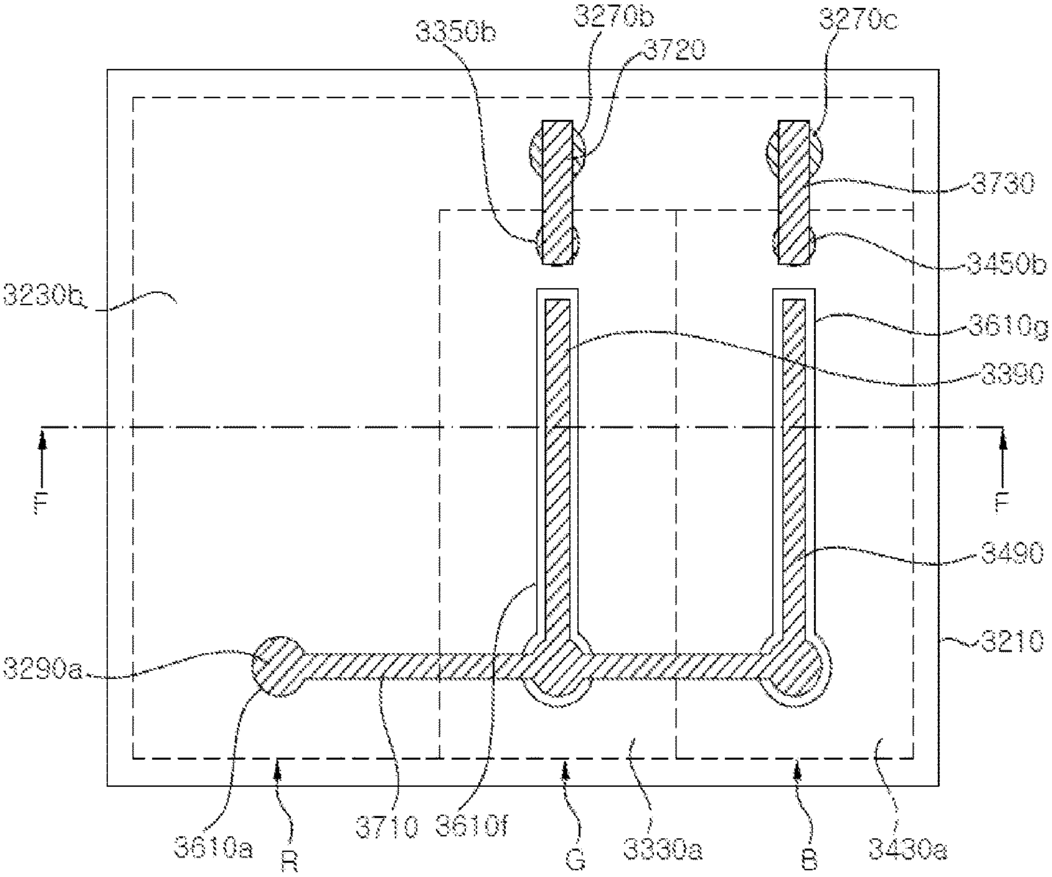


FIG. 67B

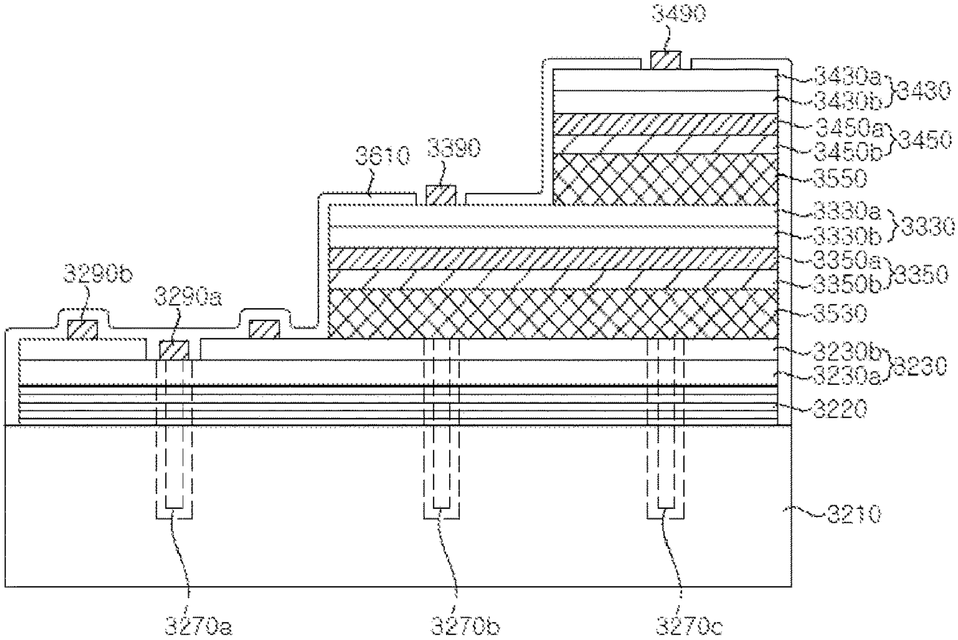


FIG. 68A

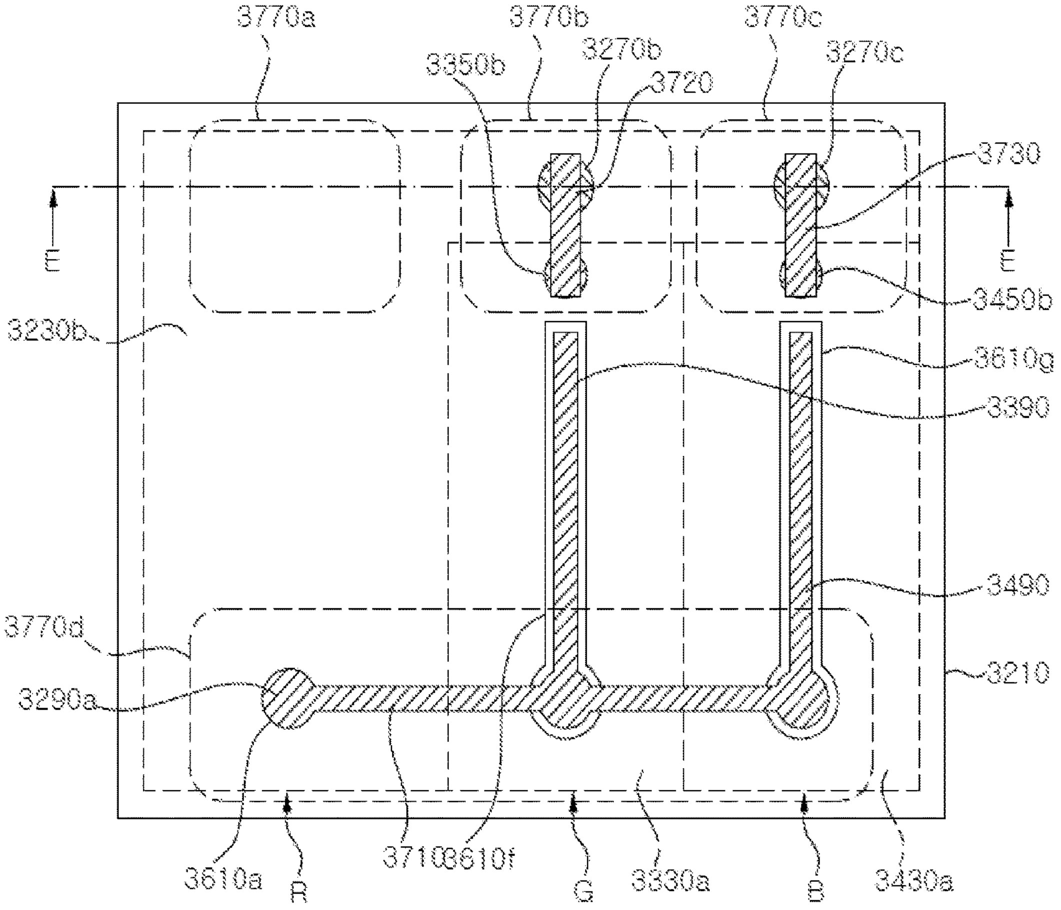


FIG. 68B

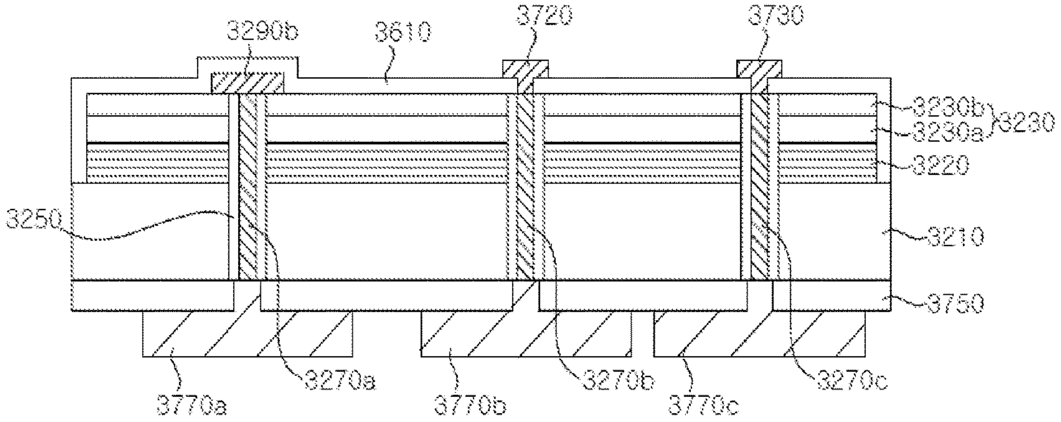


FIG. 69

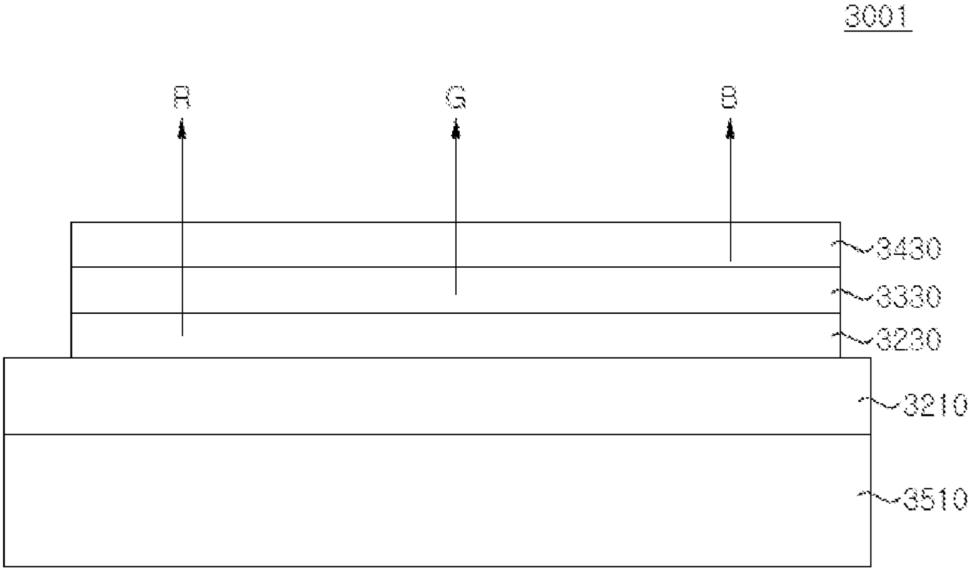

3001
R
G
B
3430
3330
3230
3210
3510

FIG. 70

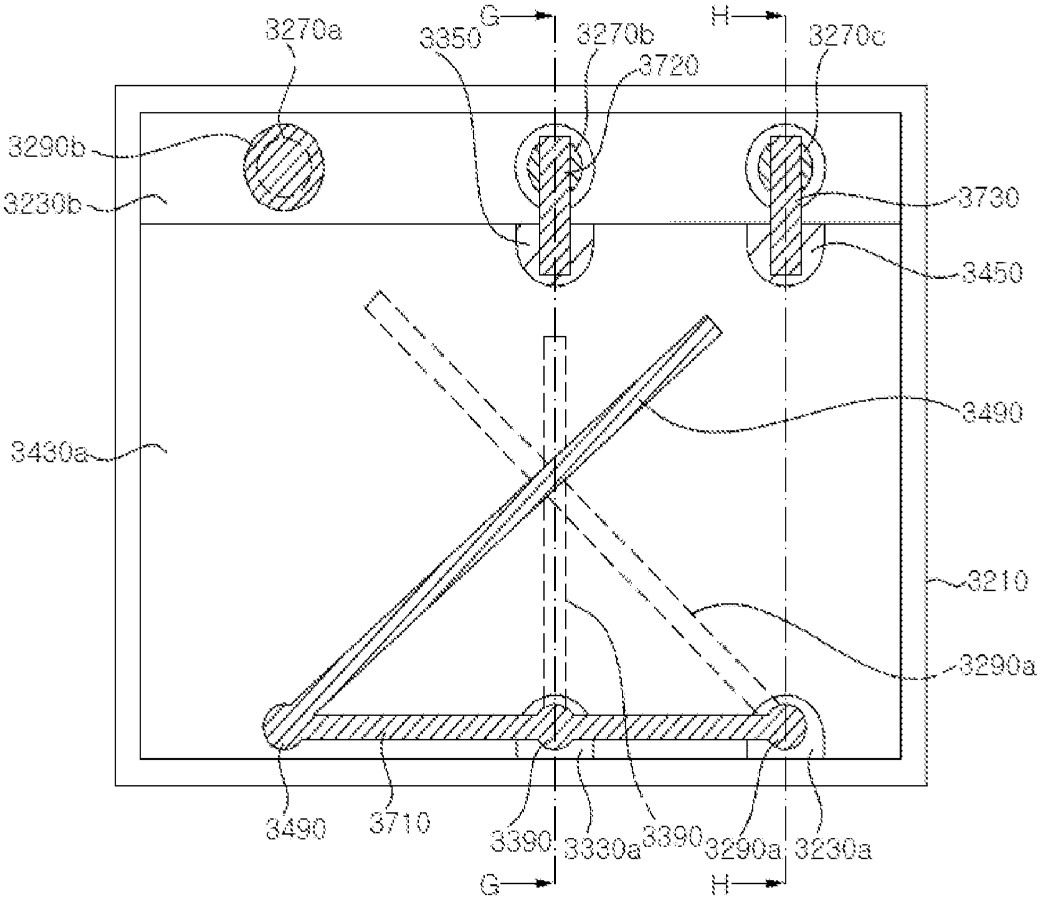

G
H
3270a
3350
3270b
3720
3270c
3290b
3230b
3730
3450
3490
3430a
3210
3290a
3490
3710
3390
3330a
3390
3290a
3230a
G
H

FIG. 71A

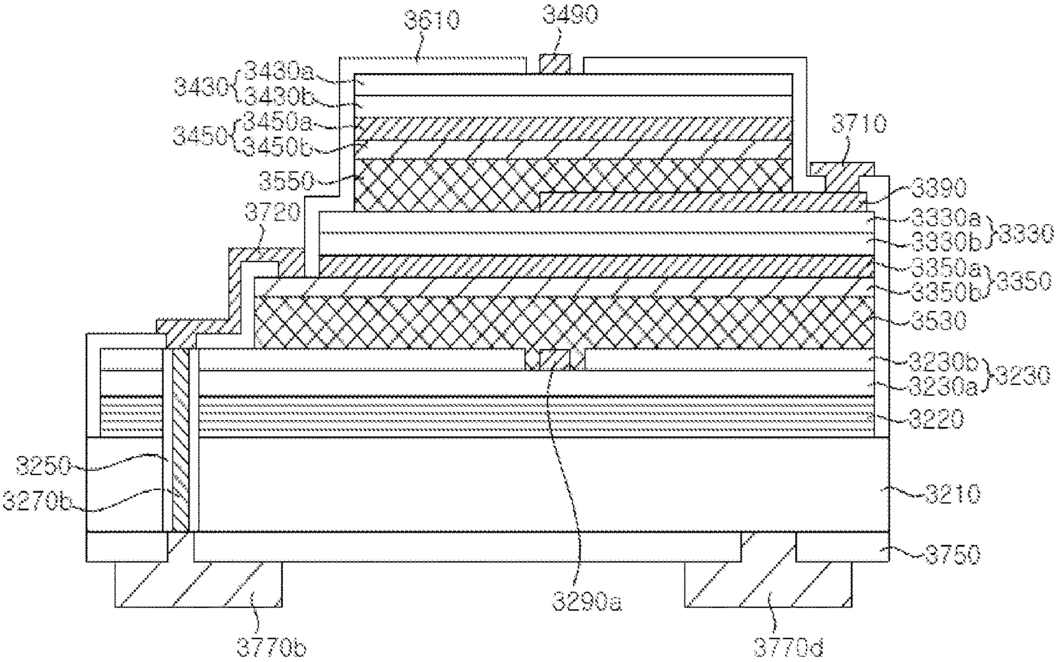
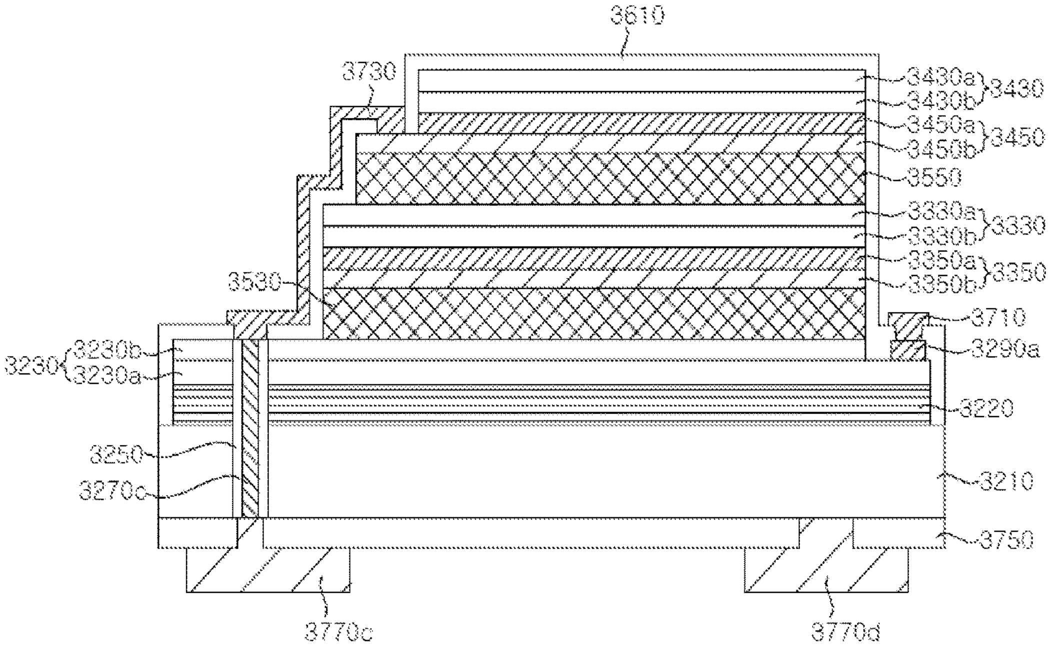


FIG. 71B



LED UNIT FOR DISPLAY AND DISPLAY APPARATUS HAVING THE SAME

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Patent Application No. 62/590,810, filed on Nov. 27, 2017, United States Provisional Patent Application No. 62/590,854, filed on Nov. 27, 2017, U.S. Provisional Patent Application No. 62/590,870, filed on Nov. 27, 2017, U.S. Provisional Patent Application No. 62/621,503, filed on Jan. 24, 2018, and U.S. Provisional Patent Application No. 62/635,284, filed on Feb. 26, 2018, the disclosures of which are hereby incorporated by reference for all purposes as if fully set forth herein.

BACKGROUND

Field

[0002] Exemplary implementations of the invention relate generally to light emitting diodes and, more particularly, to a micro light emitting diode ("micro LED") for a next generation display and a display apparatus including the same.

Discussion of the Background

[0003] A light emitting diode (LED) has been used as an inorganic light source in a wide range of fields, such as a display apparatus, an automotive lamp, general lighting, and the like. The light emitting diode is rapidly replacing the existing light sources due to its longer lifetime, lower power consumption, and faster rapid response.

[0004] A typical light emitting diode has been generally used as a backlight light source in a display apparatus. However, recently, micro LEDs have been developed as a next generation display that is capable of implementing images directly from the light emitting diodes.

[0005] In general, a display apparatus implements various colors by using mixed colors of blue, green, and red. As such, each pixel of the display apparatus includes blue, green, and red sub-pixels, and the color of the specific pixel is determined through the color of these sub-pixels, and an image is implemented by a combination of these pixels.

[0006] In a micro LED display, the micro LEDs are arranged on a two-dimensional plane correspond to each pixel, and thus, a large number of micro LEDs need to be disposed on one substrate, typically in the millions or tens of millions. However, the small form factor of the micro LED, which generally has a surface area of about 10,000 square micrometers or less, may cause various problems during manufacture of a display apparatus. For example, handling a micro LED is difficult, and thus, it is difficult to mount the micro LEDs on a display panel, particularly when millions are required to be transferred to make a single display. In addition, it is difficult to replace a defective micro LED once the micro LED is mounted on the display panel.

[0007] Further, since the sub-pixels are arranged on a two-dimensional plane, an area occupied by one pixel that includes blue, green, and red sub-pixels is relatively large. As such, arranging the sub-pixels within a limited area may require reducing the area of each sub-pixel, which in turn may deteriorate brightness of the sub-pixels due to reduction of luminous areas.

[0008] The above information disclosed in this Background section is only for understanding of the background of the inventive concepts, and, therefore, it may contain information that does not constitute prior art.

SUMMARY

[0009] Light emitting diodes constructed according to the principles and some exemplary implementations of the invention and displays using the same are capable of increasing the light emitting area of each LED sub-pixel without increasing the corresponding surface area of the pixel area and without degrading display characteristics.

[0010] Light emitting diodes constructed according to the principles and some exemplary implementations of the invention and displays using the same have a sub-pixel structure in which at least two of the sub-pixels are vertically stacked, thereby reducing the surface area required to implement the display.

[0011] Light emitting diodes constructed according to the principles and some exemplary implementations of the invention and displays using the same have sub-pixels that may be independently driven.

[0012] Light emitting diodes constructed according to the principles and some exemplary implementations of the invention and displays using the same are particularly advantageous when constructed as micro LEDs. For example, micro LEDs constructed according to the principles and some exemplary implementations of the invention are capable of being simultaneously manufactured in a plurality on a wafer level, and thus obviate the need to individually mount the micro LEDS.

[0013] Light emitting diodes constructed according to the principles and some exemplary implementations of the invention and displays using the same advantageously employ a partial reflective layer between the red LED stack and the substrate, and/or control a bandgap of a semiconductor layer of each LED stack, to control the brightness of each LED stack of a pixel that uses the micro LEDs.

[0014] Additional features of the inventive concepts will be set forth in the description which follows, and in part will be apparent from the description, or may be learned by practice of the inventive concepts.

[0015] A light emitting diode (LED) stack for a display according to an exemplary embodiment includes a support substrate, a first LED sub-unit disposed on the support substrate, a second LED sub-unit disposed on the first LED sub-unit, a third LED sub-unit disposed on the second LED sub-unit, a first color filter interposed between the first LED sub-unit and the second LED sub-unit, and configured to transmit light generated in the first LED sub-unit and to reflect light generated in the second LED sub-unit, and a second color filter interposed between the second LED sub-unit and the third LED sub-unit, and configured to transmit light generated in the first and second LED sub-units and to reflect light generated in the third LED sub-unit, in which the second LED sub-unit and the third LED sub-unit are configured to transmit light generated in the first LED sub-unit, and third LED sub-unit is configured to transmit light generated in the second LED sub-unit.

[0016] The first, second, and third LED sub-units may include first, second, and third LED stacks, respectively.

[0017] The LED stack may include a micro LED having a surface area less than about 10,000 square μm.

[0018] The second LED sub-unit and the third LED sub-unit may be configured to transmit light generated in the first LED sub-unit to the outside of the micro LED stack, and third LED sub-unit may be configured to transmit light generated in the second LED sub-unit to the outside of the micro LED stack.

[0019] The first, second, and third LED stacks may be configured to emit red light, green light, and blue light, respectively.

[0020] The first color filter and the second color filter may include at least one of a low pass filter, a band pass filter, and a band stop filter, respectively.

[0021] The first color filter and the second color filter may include a distributed Bragg reflector.

[0022] The LED stack for a display may further include a first bonding layer interposed between the support substrate and the first LED stack, a second bonding layer interposed between the first LED stack and the first color filter, and a third bonding layer interposed between the second LED stack and the second color filter, in which the second bonding layer is configured to transmit light generated in the first LED stack, and the third bonding layer is configured to transmit light generated in the first LED stack and the second LED stack.

[0023] The first bonding layer, the second bonding layer, and the third bonding layer may include at least one of a transparent inorganic insulating film, a transparent organic insulating film, and a transparent conductive thin film.

[0024] The LED stack for a display may further include a first reflective electrode disposed between the first bonding layer and the first LED stack and in ohmic contact with a p-type semiconductor layer of the first LED stack, a second transparent electrode disposed between the first color filter and the second LED stack and in ohmic contact with a p-type semiconductor layer of the second LED stack, and a third transparent electrode disposed between the second color filter and the third LED stack and in ohmic contact with a p-type semiconductor layer of the third LED stack, in which the second transparent electrode and the third transparent electrode are configured to transmit light generated in the first LED stack to the outside, and the third transparent electrode is configured to transmit light generated in the second LED stack to the outside.

[0025] The second bonding layer may be in contact with an n-type semiconductor layer of the first LED stack, and the third bonding layer may be in contact with an n-type semiconductor layer of the second LED stack.

[0026] The LED stack for a display may further include a first bonding layer interposed between the support substrate and the first LED stack, a second bonding layer interposed between the first color filter and the second LED stack, and a third bonding layer interposed between the second LED stack and the second color filter, in which the second bonding layer and the third bonding layer are configured to transmit light generated in the first LED stack and the second LED stack.

[0027] The LED stack for a display may further include a first reflective electrode disposed between the first bonding layer and the first LED stack and in ohmic contact with an n-type semiconductor layer of the first LED stack, a first transparent electrode disposed between the first LED stack and the first color filter and in ohmic contact with a p-type semiconductor layer of the first LED stack, a second transparent electrode disposed between the second LED stack and the third bonding layer and in ohmic contact with a p-type semiconductor layer of the second LED stack, and a third transparent electrode disposed between the second color filter and the third LED stack and in ohmic contact with a p-type semiconductor layer of the third LED stack, in which the first, second, and third transparent electrodes are configured to trasmit light generated in the first LED stack to the outside, and the second and third transparent electrodes are configured to transmit light generated in the second LED stack to the outside.

[0028] The LED stack for a display may further include a second reflective electrode disposed between the second bonding layer and the second LED stack, in which the second transparent electrode is in ohmic contact with an n-type semiconductor layer of the second LED stack.

[0029] A display apparatus may include a plurality of pixels arranged on a support substrate, in which at least some of the pixels include the LED stack according to an exemplary embodiment.

[0030] Each of the first, second, and third LED stacks may include a p-type semiconductor layer and an n-type semiconductor layer, the p-type semiconductor layers of each pixel may be electrically connected to a common line, and the n-type semiconductor layers of each pixel may be electrically connected to different lines from each other.

[0031] The common line may include a data line and the different lines may include scan lines.

[0032] The display apparatus may further include a lower insulating layer covering side surfaces of the first, second, and third LED stacks, in which the lower insulating layer has an opening that exposes a portion of the first, second, and third LED stacks.

[0033] The lower insulating layer may include a distributed Bragg reflector configured to reflect red light, green light, and blue light.

[0034] The display apparatus may further include a reflective electrode disposed between the support substrate and the first LED stack, in which the reflective electrode includes the common line is continuously disposed over the plurality of pixels.

[0035] The display apparatus may further include a plurality of reflective electrodes disposed between the support substrate and the first LED stack, in which each reflective electrode is disposed within each pixel region.

[0036] The third LED stack may include a roughened surface region on an upper surface thereof.

[0037] The first, second, and third LED stacks of each pixel may be drivable independently.

[0038] An LED pixel for a display according to an exemplary embodiment includes a first LED sub-unit having a first surface and a second surface, a second LED sub-unit disposed on a portion of the first surface of the first LED sub-unit, a third LED sub-unit disposed on a portion of the second LED sub-unit, a reflective electrode disposed on the second surface of the first LED sub-unit, a second transparent electrode disposed between the second LED sub-unit and the third LED sub-unit, and in ohmic contact with an upper surface of the second LED sub-unit, and a third transparent electrode in ohmic contact with an upper surface of the third LED sub-unit, in which each of the first, second, and third LED sub-units includes an n-type semiconductor layer and a p-type semiconductor layer, each of the the n-type semiconductor layers of the first, second, and third LED sub-units is electrically connected to the reflective electrode, and the first LED sub-unit, the second LED sub-unit, and the third LED sub-unit are independently drivable.

[0039] The first, second, and third LED sub-units may include first, second, and third LED stacks, respectively.

[0040] The LED pixel may include a micro LED having a surface area less than about 10,000 square μm.

[0041] The first LED stack, the second LED stack, and the third LED stack may be configured to emit red light, green light, and blue light, respectively.

[0042] A first portion of light generated in the first LED stack may be configured to be emitted to the outside without passing through the second LED stack, a second portion of light generated in the first LED stack may be configured to be emitted to the outside by transmitting through the second LED stack and the second transparent electrode, a third portion of light generated in the first LED stack may be configured to be emitted to the outside by transmitting through the second LED stack, the second transparent electrode, the third LED stack, and the third transparent electrode, a first portion of light generated in the second LED stack may be configured to be emitted to the outside without passing through the third LED stack, and a second portion of light genereated in the second LED stack may be configured to be emitted to the outside by transmitting through the third LED stack and the third transparent electrode.

[0043] Each of the p-type semiconductor layers of the first, second, and third LED stacks may be disposed on corresponding n-type semiconductor layer, the reflective electrode may be in ohmic contact with the n-type semiconductor layer of the first LED stack, and the second transparent electrode and the third transparent electrode may be in ohmic contact with the p-type semiconductor layers of the second LED stack and the third LED stack, respectively.

[0044] The LED pixel for a display may further include a first color filter interposed between the first LED stack and the second LED stack, and a second color filter interposed between the second LED stack and the third LED stack, in which the first color filter is configured to transmit light generated in the first LED stack and reflect light generated in the second LED stack, and the second color filter is configured to transmit light generated in the second LED stack and reflect light generated in the third LED stack.

[0045] The first color filter may contact the n-type semiconductor layer of the second LED stack, and the second color filter may contact the n-type semiconductor layer of the third LED stack.

[0046] The LED pixel for a display may further include a first bonding layer interposed between the first LED stack and the first color filter, and a second bonding layer interposed between the second LED stack and the second color filter, in which the second bonding layer is configured to transmit light generated in the first LED stack and the third bonding layer is configured to transmit light generated in the second LED stack.

[0047] The LED pixel for a display may further include a first ohmic electrode in ohmic contact with the p-type semiconductor layer of the first LED stack, a second ohmic electrode in contact with the n-type semiconductor layer of the second LED stack, a third ohmic electrode in contact with the n-type semiconductor layer of the third LED stack, a second current spreading layer disposed on the second transparent electrode, and a third current spreading layer disposed on the third transparent electrode, in which the second ohmic electrode is disposed on a portion of the n-type semiconductor layer of the second LED stack not overlapping the third LED stack, and the second current spreading layer is disposed on the second transparent electrode.

[0048] The third ohmic electrode and the third current spreading layer may include the same material.

[0049] The second ohmic electrode, the second current spreading layer, the third ohmic electrode, and the third current spreading layer c may include the same material.

[0050] The LED pixel for a display may further include a first current spreading layer disposed on the first ohmic electrode, in which the first ohmic electrode is transparent, and the first, second, and third current spreading layers comprise the same material.

[0051] A display apparatus may include a plurality of pixels arranged on a support substrate, in which at least some of the pixels include the LED pixel according to an exemplary embodiment.

[0052] Each of the p-type semiconductor layers of the first, second, and third LED stacks may be electrically connected to different lines from each other.

[0053] An LED stack for a display according to an exemplary embodiment includes a first LED sub-unit having a first surface and a second surface, a second LED sub-unit disposed on the first surface of the first LED sub-unit, a third LED sub-unit disposed on the second LED sub-unit, a reflective electrode disposed on the second side of the second LED sub-unit and forming ohmic contact with the first LED sub-unit, and an ohmic electrode interposed between the first LED sub-unit and the second LED sub-unit and forming ohmic contact with the first LED sub-unit, in which the second LED sub-unit and the third LED sub-unit are configured to transmit light generated from the first LED sub-unit, and the third LED sub-unit is configured to transmit light generated from the second LED sub-unit.

[0054] The first, second, and third LED sub-units may include first, second, and third LED stacks, respectively.

[0055] The LED stack may include a micro LED having a surface area less than about 10,000 square μm.

[0056] The reflective electrode and the ohmic electrode may have different reflective indices from each other.

[0057] The first, second, and third LED stacks may be configured to emit red light, green light, and blue light, respectively.

[0058] The LED stack for a display may further include a first color filter interposed between the first LED stack and the second LED stack, and configured to transmit light generated from the first LED stack and reflect light generated from the second LED stack, and a second color filter interposed between the second LED stack and the third LED stack, and configured to transmit light generated from the first and second LED stacks and reflect light generated from the third LED stack.

[0059] Each of the first color filter and the second color filter may include at least one of a low pass filter, a band pass filter, and a band stop filter.

[0060] Each of the first and second color filters may include a distributed Bragg reflector.

[0061] The LED stack for a display may further include a support substrate, a first bonding layer interposed between the support substrate and the first LED stack, a second bonding layer interposed between the first LED stack and the second LED stack, and a third bonding layer interposed between the second LED stack and the third LED stack, in which the second bonding layer is configured to transmit light generated from the first LED stack, and the third bonding layer is configured to transmit light generated from the first and second LED stacks.

[0062] The first bonding layer may adjoin the reflective electrode, and the second bonding layer may adjoin the ohmic electrode.

[0063] The LED stack for a display may further include a second transparent electrode forming ohmic contact with a p-type semiconductor layer of the second LED stack, and a third-p transparent electrode forming ohmic contact with a p-type semiconductor layer of the third LED stack.

[0064] The second bonding layer may adjoin an n-type semiconductor layer of the first LED stack, and the third bonding layer may adjoin an n-type semiconductor layer of the second LED stack.

[0065] The LED stack for a display may further include a first color filter interposed between the first LED stack and the second LED stack and configured to transmit light generated from the first LED stack and reflect light generated from the second LED stack, and a second color filter interposed between the second LED stack and the third LED stack, and configured to transmit light generated from the first and second LED stacks and reflect light generated from the third LED stack, in which the first color filter is disposed on the second bonding layer and the second color filter is disposed on the third bonding layer.

[0066] A display apparatus may include a plurality of pixels arranged on a support substrate, in which at least some of the pixels include the LED stack according to an exemplary embodiment.

[0067] Each of the first, second, and third LED stacks may include a p-type semiconductor layer and an n-type semiconductor layer, each of the p-type semiconductor layers of the first, second, and third LED stacks may be electrically connected to a common line, and each of the n-type semiconductor layers of the first, second, and third LED stacks may be electrically connected to different lines from each other.

[0068] The common line may include a data line and the different lines may include scan lines.

[0069] The display apparatus may further include a lower insulation layer covering side surfaces of the first, second, and third LED stacks, the lower insulation layer including openings exposing the ohmic electrode, the reflective electrode, the second LED stack, and the third LED stack.

[0070] The lower insulation layer may include a distributed Bragg reflector configured to reflect red, green, and blue light.

[0071] The reflective electrode may include the common line and may be continuously disposed over the plurality of pixels.

[0072] The reflective electrode may be disposed within each pixel region.

[0073] An LED stack for a display according to an exemplary embodiment includes a first LED sub-unit configured to emit a first colored light, a second LED sub-unit disposed on the first LED stack and configured to emit a second colored light, and a third LED sub-unit disposed on at least one of the first LED sub-unit and the second LED sub-unit and configured to emit a third colored light, in which the first LED sub-unit is configured to emit light through the second LED sub-unit and the third LED sub-unit, and the second LED sub-unit is configured to emit light through the third LED sub-unit.

[0074] The first, second, and third LED sub-units may include first, second, and third LED stacks, respectively.

[0075] The LED stack may include a micro LED having a surface area less than about 10,000 square μm.

[0076] The first colored light may have a longer wavelength than the second colored light, and the second colored light may have a longer wavelength than the third colored light.

[0077] The first, second, and third colored light may be red light, green light, and blue light, respectively.

[0078] The first LED stack may be configured to generate light when a portion of the second colored light is incident thereon, and the second LED stack may be configured to generate light when a portion of the third colored light is incident thereon.

[0079] The intensity of the second colored light emitted to the outside may be at least about 10 times than the intensity of the first colored light emitted caused by the second colored light, and the intensity of the third colored light emitted to the outside may be at least about 10 times than the intensity of the second colored light caused by the third colored light.

[0080] The LED stack for a display may further include a support substrate, a reflective electrode interposed between the first LED stack and the support substrate, and forming ohmic contact with the first LED stack, and an ohmic electrode interposed between the first LED stack and the second LED stack, and forming ohmic contact with the first LED stack.

[0081] The LED stack for a display may further include a first bonding layer interposed between the support substrate and the first LED stack, a second bonding layer interposed between the first LED stack and the second LED stack, and a third bonding layer interposed between the second LED stack and the third LED stack, in which the second bonding layer is configured to transmit the first colored light and the third bonding layer is configured to transmit the first colored light and the second colored light.

[0082] The first bonding layer may adjoin the reflective electrode and the second bonding layer adjoins the ohmic electrode.

[0083] The LED stack for a display may further include a second transparent electrode forming ohmic contact with a p-type semiconductor layer of the second LED stack, and a third transparent electrode forming ohmic contact with a p-type semiconductor layer of the third LED stack.

[0084] The second bonding layer may adjoin an n-type semiconductor layer of the first LED stack and the third bonding layer adjoins an n-type semiconductor layer of the second LED stack.

[0085] A display apparatus may include a plurality of pixels arranged on the support substrate, in which at least some of the pixels include the LED stack according to an exemplary embodiment.

[0086] The first LED stack may have a first area, a second area, and a third area, the first area may not be overlapped by the second and third LED stacks in plan view, the second area may be overlapped by the second LED stack and not overlapped by the third LED stack in plan view, and the third area may be overlapped by both of the second and third LED stacks in plan view.

[0087] The first, second, and third LED stacks may have substantially the same width with each other in plan view.

[0088] The width of the first LED stack may be greater than the second or third LED stacks in plan view.

[0089] The display apparatus may further include a lower insulation layer covering side surfaces of the first, second, and third LED stacks, in which the lower insulation layer includes openings exposing an ohmic electrode, the reflective electrode, the second LED stack, and the third LED stack.

[0090] The lower insulation layer may include a distributed Bragg reflector configured to reflect red, green, and blue light.

[0091] Each of the first, second, and third LED stacks may include a p-type semiconductor layer and an n-type semiconductor layer, and each of the p-type semiconductor layers of the first, second, and third LED stacks may be electrically connected to a common line, and each of the n-type semiconductor layers of the first, second, and third LED stacks may be electrically connected to different lines from each other.

[0092] The reflective electrode may include the common line and may be continuously disposed over the plurality of pixels.

[0093] The reflective electrode may be disposed within each pixel region.

[0094] The first, second, and third LED stacks may be configured to be driven independently.

[0095] An LED pixel for a display according to an exemplary embodiment includes a substrate, a first LED sub-unit disposed on the substrate, a second LED sub-unit disposed on the first LED sub-unit, a third LED sub-unit disposed on at least one of the first and second LED sub-units, and vias in the substrate, in which each of the first, second, and third LED sub-units includes a first conductivity type semiconductor layer and a second conductivity type semiconductor layer, and each of the vias is electrically connected to at least one of the first, second, and third LED sub-units.

[0096] The first, second, and third LED sub-units may include first, second, and third LED stacks, respectively.

[0097] The LED pixel may include a micro LED having a surface area less than about 10,000 square μm.

[0098] The first LED stack, the second LED stack, and the third LED stack may be configured to emit light having different wavelengths with each other.

[0099] The first LED stack, the second LED stack, and the third LED stack may be configured to emit red light, green light, and blue light, respectively.

[0100] The substrate may include a GaAs substrate, and the first LED stack comprises AlGaInP-based semiconductor layers.

[0101] The LED pixel for a display may further include a distributed Bragg reflector interposed between the substrate and the first LED stack, in which the distributed Bragg reflector may include semiconductor layers.

[0102] The distributed Bragg reflector may include AlAs layers and AlGaAs layers alternately disposed with each other.

[0103] The LED pixel for a display may further include a first bonding layer interposed between the first LED stack and the second LED stack, and a second bonding layer interposed between the second LED stack and the third LED stack.

[0104] The LED pixel for a display may further include a lower second ohmic electrode interposed between the first bonding layer and the second LED stack, and forming ohmic contact with the second LED stack, and a lower third ohmic electrode interposed between the second bonding layer and the third LED stack, and forming ohmic contact with the third LED stack.

[0105] Each of the lower second ohmic electrode and the lower third ohmic electrode may include a reflective layer.

[0106] The vias may include first, second, and third vias, the first via may be electrically connected to the second conductivity type semiconductor layer of the first LED stack, the second via may be electrically connected to the second conductivity type semiconductor layer of the second LED stack, and the third via may be electrically connected to the second conductivity type semiconductor layer of the third LED stack.

[0107] The first conductivity type semiconductor layers of the first, second, and third LED stacks may be electrically connected to one another.

[0108] The LED for a display may further include an upper first ohmic electrode contacting the first conductivity type semiconductor layer of the first LED stack, a lower first ohmic electrode contacting the second conductivity type semiconductor layer of the first LED stack, an upper second ohmic electrode contacting the first conductivity type semiconductor layer of the second LED stack, a lower second ohmic electrode contacting the second conductivity type semiconductor layer of the second LED stack, an upper third ohmic electrode contacting the first conductivity type semiconductor layer of the third LED stack, and a lower third ohmic electrode contacting the second conductivity type semiconductor layer of the third LED stack, in which the first, second, and third vias are electrically connected to the lower first ohmic electrode, the lower second ohmic electrode, and the lower third ohmic electrode, respectively, and the upper first ohmic electrode, the upper second ohmic electrode, and the upper third ohmic electrode are electrically connected to each other.

[0109] The LED pixel for a display may further include bonding pads disposed on a lower surface of the substrate, in which the vias are connected to the bonding pads, respectively.

[0110] The bonding pads may include first bonding pads insulated from the substrate and at least one second bonding pad electrically connected to the substrate, and the vias may be electrically connected to the first bonding pads, respectively.

[0111] A display apparatus may include a circuit board and a plurality of pixels arranged on the circuit board, in which at least some of the pixels include the LED pixel according to an exemplary embodiment.

[0112] The circuit board may include at least one of a passive circuit and an active circuit, and the vias are electrically connected to the circuit board.

[0113] The substrate may be continuously disposed over the plurality of pixels and is connected to the ground through electrical connection to the circuit board.

[0114] The display apparatus may further include electrode pads interposed between the substrate and the circuit board, in which at least one of the electrode pads is electrically connected to the substrate, and the vias are electrically connected to the circuit board through the electrode pads.

[0115] It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and are intended to provide further explanation of the invention as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0116] The accompanying drawings, which are included to provide a further understanding of the invention and are incorporated in and constitute a part of this specification, illustrate exemplary embodiments of the invention, and together with the description serve to explain the inventive concepts.

[0117] FIG. **1** is a schematic cross-sectional view of a light emitting diode stack for a display according to an exemplary embodiment.

[0118] FIG. **2** is schematic cross-sectional views illustrating a manufacturing method of a light emitting diode stack for a display according to an exemplary embodiment.

[0119] FIG. **3** is a schematic circuit diagram a display apparatus according to an exemplary embodiment.

[0120] FIG. **4** is a schematic plan view of a display apparatus according to an exemplary embodiment.

[0121] FIG. **5** is an enlarged plan view of one pixel of the display apparatus of FIG. **4** according to an exemplary embodiment.

[0122] FIG. **6** is a schematic cross-sectional view taken along line A-A of FIG. **5**.

[0123] FIG. **7** is a schematic cross-sectional view taken along line B-B of FIG. **5**.

[0124] FIGS. **8**A, **8**B, **8**C, **8**D, **8**E, **8**F, **8**G, **8**H, **8**I, **8**J, and **8**K are schematic plan views illustrating a manufacturing method of a display apparatus according to an exemplary embodiment.

[0125] FIG. **9** is a schematic circuit diagram a display apparatus according to another exemplary embodiment.

[0126] FIG. **10** is a schematic plan view of a pixel according to another exemplary embodiment.

[0127] FIG. **11** is a schematic cross-sectional view of a light emitting diode stack for a display according to still another exemplary embodiment.

[0128] FIGS. **12**A, **12**B, **12**C, **12**D, **12**E, and **12**F are schematic cross-sectional views illustrating a manufacturing method of a light emitting diode stack for a display according to still another exemplary embodiment.

[0129] FIG. **13** is a schematic plan view of a display apparatus according to an exemplary embodiment.

[0130] FIG. **14** is a schematic cross-sectional view of a light emitting diode pixel for a display according to an exemplary embodiment.

[0131] FIG. **15** is a schematic circuit diagram a display apparatus according to an exemplary embodiment.

[0132] FIG. **16** is a schematic plan view of a display apparatus according to an exemplary embodiment.

[0133] FIG. **17** is an enlarged plan view of one pixel of the display apparatus of FIG. **16** according to an exemplary embodiment.

[0134] FIG. **18**A is a schematic cross-sectional view taken along line A-A of FIG. **17** according to an exemplary embodiment.

[0135] FIG. **18**B is a schematic cross-sectional view taken along line B-B of FIG. **17** according to an exemplary embodiment.

[0136] FIG. **18**C is a schematic cross-sectional view taken along line C-C of FIG. **17** according to an exemplary embodiment.

[0137] FIG. **18**D is a schematic cross-sectional view taken along line D-D of FIG. **17** according to an exemplary embodiment.

[0138] FIGS. **19**A, **19**B, **20**A, **20**B, **21**A, **21**B, **21**C, **22**A, **22**B, **22**C, **23**A, **23**B, **24**A, **24**B, **25**A, **25**B, **26**A, **26**B, **27**A, **27**B, **28**A, **28**B, **29**A, **29**B, **30**A, **30**B, **31**, **32**A, **32**B, and **33** are schematic plan views and cross-sectional view illustrating a manufacturing method of a display apparatus according an exemplary embodiment.

[0139] FIG. **34** is a schematic cross-sectional view of a display apparatus according to still another exemplary embodiment.

[0140] FIG. **35** is a schematic circuit diagram of a display apparatus according to still another exemplary embodiment.

[0141] FIG. **36** is a schematic cross-sectional view of a light emitting diode stack for a display according to an exemplary embodiment.

[0142] FIGS. **37**A, **37**B, **37**C, **37**D, and **37**E are schematic cross-sectional views illustrating a method of manufacturing a light emitting diode stack for a display according to an exemplary embodiment.

[0143] FIG. **38** is a schematic circuit diagram of a display apparatus according to an exemplary embodiment.

[0144] FIG. **39** is a schematic plan view of the display apparatus according to an exemplary embodiment.

[0145] FIG. **40** is an enlarged plan view of one pixel of the display apparatus of FIG. **39** according to an exemplary embodiment.

[0146] FIG. **41** is a schematic cross-sectional view taken along line A-A of FIG. **40**.

[0147] FIG. **42** is a schematic cross-sectional view taken along line B-B of FIG. **40**.

[0148] FIGS. **43**A, **43**B, **43**C, **43**D, **43**E, **43**F, **43**G, **43**H, **43**I, **43**J, and **43**K are schematic plan views illustrating a method of manufacturing a display apparatus according to an exemplary embodiment.

[0149] FIG. **44** is a schematic circuit diagram of a display apparatus according to another exemplary embodiment.

[0150] FIG. **45** is a schematic plan view of a display apparatus according to another exemplary embodiment.

[0151] FIG. **46** is a schematic cross-sectional view of a light emitting diode stack for a display according to an exemplary embodiment.

[0152] FIGS. **47**A, **47**B, **47**C, **47**D, and **47**E are schematic cross-sectional views illustrating a method of manufacturing a light emitting diode stack for a display according to an exemplary embodiment.

[0153] FIG. **48** is a schematic circuit diagram of a display apparatus according to an exemplary embodiment.

[0154] FIG. **49** is a schematic plan view of a display apparatus according to an exemplary embodiment.

[0155] FIG. **50** is an enlarged plan view of one pixel of the display apparatus of FIG. **49** according to an exemplary embodiment.

[0156] FIG. **51** is a schematic cross-sectional view taken along line A-A of FIG. **50** according to an exemplary embodiment.

[0157] FIG. **52** is a schematic cross-sectional view taken along line B-B of FIG. **50** according to an exemplary embodiment.

[0158] FIGS. **53**A, **53**B, **53**C, **53**D, **53**E, **53**F, **53**G, **53**H, **53**I, **53**J, and **53**K are schematic plan views illustrating a method of manufacturing a display apparatus according to an exemplary embodiment.

[0159] FIG. **54** is a schematic circuit diagram of a display apparatus according to another exemplary embodiment.

[0160] FIG. **55** is a schematic plan view of a display apparatus according to another exemplary embodiment.

[0161] FIG. **56** is a schematic plan view of a display apparatus according to an exemplary embodiment.

[0162] FIG. **57** is a cross-sectional view of a light emitting diode pixel for a display according to an exemplary embodiment.

[0163] FIG. **58** is a schematic circuit diagram of a display apparatus according to an exemplary embodiment.

[0164] FIG. **59**A and FIG. **59**B are a top view and a bottom view of one pixel of a display apparatus according to exemplary embodiments, respectively.

[0165] FIG. **60**A is a schematic cross-sectional view taken along line A-A of FIG. **59**A.

[0166] FIG. **60**B is a schematic cross-sectional view taken along line B-B of FIG. **59**A according to an exemplary embodiment.

[0167] FIG. **60**C is a schematic cross-sectional view taken along line C-C of FIG. **59**A according to an exemplary embodiment.

[0168] FIG. **60**D is a schematic cross-sectional view taken along line D-D of FIG. **59**A according to an exemplary embodiment.

[0169] FIGS. **61**A, **61**B, **62**A, **62**B, **63**A, **63**B, **64**A, **64**B, **65**A, **65**B, **66**A, **66**B, **67**A, **67**B, **68**A, and **68**B are schematic plan views and cross-sectional views illustrating a method of manufacturing a display apparatus according to an exemplary embodiment.

[0170] FIG. **69** is a cross-sectional view of a light emitting diode pixel for a display according to another exemplary embodiment.

[0171] FIG. **70** is an enlarged top view of one pixel of a display apparatus according to an exemplary embodiment.

[0172] FIG. **71**A and FIG. **71**B are cross-sectional views taken along lines G-G and H-H of FIG. **70**, respectively.

DETAILED DESCRIPTION

[0173] In the following description, for the purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of various exemplary embodiments or implementations of the invention. As used herein "embodiments" and "implementations" are interchangeable words that are non-limiting examples of devices or methods employing one or more of the inventive concepts disclosed herein. It is apparent, however, that various exemplary embodiments may be practiced without these specific details or with one or more equivalent arrangements. In other instances, well-known structures and devices are shown in block diagram form in order to avoid unnecessarily obscuring various exemplary embodiments. Further, various exemplary embodiments may be different, but do not have to be exclusive. For example, specific shapes, configurations, and characteristics of an exemplary embodiment may be used or implemented in another exemplary embodiment without departing from the inventive concepts.

[0174] Unless otherwise specified, the illustrated exemplary embodiments are to be understood as providing exemplary features of varying detail of some ways in which the inventive concepts may be implemented in practice. Therefore, unless otherwise specified, the features, components, modules, layers, films, panels, regions, and/or aspects, etc. (hereinafter individually or collectively referred to as "elements"), of the various embodiments may be otherwise combined, separated, interchanged, and/or rearranged without departing from the inventive concepts.

[0175] The use of cross-hatching and/or shading in the accompanying drawings is generally provided to clarify boundaries between adjacent elements. As such, neither the presence nor the absence of cross-hatching or shading conveys or indicates any preference or requirement for particular materials, material properties, dimensions, proportions, commonalities between illustrated elements, and/or any other characteristic, attribute, property, etc., of the elements, unless specified. Further, in the accompanying drawings, the size and relative sizes of elements may be exaggerated for clarity and/or descriptive purposes. When an exemplary embodiment may be implemented differently, a specific process order may be performed differently from the described order. For example, two consecutively described processes may be performed substantially at the same time or performed in an order opposite to the described order. Also, like reference numerals denote like elements.

[0176] When an element, such as a layer, is referred to as being "on," "connected to," or "coupled to" another element or layer, it may be directly on, connected to, or coupled to the other element or layer or intervening elements or layers may be present. When, however, an element or layer is referred to as being "directly on," "directly connected to," or "directly coupled to" another element or layer, there are no intervening elements or layers present. To this end, the term "connected" may refer to physical, electrical, and/or fluid connection, with or without intervening elements. Further, the D1-axis, the D2-axis, and the D3-axis are not limited to three axes of a rectangular coordinate system, such as the x, y, and z-axes, and may be interpreted in a broader sense. For example, the D1-axis, the D2-axis, and the D3-axis may be perpendicular to one another, or may represent different directions that are not perpendicular to one another. For the purposes of this disclosure, "at least one of X, Y, and Z" and "at least one selected from the group consisting of X, Y, and Z" may be construed as X only, Y only, Z only, or any combination of two or more of X, Y, and Z, such as, for instance, XYZ, XYY, YZ, and ZZ. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items.

[0177] Although the terms "first," "second," etc. may be used herein to describe various types of elements, these elements should not be limited by these terms. These terms are used to distinguish one element from another element. Thus, a first element discussed below could be termed a second element without departing from the teachings of the disclosure.

[0178] Spatially relative terms, such as "beneath," "below," "under," "lower," "above," "upper," "over," "higher," "side" (e.g., as in "sidewall"), and the like, may be used herein for descriptive purposes, and, thereby, to describe one elements relationship to another element(s) as illustrated in the drawings. Spatially relative terms are intended to encompass different orientations of an apparatus in use, operation, and/or manufacture in addition to the orientation depicted in the drawings. For example, if the apparatus in the drawings is turned over, elements described as "below" or "beneath" other elements or features would then be oriented "above" the other elements or features. Thus, the exemplary term "below" can encompass both an orientation of above and below. Furthermore, the apparatus may be otherwise oriented (e.g., rotated 90 degrees or at other orientations), and, as such, the spatially relative descriptors used herein interpreted accordingly.

[0179] The terminology used herein is for the purpose of describing particular embodiments and is not intended to be limiting. As used herein, the singular forms, "a," "an," and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. Moreover, the terms "comprises," "comprising," "includes," and/or "including," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, components, and/or groups thereof, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof. It is also noted that, as used herein, the terms "substantially," "about," and other similar terms, are used as terms of approximation and not as terms of degree, and, as such, are utilized to account for inherent deviations in measured, calculated, and/or provided values that would be recognized by one of ordinary skill in the art.

[0180] Various exemplary embodiments are described herein with reference to sectional and/or exploded illustrations that are schematic illustrations of idealized exemplary embodiments and/or intermediate structures. As such, variations from the shapes of the illustrations as a result, for example, of manufacturing techniques and/or tolerances, are to be expected. Thus, exemplary embodiments disclosed herein should not necessarily be construed as limited to the particular illustrated shapes of regions, but are to include deviations in shapes that result from, for instance, manufacturing. In this manner, regions illustrated in the drawings may be schematic in nature and the shapes of these regions may not reflect actual shapes of regions of a device and, as such, are not necessarily intended to be limiting.

[0181] Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this disclosure is a part. Terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and should not be interpreted in an idealized or overly formal sense, unless expressly so defined herein.

[0182] As used herein, a light emitting diode stack or a light emitting diode according to exemplary embodiments may include a micro LED, which has a surface area less than about 10,000 square μm as known in the art. In other exemplary embodiments, the micro LED's may have a surface area of less than about 4,000 square μm, or less than about 2,500 square μm, depending upon the particular application.

[0183] Referring to FIG. **1**, the light emitting diode stack **100** for a display may include a support substrate **51**, a first LED stack **23**, a second LED stack **33**, a third LED stack **43**, a first-p reflective electrode **25**, a second-p transparent electrode **35**, a third-p transparent electrode **45**, a first color filter **37**, a second color filter **47**, a first bonding layer **53**, a second bonding layer **55**, and a third bonding layer **57**. As used for the exemplary embodiments disclosed herein, a light emitting diode stack may refer to a micro LED (or a micro LED stack).

[0184] The support substrate **51** supports the first, second, and third LED semiconductor stacks **23**, **33** and **43**. The support substrate **51** may have a circuit on a surface or in an inner part thereof, but the inventive concepts are not limited thereto. The support substrate **51** may include, for example, a Si substrate, or a Ge substrate.

[0185] The first LED stack **23**, the second LED stack **33**, and the third LED stack **43** each include an n-type semiconductor layer, a p-type semiconductor layer, and an active layer interposed therebetween. The active layer may have a multiple quantum well structure.

[0186] For example, the first LED stack **23** may be an inorganic light emitting diode that emits red light, the second LED stack **33** may be an inorganic light emitting diode that emits green light, and the third LED stack **43** may be an inorganic light emitting diode that emits blue light. The first LED stack **23** may include a GaInP-based well layer, and the second LED stack **33** and the third LED stack **43** may include a GaInN-based well layer. However, the inventive concepts are limited thereto, and when the light emitting diode stack **100** includes micro LEDs, the first LED stack **23** may emit any one of red, green, and blue light, and the second and third LED stacks **33** and **43** may emit a different one of the red, green, and blue light without adversely affecting operation or requiring color filters due to its small form factor.

[0187] Top and bottom surfaces of each of the first, second, and third LED stacks **23**, **33**, or **43** may include an n-type semiconductor layer and a p-type semiconductor layer, respectively. In FIG. **1**, an upper surface of each of the first to third LED stacks **23**, **33**, and **43** is described as including an n-type semiconductor layer, and a lower surface thereof is described as including a p-type semiconductor layer. Since the upper surface of the third LED stack **43** is n-type, a roughened surface may be formed on the upper surface of the third LED stack **43** through chemical etching. However, the inventive concepts are not limited thereto, and the semiconductor type of the upper surface and the lower surface of each of the LED stacks may be reversed.

[0188] The first LED stack **23** is disposed closer to the support substrate **51**, the second LED stack **33** is disposed on the first LED stack **23**, and the third LED stack **43** is disposed on the second LED stack **33**. Since the first LED stack **23** emits light having a longer wavelength than the second and third LED stacks **33** and **43**, light generated in the first LED stack **23** may be transmitted through the second and third LED stacks **33** and **43** and emitted to the outside. Further, since the second LED stack **33** emits light having a longer wavelength than the third LED stack **43**, light generated in the second LED stack **33** may be transmitted through the third LED stack **43** and emitted to the outside.

[0189] The first-p reflective electrode **25** is in ohmic contact with the p-type semiconductor layer of the first LED stack **23** and may reflect light generated from the first LED stack **23**. For example, the first-p reflective electrode **25** may include Au—Ti, Au—Sn, or the like. Further, the first-p reflective electrode **25** may include a diffusion barrier layer.

[0190] The second-p transparent electrode **35** is in ohmic contact with the p-type semiconductor layer of the second LED stack **33**. The second-p transparent electrode **35** may include a metal layer or a conductive oxide layer, which is transparent to red light and green light.

[0191] The third-p transparent electrode **45** is in ohmic contact with the p-type semiconductor layer of the third LED stack **33**. The third-p transparent electrode **45** may include a metal layer or a conductive oxide layer, which is transparent to red light, green light, and blue light.

[0192] The first-p reflective electrode **25**, the second-p transparent electrode **35**, and the third-p transparent electrode **45** are in ohmic contact with the p-type semiconductor layer of each LED stack **23**, **33**, and **43**, and may assist in current spreading.

[0193] Meanwhile, the first color filter **37** may be disposed between the first LED stack **23** and the second LED stack **33**. In addition, the second color filter **47** may be disposed between the second LED stack **33** and the third LED stack **43**. The first color filter **37** transmits light generated in the first LED stack **23** and reflects light generated in the second LED stack **33**. Meanwhile, the second color filter **47** transmits light generated in the first and second LED stacks **23** and **33** and reflects light generated in the third LED stack **43**. Thus, light generated in the first LED stack **23** may be emitted to the outside through the second LED stack **33** and the third LED stack **43**, and light generated in the second LED stack **33** may be emitted to the outside through the third LED stack **43**. Further, light generated in the second LED stack **33** may be prevented from being incident on the first LED stack **23** to be lost, and light generated in the third LED stack **43** may be prevented from being incident on the second LED stack **33** to be lost. According to an exemplary embodiment, the first color filter **37** may also reflect light generated in the third LED stack **43**.

[0194] Each of the first and second color filters **37** and **47** may be, for example, a low pass filter that passes through only a low frequency region (e.g., a long wavelength region), a band pass filter that passes through only a predetermined wavelength band, or a band stop filter that blocks only a predetermined wavelength band. In particular, the first and second color filters **37** and **47** may include a distributed Bragg reflector (DBR). The distributed Bragg reflector may reflect light at a specific wavelength band (stop band) while transmitting transmit light at another wavelength region. The distributed Bragg reflector may be formed by alternately stacking insulating layers having different refractive indices, and may be formed, for example, by alternately stacking TiO_2 and SiO_2. In addition, the stop band of the distributed Bragg reflector may be controlled by adjusting the thicknesses of TiO_2 and SiO_2. The low pass filter and the band pass filter may also be formed by alternately stacking the insulating layers having different refractive indices one above another.

[0195] The first bonding layer **53** couples the first LED stack **23** to the support substrate **51**. As shown in FIG. **1**, the first-p reflective electrode **25** may be in contact with the first bonding layer **53**. The first bonding layer **53** may be a light transmissive or opaque layer. The first bonding layer **53** may be, for example, a transparent inorganic insulating film, a transparent organic insulating film, or a transparent conductive thin film.

[0196] The second bonding layer **55** couples the second LED stack **33** to the first LED stack **23**. As shown in FIG. **1**, the second bonding layer **55** may be in contact with the first LED stack **23** and the first color filter **37**. However, the inventive concepts are not limited thereto, and a transparent conductive layer may be additionally disposed on the first LED stack **23**. The second bonding layer **55** transmits light generated in the first LED stack **23**. The second bonding layer **55** may be, for example, a transparent inorganic insulating film, a transparent organic insulating film, or a transparent conductive thin film, and may be formed of, for example, light transmissive spin-on-glass.

[0197] The third bonding layer **57** couples the third LED stack **43** to the second LED stack **33**. As shown in FIG. **1**, the third bonding layer **57** may be in contact with the second LED stack **33** and the second color filter **47**. However, the inventive concepts are not limited thereto, and a transparent conductive layer may be additionally disposed on the second LED stack **33**. The third bonding layer **57** transmits light generated in the first LED stack **23** and the second LED stack **33**. The third bonding layer **57** may be, for example, a transparent inorganic insulating film, a transparent organic insulating film, or a transparent conductive thin film, and may be formed of, for example, light transmissive spin-on-glass.

[0198] FIG. **2** is schematic cross-sectional views illustrating a manufacturing method of a light emitting diode stack for a display according to an exemplary embodiment.

[0199] Referring to FIG. **2**, first, the first LED stack **23** is grown on a first substrate **21**, and a first-p reflective electrode **25** is formed on the first LED stack **23**.

[0200] The first substrate **21** may be, for example, a GaAs substrate. Further, the first LED stack **23** is formed as AlGaInP-based semiconductor layers, and includes an n-type semiconductor layer, an active layer, and a p-type semiconductor layer. The first-p reflective electrode **25** is in ohmic contact with the p-type semiconductor layer of the first LED stack **23**.

[0201] Meanwhile, a second LED stack **33** is grown on a second substrate **31**, and a second-p transparent electrode **35** and a first color filter **37** are formed on the second LED stack **33**. The second LED stack **33** is formed of gallium nitride-based semiconductor layers, and may include a GaInN well layer. The second substrate **31** is a substrate, on which the gallium nitride-based semiconductor layer may be grown, and is different from the first substrate **21**. A composition ratio of GaInN may be determined so that the second LED stack **33** emits green light. The second-p transparent electrode **35** is in ohmic contact with the p-type semiconductor layer of the second LED stack **33**.

[0202] Further, a third LED stack **43** is grown on a third substrate **41**, and a third-p transparent electrode **45** and a second color filter **47** are formed on the third LED stack **43**. The third LED stack **43** is formed of gallium nitride-based semiconductor layers, and may include a GaInN well layer. The third substrate **41** is a substrate, on which the gallium nitride-based semiconductor layer may be grown, and is different from the first substrate **21**. A composition ratio of GaInN may be determined so that the third LED stack **43** emits blue light. Meanwhile, the third-p transparent electrode **45** is in ohmic contact with the p-type semiconductor layer of the third LED stack **43**.

[0203] The first color filter **37** and the second color filter **47** of FIG. **2** are the same as those described with reference to FIG. **1**, and thus, detailed descriptions thereof will be omitted to avoid redundancy.

[0204] Referring to FIGS. **1** and **2**, the first LED stack **23** is bonded to the support substrate **51** via the first bonding layer **53**. The first bonding layer **53** may be disposed on the support substrate **51** in advance, and the first-p reflective electrode **25** may be bonded to the first bonding layer **53** and face the support substrate **51**. Meanwhile, the first substrate **21** is removed from the first LED stack **23** using a chemical etching technique.

[0205] Then, the second LED stack **33** is bonded to the first LED stack **23** via the second bonding layer **55**. The first color filter **37** is bonded to the second bonding layer **55** and face the first LED stack **23**. The second bonding layer **55** may be disposed on the first LED stack **23** in advance, and the first color filter **37** may be disposed to face and bonded to the second bonding layer **55**. Meanwhile, the second substrate **31** may be separated from the second LED stack **33** using techniques such as laser lift-off, chemical lift-off, and the like.

[0206] Then, the third LED stack **43** is bonded to the second LED stack **33** via the third bonding layer **57**. The first color filter **47** is bonded to the third bonding layer **57** and face the second LED stack **33**. The third bonding layer **57** may be disposed on the second LED stack **33** in advance, and the first color filter **47** may be disposed to face and bonded to the third bonding layer **57**. Meanwhile, the third substrate **41** may be separated from the third LED stack **43** using techniques such as laser lift-off, chemical lift-off, and the like. In thins manner, a light emitting diode stack for a display shown in FIG. **1** is formed, in which the n-type semiconductor layer of the third LED stack **43** is exposed.

[0207] A display apparatus according to an exemplary embodiment may be formed by patterning the stack of the first to third LED stacks **23**, **33**, and **43** disposed on the support substrate **51** in pixel units, and connecting these LED stacks to one another through interconnections. Hereinafter, a display apparatus according to an exemplary embodiment will be described.

[0208] FIG. **3** is a schematic circuit diagram of a display apparatus according to an exemplary embodiment. FIG. **4** is a schematic plan view of a display apparatus according to an exemplary embodiment. FIG. **5** is an enlarged plan view of one pixel region of the display apparatus of FIG. **4** according to an exemplary embodiment. FIG. **6** is a schematic cross-sectional view taken along line A-A of FIG. **5**, and FIG. **7** is a schematic cross-sectional view taken along line B-B of FIG. **5**.

[0209] Referring to FIGS. **3** and **4**, the display apparatus according to the exemplary embodiment may be implemented to be driven in a passive matrix manner.

[0210] For example, the light emitting diode stack for a display described with reference to FIG. **1** has a structure, in which the first to third LED stacks **23**, **33** and **43** are stacked in a vertical direction, and thus, one pixel includes three light emitting diodes R, G, and B. Here, the first light emitting diode R corresponds to the first LED stack **23**, the second light emitting diode G corresponds to the second LED stack **33**, and the third light emitting diode B corresponds to the third LED stack **43**.

[0211] In FIGS. **3** and **4**, one pixel includes the first to third light emitting diodes R, G, and B, and each light emitting diode corresponds to a sub-pixel. Anodes of the first to third light emitting diodes R, G, and B are connected to a common line (e.g., a data line), and cathodes thereof are connected to different lines (e.g., scan lines). More particularly, in a first pixel, the anodes of the first to third light emitting diodes R, G, and B are connected in common to the data line Vdata1, and the cathodes thereof are connected to the scan lines Vscan**1**-**1**, Vscan**1**-**2**, and Vscan**1**-**3**, respectively. Thus, the light emitting diodes R, G, and B in the same pixel may be driven independently.

[0212] Further, each of the light emitting diodes R, G, and B may be driven in a pulse width modulation scheme or by changing the intensity of the current, thereby adjusting luminance of each sub-pixel.

[0213] Referring to FIG. **4**, a plurality of pixels are formed by patterning the LED stacks described with reference to FIG. **1**, and each of the pixels is connected to the first-p reflective electrodes **25** and interconnection lines **71**, **73**, and **75**. As shown in FIG. **3**, the first-p reflective electrode **25** may be used as the data line Vdata, and the interconnection lines **71**, **73**, and **75** may be used as the scan lines.

[0214] The pixels may be arranged in a matrix form, the anodes of the light emitting diodes R, G, and B of each pixel are connected in common to the first-p reflective electrode **25**, and the cathodes thereof are connected to the interconnection lines **71**, **73** and **75**, respectively, which are spaced apart from each other. The interconnection lines **71**, **73**, and **75** may be used as a scan line Vscan.

[0215] Referring to FIGS. **4** to **7**, a portion of the first-p reflective electrode **25**, a portion of the upper surface of the first LED stack **23**, a portion of the second-p transparent electrode **35**, a portion of the upper surface of the second LED stack **33**, a portion of the third-p transparent electrode **45**, and the upper surface of the third LED stack **43** in each pixel are exposed to the outside.

[0216] The third LED stack **43** may have a roughened surface **43***a* on the upper surface thereof. The roughened surface **43***a* may be formed on the entire upper surface of the third LED stack **43**, or may be formed on a part thereof as shown in FIG. **6**.

[0217] The first insulating layer **61** may cover a side surface of each pixel. The first insulating layer **61** may be formed of a light transmissive material such as SiO_2. In this case, the first insulating layer **61** may cover the entire upper surface of the third LED stack **43**. Alternatively, the first insulating layer **61** may include a distributed Bragg reflector to reflect light traveling towards the side surface in the first to third LED stacks **23**, **33** and **43**. In this case, the first insulating layer **61** at least partially exposes the upper surface of the third LED stack **43**.

[0218] The first insulating layer **61** may have an opening **61***a* exposing the upper surface of the third LED stack **43**, an opening **61***b* exposing the upper surface of the second LED stack **33**, an opening **61***c* (well shown in FIG. **8**H) exposing the upper surface of the first LED stack **23** an opening **61***d* exposing the third-p transparent electrode **45**, an opening **61***e* exposing the second-p transparent electrode **35**, and openings **61***f* exposing the first-p reflective electrode **25**.

[0219] The interconnection line **71** and the interconnection line **75** may be formed on the support substrate **51** in the vicinity of the first to third LED stacks **23**, **33** and **43**, and may be disposed on the first insulating layer **61** to be insulated from the first-p electrode **25**. Meanwhile, a connector **77***a* connects the third-p transparent electrode **45** to the first-p reflective electrode **25**, a connector **77***b* connects the second-p transparent electrode **35** to the first-p reflective electrode **25**, and the anodes of the first LED stack **23**, the second LED stack **33**, and the third LED stack **43** are connected in common to the first-p reflective electrode **25**.

[0220] Meanwhile, a connector **71***a* connects the upper surface of the third LED stack **43** to the interconnection line **71**, and a connector **75***a* connects the upper surface of the first LED stack **23** to the interconnection line **75**.

[0221] The second insulating layer **81** is disposed on the interconnection lines **71** and **73** and the first insulating layer **61**, and may cover the upper surface of the third LED stack **43**. The second insulating layer **81** may have an opening **81***a* that exposes a portion of the upper surface of the second LED stack **33**.

[0222] The interconnection line **73** may be disposed on the second insulating layer **81**, and a connector **73***a* may connect the upper surface of the second LED stack **33** to the interconnection line **73**. The connector **73***a* may pass over the upper part of the interconnection line **75** and is insulated from the interconnection line **75** by the second insulating layer **81**.

[0223] As described above, the electrodes of each pixel according to an exemplary embodiment may be connected to the data lines and the scan lines. In particular, FIGS. **4**-**7** show that the interconnection lines **71** and **75** are formed on the first insulating layer **61** and the interconnection line **73** is formed on the second insulating layer **81**, however, the inventive concepts are not limited thereto. For example, each of the interconnection lines **71**, **73**, and **75** may be formed on the first insulating layer **61** and covered with the second insulating layer **81**, and the second insulating layer **81** may have an opening that exposes the interconnection line **73**. In this case, the connector **73***a* may connect the upper surface of the second LED stack **33** to the interconnection line **73** through the openings of the second insulating layer **81**.

[0224] Meanwhile, the interconnection lines **71**, **73**, and **75** may be formed in the support substrate **51**, and the connectors **71***a*, **73***a*, and **75***a* may connect the upper surfaces of the first to third LED stacks **23**, **33** and **43** to the interconnection lines **71**, **73**, and **75** on the first insulating layer **61**.

[0225] FIGS. **8**A to **8**K are schematic plan views illustrating a manufacturing method of a display apparatus according to an exemplary embodiment.

[0226] First, a light emitting diode stack **100** shown in FIG. **1** is provided.

[0227] Next, referring to FIG. **8**A, a roughened surface **43***a* may be formed on the upper surface of the third LED stack **43**. The roughened surface **43***a* may be formed to correspond each pixel region on the upper surface of the third LED stack **43**. The roughened surface **43***a* may be formed by a chemical etching technique, for example, by a photo-enhanced chemical etch (PEC) technique.

[0228] The roughened surface **43***a* may be partially formed within each pixel region in consideration of the region of the third LED stack **43** to be further etched, but the inventive concepts are not limited thereto, and may be formed over the entire upper surface of the third LED stack **43**.

[0229] Referring to FIG. **8**B, a peripheral region of the third LED stack **43** is then etched in each pixel region to expose the third-p transparent electrode **45**. The remaining third LED stack **43** may have a rectangular or square shape, and a plurality of depression parts may be formed along the edges thereof.

[0230] Referring to FIG. **8**C, the exposed third-p transparent electrode **45** is then removed except for a part thereof that corresponds to one depression part formed in the third LED stack **43**, to expose the upper surface of the second LED stack **33**. The upper surface of the second LED stack **33** is exposed around the third LED stack **43** and in other depression parts of the third LED stack **43** other than the one where the third-p transparent electrode **45** is remained.

[0231] Referring to FIG. **8**D, the exposed second LED stack **33** is removed except for a part thereof that corresponds to another depression part of the third LED stack **43**, to thereby expose the second-p transparent electrode **35**.

[0232] Referring to FIG. **8**E, the exposed second-p transparent electrode **35** is then removed except for a part that thereof that corresponds to still another depression part of the third LED stack **43**, to expose the upper surface of the first LED stack **23**. Thus, the upper surface of the first LED stack **23** is exposed around the third LED stack **43**, and the upper surface of the first LED stack **23** is also exposed to at least one of the depression parts of the third LED stack **43**.

[0233] Referring to FIG. **8**F, the exposed first LED stack **23** is removed except for a part thereof that corresponds to yet another depression part of the third LED stack **43**, to expose the first-p reflective electrode **25**. The first-p reflective electrode **25** is exposed around the third LED stack **43**.

[0234] Referring to FIG. **8**G, the first-p reflective electrode **25** is patterned to form linear interconnection lines such that the support substrate **51** may be exposed. The first-p reflective electrode **25** may connect the pixels arranged in a column to each other as shown in FIG. **4**.

[0235] Referring to FIG. **8**H, a first insulating layer (**61** in FIGS. **6** and **7**) is formed to cover the pixel. In particular, the first insulating layer **61** covers side surfaces of the first to third LED stacks **23**, **33**, and **43** while covering the first-p reflective electrode **25**. In addition, the first insulating layer **61** may at least partially cover the upper surface of the third LED stack **43**. When the first insulating layer **61** is a transparent layer, such as SiO_2, the first insulating layer **61** may cover the entire upper surface of the third LED stack **43**. Alternatively, when the first insulating layer **61** includes a distributed Bragg reflector, the first insulating layer **61** may expose at least a portion of the upper surface of the third LED stack **43** so that light is emitted to the outside.

[0236] Meanwhile, the first insulating layer **61** may include an opening **61***a* exposing the third LED stack **43**, an opening **61***b* exposing the second LED stack **33**, an opening **61***c* exposing the first LED stack **23**, an opening **61***d* exposing the third-p transparent electrode **45**, an opening **61***e* exposing the second-p transparent electrode **35**, and an opening **61***f* exposing the first-p reflective electrode **25**. At least two openings **61***f* exposing the first-p reflective electrode **25** may be formed.

[0237] Referring to FIG. **8**I, interconnection lines **71** and **75** and connectors **71***a*, **75***a*, **77***a*, and **77***b* are then formed by using a lift-off technique or the like. The interconnection lines **71** and **75** are insulated from the first-p reflective electrode **25** by the first insulating layer **61**. The connector **71***a* electrically connects the third LED stack **43** to the interconnection line **71**, and the connector **75***a* electrically connects the first LED stack **23** to the interconnection line **75**. Meanwhile, the connector **77***a* electrically connects the third-p transparent electrode **45** to the first-p reflective electrode **25**, and the connector **77***b* electrically connects the second-p transparent electrode **35** to the first-p reflective electrode **25**.

[0238] Referring to FIG. **8**J, a second insulating layer (**81** in FIG. **6** and FIG. **7**) then covers the interconnection lines **71** and **75** and the connectors **71***a*, **75***a*, **77***a*, and **77***b*. The second insulating layer **81** may also cover the entire upper surface of the third LED stack **43**. Meanwhile, the second insulating layer **81** has an opening **81***a* exposing the upper surface of the second LED stack **33**. The second insulating layer **81** may be formed of, for example, a silicon oxide film or a silicon nitride film, and may also include a distributed Bragg reflector. When the second insulating layer **81** includes a distributed Bragg reflector, the second insulating layer **81** may at least partially expose the upper surface of the third LED stack **43** to emit light to the outside.

[0239] Referring to FIG. **8**K, the interconnection line **73** and the connector **73***a* are then formed by a lift-off technique or the like. The interconnection line **73** is disposed on the second insulating layer **81** and is insulated from the first-p reflective electrode **25** and the interconnection lines **71** and **75**. The connector **73***a* electrically connects the second LED stack **33** and the interconnection line **73**. The connector **73***a* may cross over an upper part of the interconnection line **75** and is insulated from the interconnection line **75** by the second insulating layer **81**.

[0240] In this manner, a pixel region shown in FIG. **5** may be formed. Further, as shown in FIG. **4**, the plurality of pixels may be formed on the support substrate **51**, and these pixels may be connected to each other by the first-p reflective electrode **25** and the interconnection lines **71**, **73**, and **75** so as to be driven in a passive matrix manner.

[0241] As described above, a manufacturing method of a display apparatus driven in a passive matrix manner has been described according to an exemplary embodiment. However, the inventive concepts are not limited to the particular manufacturing method described above, and a display apparatus to be driven in a passive matrix manner may be manufactured in various ways by using the light emitting diode stack shown in FIG. **1**. For example, the interconnection line **73** has been described as being formed on the second insulating layer **81**, but the interconnection line **73** may be formed on the first insulating layer **61** together with the interconnection lines **71** and **75**, and the connector **73***a* may be formed on the second insulating layer **81** to connect the second LED stack **33** to the interconnection line **73**. Further, the interconnection lines **71**, **73**, and **75** may be provided in the support substrate **51**.

[0242] FIG. **9** is a schematic circuit diagram of a display apparatus according to another exemplary embodiment. While the display apparatus described with reference to FIGS. **3**-**8** is configured to be driven in a passive matrix manner, the display apparatus according to the illustrated embodiment is for active matrix driving.

[0243] Referring to FIG. **9**, a driving circuit according to an exemplary embodiment includes two or more transistors Tr**1** and Tr**2** and a capacitor. When power supply is connected to selection lines Vrowl to Vrow**3**, and a data voltage is applied to the data lines Vdata**1** to Vdata**3**, a voltage is applied to the corresponding light emitting diode. Further, charges are charged in the corresponding capacitor in accordance with the values of Vdata**1** to Vdata**3**. The transistor Tr**2** may maintain a turn-on state by the charged voltage of the capacitor, and thus, even when power supply is cut off to the selection line Vrowl, voltage of the capacitor may be maintained, and the voltage may be applied to the light emitting diodes LED**1** to LED**3**. Further, currents flowing through the LED**1** to the LED**3** may be changed according to values of Vdata**1** to Vdata**3**. Since the current may always be supplied through Vdd, light may be emitted continuously.

[0244] The transistors Tr**1** and Tr**2** and the capacitor may be formed in the support substrate **51**. For example, a thin film transistor formed on a silicon substrate may be used for active matrix driving.

[0245] The light emitting diodes LED**1**, LED, and LED**3** may correspond to the first, second, and third LED stacks **23**, **33**, and **43** stacked in one pixel. Anodes of the first to third LED stacks **23**, **33**, and **43** may be connected to the transistor Tr**2**, and cathodes thereof may be grounded.

[0246] While FIG. **9** shows a driving circuit of a display apparatus for active matrix driving, the inventive concepts are not limited thereto, and other circuits may be used. Further, while the anodes of the light emitting diodes LED**1** to LED**3** are described as being connected to the different transistors Tr**2** and the cathodes thereof are grounded, alternatively, the anodes of the light emitting diodes may be connected to the current supplies Vdd, and the cathodes thereof may be connected to different transistors.

[0247] FIG. **10** is a schematic plan view of a display apparatus according to still another exemplary embodiment. Hereinafter, one pixel of the plurality of pixels arranged on the support substrate **151** will be described.

[0248] Referring to FIG. **10**, the pixel according to an exemplary embodiment is generally similar to the pixel described with reference to FIGS. **4** to **7**, except that the support substrate **151** is a thin film transistor panel including a transistor and a capacitor, and the first-p reflective electrode **25** is defined within a lower region of the first LED stack **23**.

[0249] The cathode of the third LED stack **43** is connected to the support substrate **151** through the connector **171***a*. For example, as shown in FIG. **9**, the cathode of the third LED stack **43** (e.g., LED **3**) may be electrically connected to the support substrate **151** and grounded. The cathodes of the second LED stack **33** (e.g., LED **2**) and the first LED stack **23** (e.g., LED **1**) may also be connected to the support substrate **151** through the connectors **173***a* and **175***a*, and are grounded, respectively.

[0250] Meanwhile, the first-p reflective electrode **25** is connected to a transistor (Tr**2** in FIG. **9**) provided in the support substrate **151**. The third-p transparent electrode **45** and the second-p transparent electrode **35** are also connected to the transistor (Tr**2** in FIG. **9**) provided in the support substrate **151** through the connectors **171***b* and **173***b*, respectively.

[0251] By connecting the first to third LED stacks **23**, **33**, and **43** as described above, a circuit for active matrix driving as shown in FIG. **9** may be constructed.

[0252] While FIG. **10** shows a pixel of a display apparatus for active matrix driving, the inventive concepts are not limited thereto, and various modifications may be made to various circuits for active matrix driving.

[0253] Meanwhile, referring back to FIG. **1**, the first-p reflective electrode **25**, the second-p transparent electrode **35**, and the third-p transparent electrode **45** are described as being in ohmic contact with the p-type semiconductor layers of the first LED stack **23**, the second LED stack **33**, and the third LED stack **43**, respectively, but the ohmic contact layer is not separately provided in the n-type semiconductor layers. This is because when a pixel size is as small as 200 micrometers or less, there is less difficulty in current spreading even without forming a separate ohmic contact layer in the n-type semiconductor layer. However, for current spreading, transparent electrode layers may still be disposed on the n-type semiconductor layer of each LED stack if needed.

[0254] The first to third LED stacks **23**, **33**, and **43** may be bonded to each other by various configurations.

[0255] FIG. **11** is a schematic cross-sectional view of a light emitting diode stack for a display according to still another exemplary embodiment.

[0256] Referring to FIG. **11**, the light emitting diode stack **101** may include the support substrate **51**, the first LED stack **23**, the second LED stack **33**, the third LED stack **43**, the second-p transparent electrode **35**, the third-p transparent electrode **45**, the first color filter **137**, the second color filter **47**, a first bonding layer **153**, a second bonding layer **155**, and a third bonding layer **157**, similarly to the light emitting diode stack **100** of FIG. **1**. The light emitting diode stack **101** may further include a first-n reflective electrode **129**, a first-p transparent electrode **125**, and a second-n transparent electrode **139**.

[0257] The support substrate **51** supports the semiconductor stacks **23**, **33**, and **43**. The support substrate **51** may have a circuit on a surface or in an inner part thereof, but the inventive concepts are not limited thereto. The support substrate **51** may include, for example, a Si substrate or a Ge substrate.

[0258] The first LED stack **23**, the second LED stack **33**, and the third LED stack **43** are similar to those described with reference to FIG. **1**, and thus detailed descriptions thereof will be omitted to avoid redundancy. The light emitting diode stack **101** is different from that of FIG. **1** in that the lower surfaces of the first LED stack **23** and the second LED stack **33** are n-type, and the upper surfaces thereof are p-type. The lower surface of the third LED stack **43** is the p-type and the upper surface thereof is the n-type, which is substantially the same as that of FIG. **1**.

[0259] Since the upper surface of the first LED stack **23** is p-type, the first-p transparent electrode **125** is in ohmic contact with the upper surface of the first LED stack **23**. The first-p transparent electrode **125** transmits light generated in the first LED stack **23**, for example, red light.

[0260] The first-n reflective electrode **129** is in ohmic contact with the lower surface of the first LED stack **23**. The first-n reflective electrode **129** is in ohmic contact with the first LED stack **23** and reflects light generated in the first LED stack **23**. The first-n reflective electrode **129** may be formed of, for example, Au—Ti, Au—Sn, or the like. Further, the first-n reflective electrode **129** may include a diffusion barrier layer.

[0261] The second-p transparent electrode **35** is in ohmic contact with the p-type semiconductor layer of the second LED stack **33**. Since the upper surface of the second LED stack **33** is the p-type, the second-p transparent electrode **35** is disposed on the second LED stack **33**. The second-p transparent electrode **35** may be formed of a metal layer or a conductive oxide layer, which is transparent to red light and green light.

[0262] The second-n transparent electrode **139** is in ohmic contact with the lower surface of the second LED stack **33**. The second-n transparent electrode **139** may also be formed of a metal layer or a conductive oxide layer, which is transparent to red light and green light. The second-n transparent electrode **139** is partially exposed by patterning the second LED stack **33** to provide a connection terminal for electrical connection to the n-type semiconductor layer of the second LED stack **33**.

[0263] The third-p transparent electrode **45** is in ohmic contact with the p-type semiconductor layer of the third LED stack **33**. The third-p transparent electrode **45** may be formed of a metal layer or a conductive oxide layer, which is transparent to red light, green light, and blue light.

[0264] The first color filter **137** is disposed between the first LED stack **23** and the second LED stack **33**. Further, the second color filter **47** is disposed between the second LED stack **33** and the third LED stack **43**. The first color filter **137** transmits light generated in the first LED stack **23** and reflects light generated in the second LED stack **33**. The second color filter **47** transmits light generated in the first and second LED stacks **23** and **33** and reflects light generated in the third LED stack **43**. Thus, light generated in the first LED stack **23** may be emitted to the outside through the second LED stack **33** and the third LED stack **43**, and light generated in the second LED stack **33** may be emitted to the outside through the third LED stack **43**. Further, it is possible to prevent light generated in the second LED stack **33** from being incident on the first LED stack **23** to be lost, or light generated in the third LED stack **43** from being incident on the second LED stack **33** to be lost.

[0265] According to some exemplary embodiments, the first color filter **137** may reflect light generated in the third LED stack **43**.

[0266] Each of the first and second color filters **137** and **47** may be, for example, a low pass filter that passes through only a low frequency region, that is, a long wavelength region, a band pass filter that passes through only a predetermined wavelength band, or a band stop filter that blocks only the predetermined wavelength band. In particular, the first and second color filters **137** and **47** may be the band stop filter including a distributed Bragg reflector (DBR). The distributed Bragg reflector may be formed by alternately stacking insulating layers having different refractive indices, for example, by alternately stacking TiO_2 and SiO_2. In addition, the stop band of the distributed Bragg reflector may be controlled by adjusting the thicknesses of TiO_2 and SiO_2. The low pass filter and the band pass filter may also be formed by alternately stacking insulating layers having different refractive indices.

[0267] The first bonding layer **153** couples the first LED stack **23** to the support substrate **51**. As shown in FIG. **11**, the first-n reflective electrode **129** may be in contact with the first bonding layer **153**. The first bonding layer **153** may be light transmissive or opaque. The first bonding layer **153** may be, for example, a transparent inorganic insulating film, a transparent organic insulating film, or a transparent conductive thin film.

[0268] The second bonding layer **155** couples the second LED stack **33** to the first LED stack **23**. As shown in FIG. **11**, the second bonding layer **155** may be disposed on the first color filter **137** and may be in contact with the second-n transparent electrode **139**. The second bonding layer **155** transmits light generated in the first LED stack **23**. The second bonding layer **155** may be, for example, a transparent inorganic insulating film, a transparent organic insulating film, or a transparent conductive thin film, and may be formed of, for example, light transmissive spin-on-glass.

[0269] The third bonding layer **157** couples the third LED stack **43** to the second LED stack **33**. As shown in FIG. **11**, the third bonding layer **157** may be in contact with the second-p transparent electrode **35** and in contact with the second color filter **47**. The third bonding layer **157** transmits light generated in the first LED stack **23** and the second LED stack **33**. The third bonding layer **157** may be, for example, a transparent inorganic insulating film, a transparent organic insulating film, or a transparent conductive thin film, and may be formed of, for example, light transmissive spin-on-glass.

[0270] FIGS. **12**A to **12**F are schematic cross-sectional views illustrating a manufacturing method of a light emitting diode stack for a display according to still another exemplary embodiment.

[0271] Referring to FIG. **12**A, the third LED stack **43** is grown on the third substrate **41**, and the third-p transparent electrode **45** and the second color filter **47** are formed on the third LED stack **43**. The third LED stack **43** may be formed of gallium nitride-based semiconductor layers and may include a GaInN well layer. The third substrate **41** is a substrate on which the gallium nitride-based semiconductor layer may be grown, for example, a sapphire substrate. A composition ratio of GaInN may be determined so that the third LED stack **43** emits blue light. The third-p transparent electrode **45** is in ohmic contact with the p-type semiconductor layer of the third LED stack **43**.

[0272] Referring to FIG. **12**B, the second LED stack **33** is grown on a second substrate **31**, and the second-p transparent electrode **35** is formed on the second LED stack **33**. The second LED stack **33** may be formed of gallium nitride-based semiconductor layers and may include a GaInN well layer. The second substrate **31** is a substrate on which the gallium nitride-based semiconductor layer may be grown, and may be the same as the third substrate **41**. A composition ratio of GaInN may be determined so that the second LED stack **33** emits green light. The second-p transparent electrode **35** is in ohmic contact with the p-type semiconductor layer of the second LED stack **33**.

[0273] The third bonding layer **157** is provided on the second color filter **47**, and the second substrate **31** is disposed so that the second-p transparent electrode **35** of the second substrate **31** is in contact with the third bonding layer **157**. The third bonding layer **157** may be formed of, for example, a spin-on glass. In this manner, the second LED stack **33** is bonded to the third LED stack **43**.

[0274] Referring to FIG. **12**C, the second substrate **31** is then separated from the second LED stack **23**. The second substrate **31** may be separated from the second LED stack **33** by using techniques, such as laser lift-off, chemical lift-off, or the like. As the second substrate **31** is separated, the second LED stack **33** is exposed. Then, the second-n transparent electrode **139** is formed on the exposed second LED stack **33**. The second-n transparent electrode **139** may be formed of a metal or a conductive oxide layer. According to an exemplary embodiment, the second-n transparent electrode **139** may be omitted.

[0275] Referring to FIG. **12**D, the first LED stack **23** is grown on the first substrate **21**, the first-p transparent electrode **125** is formed on the first LED stack **23**, and the first color filter **137** is formed on the first-p transparent electrode **125**.

[0276] The first substrate **21** may be, for example, a GaAs substrate. Further, the first LED stack **23** is formed of AlGaInP-based semiconductor layers, and includes an n-type semiconductor layer, an active layer, and a p-type semiconductor layer. The first-p transparent electrode **125** is in ohmic contact with the p-type semiconductor layer of the first LED stack **23**.

[0277] The first color filter **137** is substantially the same as that described with reference to FIG. **1**, and thus, detailed descriptions thereof will be omitted to avoid redundancy.

[0278] The second bonding layer **155** is provided on the second-n transparent electrode **139**, and the first substrate **21** is disposed so that the first color filter **137** of the first substrate **21** is in contact with the second bonding layer **155**. The second bonding layer **155** may be formed of, for example, a spin-on glass. Thus, the first LED stack **23** is bonded to the second LED stack **33**.

[0279] Referring to FIG. **12**E, after the first LED stack **23** is bonded on the second LED stack **33**, the first substrate **21** is removed from the first LED stack **23** by using a chemical etching technique. Thus, the first LED stack **23** is exposed.

[0280] Referring to FIG. **12**F, the first-n reflective electrode **129** is formed on the exposed first LED stack **23**. The first-n reflective electrode **129** includes a metal layer reflecting light generated in the first LED stack **23**. Then, the first bonding layer **153** is disposed on the first-n reflective electrode **129**, and the support substrate **51** is bonded thereon. Then, the third substrate **41** may be separated from the third LED stack **43** by using techniques, such as laser lift-off, chemical lift-off, and the like. In this manner, a light emitting diode stack **101** for a display in which the n-type semiconductor layer of the third LED stack **43** is exposed as shown in FIG. **11** may be provided.

[0281] A display apparatus may be formed by patterning the light emitting diode stack **101** including the first to third LED stacks **23**, **33** and **43** disposed on the support substrate **51** in pixel units, and connecting the first to third LED stacks **22**, **33**, and **43** by interconnection lines.

[0282] According to exemplary embodiments, the plurality of pixels may be formed at a wafer level by using the light emitting diode stack **100** or **101** for a display, which may obviate the process of individually mounting the light emitting diodes. Furthermore, since the first to third LED stacks **23**, **33**, and **43** have a vertically stacked structure, an area of the sub-pixel may be secured within a limited pixel area. In addition, since light generated in the first LED stack **23**, the second LED stack **33**, and the third LED stack **43** is transmitted through the second and third LED stacks **33** and **43**, and emitted to the outside, it is possible to reduce light loss.

[0283] FIG. **13** is a schematic plan view of a display apparatus according to an exemplary embodiment, and FIG. **14** is a schematic cross-sectional view of a light emitting diode pixel for a display according to an exemplary embodiment.

[0284] Referring to FIG. **13**, the display apparatus **200** includes a support substrate **251** and a plurality of pixels **20** arranged on the support substrate **251**. Each pixel **20** includes first to third sub-pixels R, G, and B.

[0285] Referring to FIG. **14**, the support substrate **251** supports the LED stacks **223**, **233**, and **243**. The support substrate **251** may have a circuit on a surface or an inner part, but the inventive concepts are not limited thereto. The support substrate **251** may include, for example, a glass substrate, a sapphire substrate, a Si substrate, or a Ge substrate.

[0286] The first sub-pixel R includes the first LED stack **223**, the second sub-pixel G includes the second LED stack

233, and the third sub-pixel B includes the third LED stack **243**. The first sub-pixel R is configured to emit light in the first LED stack **223**, the second sub-pixel G is configured to emit light in the second LED stack **233**, and the third sub-pixel B is configured to emit light in the third LED stack **243**. The first to third LED stacks **223**, **233**, and **243** may be driven independently of each other.

[0287] The first LED stack **223**, the second LED stack **233**, and the third LED stack **243** are stacked in a vertical direction and overlap with each other. In particular, the second LED stack **233** is disposed on a partial region of the first LED stack **223**. The second LED stack **233** may be formed toward one side on the first LED stack **223**. Further, the third LED stack **243** is disposed on a partial region of the second LED stack **233**, and may be formed toward one side on the second LED stack **233**. FIG. **14** shows that the third LED stack **243** is disposed adjacent to the right side of the second LED stack **233**, but the inventive concepts are limited thereto, and may be disposed adjacent toward the left side of the second LED stack **233**.

[0288] A portion of light R generated in the first LED stack **223** may be emitted in a region not covered with the second LED stack **233**, another portion of light R may be emitted through the second LED stack **233**, and the other portion may be emitted through each of the second LED stack **233** and the third LED stack **243**. A portion of light G generated in the second LED stack **233** may be emitted in a region not covered with the third LED stack **243**, and the other portion may be emitted through the third LED stack **243**. Light B generated in the third LED stack **243** may be emitted through a top surface thereof.

[0289] In general, in the first LED stack **223**, a region covered with the second LED stack **233** may have light loss, and therefore, light with higher intensity per unit area may be emitted in a region not covered with the second LED stack **233**. As such, an area of the region covered with the second LED stack **233** and an area of the region not covered with the second LED stack **233** in the first LED stack **223** may be adjusted to control the intensity of light emitted from the first LED stack **223**. Likewise, an area of the region covered with the third LED stack **243** and an area of the region not covered with the third LED stack **243** in the second LED stack **233** may be adjusted to control the intensity of light emitted from the second LED stack **233**.

[0290] For example, when the first LED stack **223** emits red light, the second LED stack **233** emits green light, and the third LED stack **243** emits blue light, since the green light has a high visibility, it may be necessary to decrease the intensity of green light. As such, the area of the region of the second LED stack **233** that is not covered with the third LED stack **243** may be smaller than the area of the third LED stack **243**. In addition, since red light has a low visibility, it may be necessary to increase the intensity of red light. As such, the area of the region of the first LED stack **223** that is not covered with the second LED stack **233** may be larger than the area of the third LED stack **243**.

[0291] The first LED stack **223**, the second LED stack **233**, and the third LED stack **243** each includes an n-type semiconductor layer, a p-type semiconductor layer, and an active layer interposed therebetween. The active layer may have a multiple quantum well structure. The first to third LED stacks **223**, **233**, and **243** may include different active layers, and thus may emit light at different wavelengths. For example, the first LED stack **223** may be an inorganic light emitting diode that emits red light, the second LED stack **233** may be an inorganic light emitting diode that emits green light, and the third LED stack **243** may be an inorganic light emitting diode that emits blue light. To this end, the first LED stack **223** may include a GaInP-based well layer, and the second LED stack **233** and the third LED stack **243** may include a GaInN-based well layer.

[0292] FIG. **15** is a schematic circuit diagram of a display apparatus according to an exemplary embodiment.

[0293] Referring to FIG. **15**, a display apparatus according to an exemplary embodiment may be implemented to be driven in a passive matrix manner. As described with reference to FIGS. **13** and **14**, one pixel includes first to third sub-pixels R, G, and B. The first LED stack **223** of the first sub-pixel R emits light at a first wavelength, the second LED stack **233** of the second sub-pixel G emits light at a second wavelength, and the third LED stack **243** of the third sub-pixel B emits light at a third wavelength. Cathodes of the first to third sub-pixels R, G, and B may be connected to a common line, for example a data line Vdata **225**, and the anodes thereof may be connected to different lines, for example scan lines Vscan **271**, **273**, and **275**.

[0294] More particularly, the cathodes of the first to third sub-pixels R, G, and B of a first pixel are connected in common to the data line Vdata**1**, and the anodes thereof are connected to the scan lines Vscan**1**-**1**, Vscan**1**-**2**, and Vscan**1**-**3**. Thus, the sub-pixels R, G, and B in the same pixel may be driven individually.

[0295] Further, each of the LED stacks **223**, **233**, and **243** may be driven in a pulse width modulation scheme or by changing the intensity of the current, thereby adjusting luminance of each sub-pixel. Further, it is possible to adjust the luminance by adjusting an area of the first to third LED stacks **223**, **233**, and **243** and an area of a region where the LED stacks **223**, **233**, and **243** do not overlap as shown in FIG. **14**.

[0296] FIG. **16** is a schematic plan view of a display apparatus according to an exemplary embodiment. The display apparatus **200**A includes a plurality of pixels **20**A aligned on a support substrate **251** in accordance to a circuit diagram of FIG. **15**. FIG. **17** is an enlarged plan view of one pixel **20**A region of the display apparatus of FIG. **16**. FIGS. **18**A to **18**D are schematic cross-sectional views taken along lines A-A, B-B, C-C, and D-D of FIG. **17**, respectively.

[0297] Referring to FIGS. **16**, **17**, **18**A, **18**B, **18**C and **18**D, the display apparatus **200**A may include the support substrate **251**, and a plurality of pixels **20**A disposed on the support substrate **251**. Each pixel **20**A includes first to third sub-pixels R, G, and B. More particularly, the pixel **20**A includes the first LED stack **223**, the second LED stack **233**, the third LED stack **243**, a reflective electrode **225**, a first ohmic electrode **229**, a second transparent electrode **236**, a second ohmic electrode **237**, a second current spreading layer **239**, a third transparent electrode **246**, a third ohmic electrode **247**, a third current spreading layer **249**, a first color filter **235**, a second color filter **245**, a first bonding layer **253**, a second bonding layer **255**, a third bonding layer **257**, an insulating layer **227**, a lower insulating layer **261**, an upper insulating layer **263**, interconnection lines **271**, **273**, and **275**, and connectors **271***a*, **273***a*, **275***a*, **277***a*, and **277***b*.

[0298] Each sub-pixel R, G, and B is connected to the reflective electrodes **225** and the interconnection lines **271**, **273**, and **275**. As shown in FIG. **15**, the reflective electrode

225 may be used as the data line Vdata, and the interconnection lines **271**, **273**, and **275** may be used as the scan line Vscan.

[0299] As shown in FIG. **16**, the pixels **20**A may be arranged in a matrix form, the cathodes of the sub-pixels R, G, and B of each pixel **20**A are connected in common to the reflective electrode **225**, and the anodes thereof are connected to the interconnection lines **271**, **273**, and **275**, respectively, which are spaced apart from each other. The connectors **271***a*, **273***a*, and **275***a* may connect the interconnection lines **271**, **273**, and **275** with the sub-pixels R, G, and B, respectively.

[0300] The support substrate **251** supports the LED stacks **223**, **233**, and **243**. The support substrate **251** may have a circuit on the surface or in the inner part thereof, but the inventive concepts are not limited thereto. The support substrate **251** may include, for example, a glass substrate, a sapphire substrate, a Si substrate, or a Ge substrate.

[0301] The first LED stack **223** includes a first conductivity type semiconductor layer **223***a* and a second conductivity type semiconductor layer **223***b*, the second LED stack **233** includes a first conductivity type semiconductor layer **233***a* and a second conductivity type semiconductor layer **233***b*, and the third LED stack **243** includes a first conductivity type semiconductor layer **243***a* and a second conductivity type semiconductor layer **243***b*. In addition, although not shown, an active layer may be interposed between the first conductivity type semiconductor layers **223***a*, **233***a*, and **243***a* and the second conductivity type semiconductor layers **223***b*, **233***b*, and **243***b*, respectively.

[0302] According to an exemplary embodiment, the first conductivity type semiconductor layers **223***a*, **233***a*, and **243***a* are n-type semiconductor layers, and the second conductivity type semiconductor layers **223***b*, **233***b*, and **243***b* are p-type semiconductor layers, respectively. A roughened surface may be formed on at least one surface of the first conductivity type semiconductor layers **223***a*, **233***a*, and **243***a* by surface texturing.

[0303] The first LED stack **223** is disposed closer to the support substrate **251**, the second LED stack **233** is disposed on the first LED stack **223**, and the third LED stack **243** is disposed on the second LED stack **233**. Further, the second LED stack **233** is disposed on a partial region of the first LED stack **223**, and thus, the first LED stack **223** partially overlaps the second LED stack **233**. In addition, the third LED stack **243** is disposed on a partial region of the second LED stack **233**, and thus, the second LED stacks **223** and **233** partially overlap the third LED stack **243**. As such, at least a portion of light generated in the first LED stack **223** may be emitted to the outside without passing through the second and third LED stacks **233** and **243**. In addition, at least a portion of light generated in the second LED stack **233** may be emitted to the outside without passing through the third LED stack **243**.

[0304] The first LED stack **223**, the second LED stack **233**, and the third LED stack **243** may include substantially the same material as those of the LED stacks **223**, **233**, and **234** of FIG. **14**, and thus, detailed descriptions thereof will be omitted to avoid redundancy.

[0305] The reflective electrode **225** is in ohmic contact with a lower surface of the first LED stack **223**, more particularly, the first conductivity type semiconductor layer **223***a*. The reflective electrode **225** includes a reflective layer to reflect light emitted from the first LED stack **223**. The reflective electrode **225** may overlap substantially the entire lower surface of the first LED stack **223**. Further, the reflective electrode **225** may be connected in common to the plurality of pixels **20***a*, and used as the data line Vdata.

[0306] The reflective electrode **225** may be formed of a material layer forms an ohmic contact with the second conductivity type semiconductor layer **223***b* of the first LED stack **223**, and further may include a reflective layer that reflects light generated in the first LED stack **223**, for example, red light.

[0307] The reflective electrode **225** may include an ohmic reflective layer, and may be formed of, for example, an Au—Te alloy, an Au—Ge alloy, or the like. These alloys have high reflectance with respect to light in a red region, and forms an ohmic contact with the first conductivity type semiconductor layer **223***a*.

[0308] The first ohmic electrode **229** is in ohmic contact with the second conductivity type semiconductor layer **223***b* of the first sub-pixel R. The first ohmic electrode **229** may be formed of, for example, an Au—Zn alloy, an Au—Be alloy, or the like. The first ohmic electrode **229** may include a pad region and an extension part. As shown in FIG. **18**B, a connector **275***a* may be connected to the pad region of the first ohmic electrode **229**. The first ohmic electrode **229** may be spaced apart from the second LED stack **233**.

[0309] The second ohmic electrode **237** is in ohmic contact with the first conductivity type semiconductor layer **233***a* of the second LED stack **233**. The second ohmic electrode **237** may be disposed on the first conductivity type semiconductor layer **233***a*. For example, the second conductivity type semiconductor layer **233***b* and the active layer disposed on the first conductivity type semiconductor layer **233***a* may be partially removed to expose the first conductivity type semiconductor layer **233***a*, and the second ohmic electrode **237** may be disposed on the exposed first conductivity type semiconductor layer **233***a*.

[0310] As shown in FIG. **18**C, the connector **277***b* may electrically connect the second ohmic electrode **237** to the reflective electrode **225**. The second ohmic electrode **237** may be spaced apart from the third LED stack **243**.

[0311] The second transparent electrode **236** is in ohmic contact with the second conductivity type semiconductor layer **233***b* on an upper surface of the second LED stack **233**. The second transparent electrode **236** may cover substantially the entire regions of the second conductivity type semiconductor layer **233***b*. As such, the second transparent electrode **236** may surround the third LED stack **243** in a plan view, while being interposed between the second LED stack **233** and the third LED stack **243**. The second transparent electrode **236** may be formed of a transparent oxide layer or a transparent metal layer.

[0312] The second transparent electrode **236** according to an exemplary embodiment is disposed on the upper surface side of the second LED stack **233**, which is relatively spaced further away from the support substrate **251**. In this manner, the second transparent electrode **236** may be formed on the second LED stack **233** after a growth substrate of the second LED stack **233** is removed. As such, the second transparent electrode **236** is prevented from being damaged during removal of the growth substrate.

[0313] The second current spreading layer **239** may be disposed on the second transparent electrode **236**, and may be electrically connected to the second conductivity type semiconductor layer **233***b* through the second transparent electrode **236**. The second current spreading layer **239** may be spaced apart from the third LED stack **243**. The second current spreading layer **239** may include a pad region and an extension part as shown in FIG. **17**, and a connector **273***a* may be connected to the pad region of the second current spreading layer **239**.

[0314] The second ohmic electrode **237** and the second current spreading layer **239** may be formed together with the same material layer during the same process. Accordingly, the second ohmic electrode **237** and the second current spreading layer **239** may have substantially the same layer structure.

[0315] The third ohmic electrode **247** is in ohmic contact with the first conductivity type semiconductor layer **243***a* of the third LED stack **243**. The third ohmic electrode **247** may be disposed on the first conductivity type semiconductor layer **243***a*. For example, the second conductivity type semiconductor layer **243***b* and the active layer disposed on the first conductivity type semiconductor layer **243***a* may be partially removed to expose the first conductivity type semiconductor layer **243***a*, and the third ohmic electrode **247** may be disposed on the exposed first conductivity type semiconductor layer **243***a*. As shown in FIG. **18**D, the connector **277***a* may electrically connect the third ohmic electrode **247** to the reflective electrode **225**.

[0316] The third transparent electrode **246** may be in ohmic contact with the second conductivity type semiconductor layer **243***b* of the third LED stack **243**. The third transparent electrode **246** may cover substantially the entire regions of the second conductivity type semiconductor layer **243***b*. The third transparent electrode **246** may be formed of a transparent oxide layer or a transparent metal layer.

[0317] The third transparent electrode **246** according to an exemplary embodiment is disposed on an upper surface side of the third LED stack **243**, which is relatively spaced further away from the support substrate **251**. In this manner, the third transparent electrode **246** may be formed on the third LED stack **243** after a growth substrate of the third LED stack **243** is removed. Therefore, the third transparent electrode **246** is prevented from being damaged during removal of the growth substrate.

[0318] The third current spreading layer **249** may be disposed on the third transparent electrode **246**, and may be electrically connected to the second conductivity type semiconductor layer **243***b* through the third transparent electrode **246**. The third current spreading layer **246** may include a pad region and an extension part, and as shown in FIG. **18**D, the connector **271***a* may be connected to the pad region of the third current spreading layer **249**.

[0319] Each of the first ohmic electrode **229**, the second current spreading layer **239**, and the third current spreading layer **246** may include an extension part to assist in current dispersion within each LED stack.

[0320] The third ohmic electrode **247** and the third current spreading layer **249** may be formed together with the same material layer during the same process. Accordingly, the third ohmic electrode **247** and the third current spreading layer **249** may have substantially the same layer structure. Further, all of the second ohmic electrode **237**, the second current spreading layer **239**, the third ohmic electrode **247**, and the third current spreading layer **249** may be formed in the same process and have substantially the same layer structure.

[0321] The first color filter **235** may be disposed between the first LED stack **223** and the second LED stack **233**. In addition, the second color filter **245** may be disposed between the second LED stack **233** and the third LED stack **243**. The first color filter **235** transmits light generated in the first LED stack **223** and reflects light generated in the second LED stack **233**. Meanwhile, the second color filter **245** transmits light generated in the first and second LED stacks **223** and **233** and reflects light generated in the third LED stack **243**. Thus, light generated in the first LED stack **223** may be emitted to the outside through the second LED stack **233** and the third LED stack **243**, and light generated in the second LED stack **233** may be emitted to the outside through the third LED stack **243**. Further, it is possible to prevent light generated in the second LED stack **233** from being incident on the first LED stack **223** to be lost, or light generated in the third LED stack **243** from being incident on the second LED stack **233** to be lost.

[0322] According to some exemplary embodiments, the first color filter **237** may reflect light generated in the third LED stack **243**.

[0323] Each of the first and second color filters **235** and **245** may be, for example, a low pass filter that passes through only a low frequency region, that is, a long wavelength region, a band pass filter that passes through only a predetermined wavelength band, or a band stop filter that blocks only the predetermined wavelength band. In particular, the first and second color filters **237** and **247** may be formed by alternately stacking the insulating layers having different refractive indices. For example, the first and second color filters **235** and **245** may be formed by alternately stacking TiO_2 and SiO_2. In particular, the first and second color filters **235** and **245** may include a distributed Bragg reflector (DBR). The stop band of the distributed Bragg reflector may be controlled by adjusting the thicknesses of TiO_2 and SiO_2. The low pass filter and the band pass filter may also be formed by alternately stacking the insulating layers having different refractive indices.

[0324] The first bonding layer **253** couples the first LED stack **223** to the support substrate **251**. The reflective electrode **225** may be in contact with the first bonding layer **253**. The first bonding layer **253** may be light transmissive or non-transmissive. The first bonding layer **253** may be formed of an organic material layer or an inorganic material layer. Examples of the organic layer may include SUB, poly(methylmethacrylate) (PMMA), polyimide, parylene, benzocyclobutene (BCB), or the like. Examples of the inorganic layer may include Al_2O_3, SiO_2, SiN_x, or the like. The organic material layer may be bonded at a high vacuum and high pressure. The inorganic material layers may be surface-planarized by, for example, a chemical mechanical polishing process, then surface energy may be controlled by using plasma, or the like, and may be bonded at high vacuum using the surface energy. In particular, by using an adhesive layer that absorbs light, such as black epoxy, as in the first bonding layer **253**, a contrast ratio of the display apparatus may be improved. The first bonding layer **253** may also be formed of spin-on-glass.

[0325] The second bonding layer **255** couples the first LED stack **223** to the second LED stack **233**. The second bonding layer **255** may be disposed between the first LED stack **223** and the first color filter **235**. The second bonding layer **255** may transmit light generated in the first LED stack

223 and may be formed of the light transmissive bonding material described above with reference to the first bonding layer **253**.

[0326] The insulating layer **227** may be interposed between the second bonding layer **255** and the first LED stack **223**. The insulating layer **227** may be in contact with the second conductivity type semiconductor layer **223***b*. The insulating layer **227** may be formed of, for example, SiO_2, thereby improving bonding strength of the second bonding layer **255**.

[0327] The third bonding layer **257** couples the second LED stack **233** and the third LED stack **243**. The third bonding layer **257** may be disposed between the second LED stack **236** and the second color filter **245** to bond the second LED stack **236** and the second color filter **245**. The third bonding layer **257** may transmit light generated in the first and second LED stacks **223** and **233**, and may be formed of the light transmissive bonding material described above with reference to the first bonding layer **253**.

[0328] The lower insulating layer **261** may cover the first to third LED stacks **223**, **233**, and **243**. In particular, the lower insulating layer **261** covers the reflective electrode **225** exposed around the first LED stack **223**. Meanwhile, the lower insulating layer **261** may have openings for providing an electrical connection path.

[0329] The upper insulating layer **263** covers the lower insulating layer **261**. The upper insulating layer **263** may also have openings for providing an electrical connection path.

[0330] The lower insulating layer **261** and the upper insulating layer **263** are not particularly limited as long as they have insulating properties, and may be formed of, for example, silicon oxide or silicon nitride.

[0331] As shown in FIGS. **16** and **17**, the interconnection lines **271**, **273**, and **275** may be arranged to be orthogonal to the exposed reflective electrode **225** in plan view. The interconnection line **271** and the interconnection line **275** may be disposed on the upper insulating layer **263** and may be connected to the third current spreading layer **249** and the first ohmic electrode **229** through the connectors **271***a* and **275***a*, respectively. To this end, the upper insulating layer **263** and the lower insulating layer **261** may have openings exposing the third ohmic electrode **247** and the first ohmic electrode **229**.

[0332] The interconnection line **273** is disposed on the lower insulating layer **261** and is insulated from the reflective electrode **225**. The interconnection line **273** may be disposed between the lower insulating layer **261** and the upper insulating layer **263**, and may be connected to the second current spreading layer **239** through the connector **273***a*. To this end, the lower insulating layer **261** has an opening exposing the second current spreading layer **239**.

[0333] The connectors **277***a* and **277***b* are disposed between the lower insulating layer **261** and the upper insulating layer **263**, respectively. As such, the third ohmic electrode **247** and the second ohmic electrode **237** are electrically connected to the reflective electrode **225**. To this end, the lower insulating layer **261** may have openings exposing the third ohmic electrode **247** and the second ohmic electrode **237**.

[0334] The interconnection line **271** and the interconnection line **273** may be insulated from each other by the upper insulating layer **263**, and thus the interconnection lines **271** and **273** may be arranged to overlap each other in the vertical direction.

[0335] The display apparatus **200**A of FIGS. **16** to **18** has a structure in which the electrodes of each pixel are connected to the data lines and the scan lines. In particular, the interconnection lines **271** and **275** of FIG. **16** are disposed on the upper insulating layer **263**, and the interconnection line **273** is disposed between the lower insulating layer **261** and the upper insulating layer **263**. However, the inventive concepts are not limited thereto. For example, the interconnection lines **271** and **275** may be formed on the lower insulating layer **261** together with the interconnection line **273** and may be covered with the upper insulating layer **263**, and the connectors **271***a* and **275***a* may be formed on the upper insulating layer **263**.

[0336] Hereinafter, a manufacturing method of a display apparatus **200**A according to the above-described exemplary embodiment will be described.

[0337] FIGS. **19**A to **33** are schematic plan views and cross-sectional views illustrating a manufacturing method of a display apparatus according to exemplary embodiments. In FIGS. **19**A to **33**, various cross-sectional views are taken along line A-A of the corresponding plan view.

[0338] Referring to FIGS. **19**A and **19**B, the first LED stack **223** is grown on the first substrate **21**. The first substrate **21** may be, for example, a GaAs substrate. The first LED stack **223** is formed with AlGaInP-based semiconductor layers and includes a first conductivity type semiconductor layer **223***a*, an active layer, and a second conductivity type semiconductor layer **223***b*.

[0339] The insulating layer **227** may be formed on the first LED stack **223**. The insulating layer **227** may be patterned to have openings exposing the second conductivity type semiconductor layer **223***b*. The insulating layer **227** may be formed of a hydrophilic material layer, for example, SiO_2. According to an exemplary embodiment, the insulating layer **227** may be omitted.

[0340] The first ohmic electrode **229** may be formed in the opening of the insulating layer **227**. The first ohmic electrode **229** may be formed of, for example, an Au—Zn alloy, an Au—Be alloy, or the like. The first ohmic electrode **229** may be formed to have a pad region and an extension part. The first ohmic electrode **229** may be formed by a lift-off technique, and be formed in each pixel region. The first ohmic electrode **229** may be disposed toward one side of a pixel region as shown in FIG. **19**A.

[0341] Next, referring to FIG. **20**A, a preliminary substrate **321***a* may be attached to the first LED stack **223** through the bonding layer **323***a*. The preliminary substrate **321***a* is not particularly limited, and may be any substrate capable of supporting the first LED stack **223**. Meanwhile, the first substrate **221** is removed from the first LED stack **223** using a chemical etching technique to expose the first conductivity type semiconductor layer **223***a* of the first LED stack **223**. The exposed surface of the first conductivity type semiconductor layer **223***a* may be roughened by surface texturing.

[0342] The reflective electrode **225** is formed on the exposed first LED stack **223**. The reflective electrode **225** may be formed of, for example, an Au—Te alloy, an Au—Ge alloy, or the like. The reflective electrode **225** may be formed by using a lift-off technique, and may be patterned to have a specific shape. For example, the reflective electrode **225**

may be patterned to have a shape that longitudinally connects a plurality of pixels. However, the inventive concepts are not limited thereto, and the reflective electrode **225** may be formed on substantially the entire surface of the first LED stack **223** without patterning, and then patterned at later steps. The reflective electrode **225** may be in ohmic contact with the first conductivity type semiconductor layer **223***a* of the first LED stack **223**, which may be the n-type semiconductor layer.

[0343] Referring to FIG. **20**B, the support substrate **251** is bonded to the first LED stack **223** via the first bonding layer **253**. The reflective electrode **225** on the first LED stack **223** may be disposed to face the support substrate **251** to be bonded to the support substrate **251**. Thus, the first bonding layer **253** may be in contact with the reflective electrode **225** and the first conductivity type semiconductor layer **223***a*.

[0344] After the supporting substrate **251** is bonded, the preliminary substrate **321***a* and *s* the bonding layer **323***a* may be removed. Thus, the insulating layer **227** and the first ohmic electrode **229** may be exposed.

[0345] Referring to FIG. **21**A, the second LED stack **233** is grown on the second substrate **31**. The second LED stack **233** may be formed of gallium nitride semiconductor layers and may include a first conductivity type semiconductor layer **233***a*, a GaInN well layer, and a second conductivity type semiconductor layer **233***b*. The second substrate **31** is a substrate on which the gallium nitride-based semiconductor layer may be grown, and may be different from the first substrate **21**. A composition ratio of GaInN may be determined so that the second LED stack **233** emits green light.

[0346] Referring to FIG. **21**B, a preliminary substrate **321***b* is attached onto the second LED stack **233** via the bonding layer **323***b*. The preliminary substrate **321***b* is not particularly limited, and may be any substrate capable of supporting the second LED stack **233**.

[0347] Referring to FIG. **21**C, the second substrate **231** is then removed. The second substrate **31** may be separated from the second LED stack **233** by using techniques, such as laser lift-off, chemical lift-off, or the like, to expose the first conductivity type semiconductor layer **233***a* of the second LED stack **233**. The exposed surface of the first conductivity type semiconductor layer **233***a* may be roughened by surface texturing.

[0348] The first color filter **235** may be formed on the exposed first conductivity type semiconductor layer **233***a*. The first color filter **235** may be in contact with the first conductivity type semiconductor layer **233***a*. The material of the first color filter **235** is substantially the same as that of FIG. **18**A, detailed descriptions thereof will be omitted to avoid redundancy.

[0349] Referring to FIG. **22**A, the third LED stack **243** is grown on the third substrate **41**. The third LED stack **243** may be formed of gallium nitride-based semiconductor layers and may include a first conductivity type semiconductor layer **243***a*, a GaInN well layer, and a second conductivity type semiconductor layer **243***b*. The third substrate **41** is a substrate on which the gallium nitride-based semiconductor layer may be grown, and may be different from the first substrate **21**. A composition ratio of GaInN may be determined so that the third LED stack **243** emits blue light.

[0350] Referring to FIG. **22**B, a preliminary substrate **321***c* is attached onto the third LED stack **243** via the bonding layer **323***c*. The preliminary substrate **321***c* is not particularly limited, and may be any substrate capable of supporting the third LED stack **243**.

[0351] Referring to FIG. **22**C, the third substrate **41** is then removed. The third substrate **41** may be separated from the third LED stack **243** by using techniques such as laser lift-off, chemical lift-off, or the like, to expose the first conductivity type semiconductor layer **243***a* of the third LED stack **243**. The exposed surface of the first conductivity type semiconductor layer **243***a* may be roughened by surface texturing.

[0352] The second color filter **245** may be formed on the exposed first conductivity type semiconductor layer **243***a*. The second color filter **245** may be in contact with the first conductivity type semiconductor layer **243***a*. The material of the second color filter **245** is substantially the same as that of FIG. **18**A, and thus, detailed descriptions thereof will be omitted to avoid redundancy.

[0353] Meanwhile, since the first LED stack **223**, the second LED stack **233**, and the third LED stack **243** are grown on different substrates, the order of formation of the LED stacks are not particularly limited.

[0354] Referring to FIGS. **23**A and **23**B, first, the second LED stack **233** of FIG. **21**C is bonded to the exposed insulating layer **227** and the first ohmic electrode **229** of FIG. **20**B via the second bonding layer **255**.

[0355] The first color filter **235** may be disposed to face the support substrate **251** and bonded to the insulating layer **227** through the second bonding layer **255**. The second bonding layer **255** may be formed of a light transmissive material.

[0356] Subsequently, the preliminary substrate **321***b* and the bonding layer **323***b* are removed to expose the second conductivity type semiconductor layer **233***b*, and the second transparent electrode **236** is formed on the exposed second conductivity type semiconductor layer **233***b*. The second transparent electrode **236** is in ohmic contact with the second conductivity type semiconductor layer **233***b*. The second transparent electrode **236** may cover substantially the entire regions of the second conductivity type semiconductor layer **233***b*.

[0357] Since the second transparent electrode **236** is formed after the second substrate **31** is removed from the second LED stack **233**, the second transparent electrode **236** may be prevented from being damaged during a removing process of the second substrate **231**.

[0358] Referring to FIGS. **24**A and **24**B, the third LED stack **243** of FIG. **22**C is bonded to the second LED stack **233**, on which the second transparent electrode **236** is formed, via the third bonding layer **257**.

[0359] The second color filter **245** may be disposed to face the second LED stack **233** and bonded to the second transparent electrode **236** through the third bonding layer **257**. The third bonding layer **257** may be formed of a light transmissive material.

[0360] Subsequently, the preliminary substrate **321***c* and the bonding layer **323***c* are removed to expose the second conductivity type semiconductor layer **243***b*, and the third transparent electrode **246** is formed on the exposed second conductivity type semiconductor layer **243***b*. The third transparent electrode **246** is in ohmic contact with the second conductivity type semiconductor layer **243***b*. The third transparent electrode **246** may cover substantially the entire regions of the second conductivity type semiconductor layer **243***b*.

[0361] Referring to FIGS. **25**A and **25**B, the third transparent electrode **246**, the second conductivity type semiconductor layer **243***b*, and the active layer are patterned to expose the first conductivity type semiconductor layer **243***a* in each pixel region. The third transparent electrode **246** may be remained while being defined within a third sub-pixel region, and may include a recessed part as shown in FIG. **25**A.

[0362] Then, the third ohmic electrode **247** and the third current spreading layer **249** are formed on the third transparent electrode **246** and the first conductivity type semiconductor layer **243***a*, respectively. The third ohmic electrode **247** may be formed in the recessed part. The third ohmic electrode **247** and the third current spreading layer **249** may be formed with the same material layer during the same process, and thus, the third ohmic electrode **247** and the third current spreading layer **249** may have substantially the same structure. However, the inventive concepts are not limited thereto, and the third ohmic electrode **247** and the third current spreading layer **249** may be formed in separate processes. For example, the third current spreading layer **249** may be formed before the third transparent electrode **246** is patterned, and the third ohmic electrode **247** may be formed after the first conductivity type semiconductor layer **243***a* is exposed, or vice versa. Further, the third ohmic electrode **247** and the third current spreading layer **249** may be formed together with the second current spreading layer **239** to be described below.

[0363] Referring to FIGS. **26**A and **26**B, the second transparent electrode **236** is exposed by sequentially patterning the first conductivity type semiconductor layer **243***a*, the second color filter **245**, and the third bonding layer **257**. In this manner, the third sub-pixel region B is defined, and the second transparent electrode **236** is exposed around the third sub-pixel region B.

[0364] Referring to FIGS. **27**A and **27**B, the second transparent electrode **236**, the second conductivity type semiconductor layer **233***b*, and the active layer are patterned to expose the first conductivity type semiconductor layer **233***a*. The second transparent electrode **236** may be remained while being defined within a second sub-pixel region, and may include a recessed part as shown in FIG. **27**A.

[0365] Then, the second ohmic electrode **237** and the second current spreading layer **239** are formed on the second transparent electrode **236** and the first conductivity type semiconductor layer **233***a*, respectively. The second ohmic electrode **237** may be formed in the recessed part. The second ohmic electrode **237** and the second current spreading layer **239** may be formed with the same material layer during the same process, and thus, the second ohmic electrode **237** and the second current spreading layer **239** may have substantially the same structure.

[0366] Further, the third ohmic electrode **247** and the third current spreading layer **249** may also be formed together with the second ohmic electrode **237** and the second current spreading layer **239** with the same material layer during the same process.

[0367] However, the inventive concepts are not limited thereto, and the second ohmic electrode **237** and the second current spreading layer **239** may be formed in separate processes. For example, the second current spreading layer **239** may be formed first before the second transparent electrode **236** is patterned, and the second ohmic electrode **237** may be formed after the first conductivity type semiconductor layer **233***a* is exposed, or vice versa.

[0368] Referring to FIGS. **28**A and **28**B, the second transparent electrode **23***b* is exposed by sequentially patterning the first conductivity type semiconductor layer **233***a*, the first color filter **235**, the second bonding layer **255**, and the insulating layer **227**. In this manner, the second sub-pixel region B is defined, and the second conductivity type semiconductor layer **223***b* is exposed around the second sub-pixel region G. In addition, the first ohmic electrode **229** is exposed on the outer side of the second LED stack **233**, and the second LED stack **233** partially overlaps with the third LED stack **243**. In particular, the third LED stack **243** is disposed to be defined within a region of the second LED stack **233**.

[0369] Referring to FIGS. **29**A and **29**B, the first LED stack **223** is patterned to remove the first LED stack **223** at a portion other than the first sub-pixel R region. Meanwhile, the first ohmic electrode **229** may be remained in the first sub-pixel R region. The first LED stack **223** partially overlaps the second LED stack **233** and the third LED stack **243**. In particular, the second LED stack **233** and the third LED stack **243** are disposed to be defined within a region of the first LED stack **223**.

[0370] Meanwhile, by patterning the first LED stack **223**, the reflective electrode **225** may be exposed and the surface of the first bonding layer **253** may also be partially exposed. According to another exemplary embodiment, an insulating layer may be disposed on the first bonding layer **253**, and thus, the insulating layer may be exposed rather than the first bonding layer **253**.

[0371] According to an exemplary embodiment, each of the first ohmic electrode **229**, the second current spreading layer **239**, and the third current spreading layer **249** may include a pad region and an extension part, and the extension part may extend along a length direction of the exposed reflective electrode **225**. However, the inventive concepts are not limited thereto.

[0372] Referring to FIGS. **30**A and **30**B, the lower insulating layer **261** is then formed to cover the first to third LED stacks **223**, **233**, and **243**, and the reflective electrode **225** and the first bonding layer **253**. The second transparent electrode **236** and the third transparent electrode **246** are also covered by the lower insulating layer **261**. The lower insulating layer **261** may be patterned to form openings exposing the first ohmic electrode **229**, the second ohmic electrode **237**, the second current spreading layer **239**, the third ohmic electrode **247**, the third current spreading layer **249**, and the reflective electrode **225**.

[0373] Referring to FIG. **31**, the interconnection line **273** and connectors **273***a*, **277***a*, and **277***b* are formed on the lower insulating layer **261**. The connector **273***a* connects the second current spreading layer **239** to the interconnection line **273**, the connector **277***a* connects the third ohmic electrode **247** to the reflecting electrode **225**, and the connector **277***b* connects the second ohmic electrode **237** to the reflective electrode **225**. A cross-sectional view taken along line A-A of FIG. **31** is the same as FIG. **30**B.

[0374] Referring to FIGS. **32**A and **32**B, the upper insulating layer **263** is then formed to cover the interconnection line **273** and the connectors **273***a*, **277***a* and **277***b*. The upper insulating layer **263** may be patterned to expose the pad regions of the first ohmic electrode **229** and the third current spreading layer **249**.

[0375] Referring to FIG. **33**, interconnection lines **271** and **275** and connectors **271***a* and **275***a* are then formed on the upper insulating layer **263**. The connector **271***a* connects the interconnection line **271** to the third current spreading layer **249**, and the connector **275***a* connects the interconnection line **275** to the first ohmic electrode **229**.

[0376] As such, the display apparatus **200**A described with reference to FIGS. **16** and **17** is manufactured.

[0377] FIG. **34** is a schematic cross-sectional view of a display apparatus according to another exemplary embodiment.

[0378] Referring to FIG. **34**, the display apparatus according to an exemplary substantially similar to the display apparatus of FIGS. **16** and **17**, except that the transparent electrode **226** is disposed on the upper surface of the first LED stack **223**, and the first current spreading layer **229** is disposed on the transparent electrode **226**. In particular, the transparent electrode **226** is disposed on the first conductivity type semiconductor layer **223***a* to be in ohmic contact with the first conductivity type semiconductor layer **223***a*. The transparent electrode **226** may cover substantially the entire upper surface of the first LED stack **223**, and thus, may be interposed between the first LED stack **223** and the second LED stack **233** as well as the outer side of the second LED stack **233**.

[0379] The transparent electrode **226** may be formed to cover most of the region of the second conductivity type semiconductor layer **223***b* before forming the insulating layer **227** described with reference to FIG. **19**A. In addition, the insulating layer **227** may be omitted. Meanwhile, the first current spreading layer **229** may be formed directly on the transparent electrode **226**. Alternatively, the first current spreading layer **229** may be formed after the first conductivity type semiconductor layer **233***a*, the first color filter **235**, the second bonding layer **255**, and the insulating layer **227** are patterned to expose the transparent electrode **226** so as to define the second sub-pixel region G, as described with reference to FIGS. **28**A and **28**B.

[0380] In this manner, since the first current spreading layer **229** may not need to be in ohmic contact with the first conductivity type semiconductor layer **223***a* by forming the transparent electrode **226**, the first current spreading layer **229** may be formed with the second current spreading layer **239** or the third current spreading layer **249** with the same material layer. Thus, the first current spreading layer **229** may also be formed together with the same material layer during the same process when forming the second ohmic electrode **237**, the second current spreading layer **239**, the third ohmic electrode **247**, and the third current spreading layer **249**.

[0381] Meanwhile, the display apparatus of FIG. **34** is described as including pixels driven in a passive matrix driving manner, however the inventive concepts are not limited thereto, and the pixels may be driven in the active matrix driving manner.

[0382] FIG. **35** is a schematic circuit diagram of a display apparatus according to still another exemplary embodiment. Here, the circuit diagram of the display apparatus is driven in the active matrix manner.

[0383] Referring to FIG. **35**, a driving circuit according to an exemplary embodiment includes two or more transistors Tr**1** and Tr**2** and a capacitor. When power is connected to selection lines Vrowl to Vrow**3**, and a data voltage is applied to the data lines Vdata**1** to Vdata**3**, a voltage is applied to the corresponding light emitting diode. Further, charges are charged in the corresponding capacitor in accordance with the values of Vdata**1** to Vdata**3**. The transistor Tr**2** may maintain a turn-on state by the charged voltage of the capacitor, and thus, even when power supply is cut off to the selection line Vrowl, voltage of the capacitor may be maintained, and the voltage may be applied to the light emitting diodes LED**1** to LED**3**. Further, currents flowing through the LED**1** to the LED**3** may be changed according to values of Vdata**1** to Vdata**3**. Since the current may always be supplied through Vdd, light may be emitted continuously.

[0384] The transistors Tr**1** and Tr**2** and the capacitor may be formed in the support substrate **251**. The support substrate **251** may also have contact pads on its surface to connect the transistors to the capacitors. In addition, the selection line and the data line may be provided in or on the support substrate **251**, and thus, the interconnection lines **271**, **273**, and **275** described above may be omitted.

[0385] The light emitting diodes LED**1** to LED**3** may correspond to the first to third LED stacks **223**, **233**, and **243**, respectively, in one pixel. The anodes of the first to third LED stacks **223**, **233**, and **243** are connected to the transistor Tr**2**, and the cathodes thereof are grounded. The first ohmic electrode **229**, the second current spreading layer **239**, and the third current spreading layer **249** may be connected to the connection pads on the support substrate **251**, respectively, via the connectors to be connected to the transistor Tr**2**, and the reflective electrode **225** may be connected to the connection pad of the support substrate **251** and grounded.

[0386] The first to third LED stacks **223**, **233**, and **243** may be connected in common to the reflective electrode **225** and grounded. Further, the reflective electrode **225** may be disposed continuously in two or more pixels, or in all pixels. Thus, the reflective electrode **225** may be connected in common to all the LED stacks in the display apparatus. In this manner, noise of an active matrix drive circuit may be eliminated by disposing the reflective electrode **225** between the pixels and the substrate **251**.

[0387] While FIG. **35** illustrates a circuit diagram for an active matrix according to an exemplary embodiment, but the inventive concepts are not limited thereto, and other circuits may be used.

[0388] According to exemplary embodiments, a plurality of pixels may be formed at a wafer level by using wafer bonding, and thus, a display apparatus may be formed without individually mounting the light emitting diodes.

[0389] FIG. **36** is a schematic cross-sectional view of a light emitting diode stack for a display according to an exemplary embodiment.

[0390] Referring to FIG. **36**, the light emitting diode stack **1000** includes a support substrate **1510**, a first LED stack **1230**, a second LED stack **1330**, a third LED stack **1430**, a reflective electrode **1250**, an ohmic electrode **1290**, a second-p transparent electrode **1350**, a third-p transparent electrode **1450**, an insulation layer **1270**, a first color filter **1370**, a second color filter **1470**, a first bonding layer **1530**, a second bonding layer **1550**, and a third bonding layer **1570**. In addition, the first LED stack **1230** may include an ohmic contact portion **1230***a* for ohmic contact.

[0391] The support substrate **1510** supports the semiconductor stacks **1230**, **1330**, and **1430**. The support substrate **1510** may include a circuit on a surface thereof or therein, but the inventive concepts are not limited thereto. The support substrate **1510** may include, for example, a Si substrate or a Ge substrate.

[0392] Each of the first LED stack **1230**, the second LED stack **1330**, and the third LED stack **1430** includes an n-type semiconductor layer, a p-type semiconductor layer, and an active layer interposed therebetween. The active layer may have a multi-quantum well structure.

[0393] For example, the first LED stack **1230** may be an inorganic light emitting diode configured to emit red light, the second LED stack **1330** may be an inorganic light emitting diode configured to emit green light, and the third LED stack **1430** may be an inorganic light emitting diode configured to emit blue light. The first LED stack **1230** may include a GaInP-based well layer, and each of the second LED stack **1330** and the third LED stack **1430** may include a GaInN-based well layer. However, the inventive concepts are limited thereto, and when the light emitting diode stack **1000** includes micro LEDs, the first LED stack **1230** may emit any one of red, green, and blue light, and the second and third LED stacks **1330** and **1430** may emit a different one of the red, green, and blue light without adversely affecting operation or requiring color filters due to its small form factor.

[0394] In addition, both surfaces of each of the first to third LED stacks **1230**, **1330**, **1430** are an n-type semiconductor layer and a p-type semiconductor layer, respectively. In the illustrated exemplary embodiment, each of the first to third LED stacks **1230**, **1330**, and **1430** has an n-type upper surface and a p-type lower surface. Since the third LED stack **1430** has an n-type upper surface, a roughened surface may be formed on the upper surface of the third LED stack **1430** through chemical etching. However, the inventive concepts are not limited thereto, and the semiconductor types of the upper and lower surfaces of each of the LED stacks can be alternatively arranged.

[0395] The first LED stack **1230** is disposed near the support substrate **1510**, the second LED stack **1330** is disposed on the first LED stack **1230**, and the third LED stack **1430** is disposed on the second LED stack **1330**. Since the first LED stack **1230** emits light having a longer wavelength than the second and third LED stacks **1330** and **1430**, light generated from the first LED stack **1230** can be emitted outside through the second and third LED stacks **1330** and **1430**. In addition, since the second LED stack **1330** emits light having a longer wavelength than the third LED stack **1430**, light generated from the second LED stack **1330** can be emitted outside through the third LED stack **1430**.

[0396] The reflective electrode **1250** forms ohmic contact with the p-type semiconductor layer of the first LED stack **1230**, and reflects light generated from the first LED stack **1230**. For example, the reflective electrode **1250** may include an ohmic contact layer **1250***a* and a reflective layer **1250***b*.

[0397] The ohmic contact layer **1250***a* partially contacts the p-type semiconductor layer of the first LED stack **1230**. In order to prevent absorption of light by the ohmic contact layer **1250***a*, a region in which the ohmic contact layer **1250***a* contacts the p-type semiconductor layer may not exceed 50% of the total area of the p-type semiconductor layer. The reflective layer **1250***b* covers the ohmic contact layer **1250***a* and the insulation layer **1270**. As shown in FIG. **36**, the reflective layer **1250***b* may cover substantially the entire ohmic contact layer **1250***a*, without being limited thereto. Alternatively, the reflective layer **1250***b* may cover a portion of the ohmic contact layer **1250***a*.

[0398] Since the reflective layer **1250***b* covers the insulation layer **1270**, an omnidirectional reflector can be formed by the stacked structure of the first LED stack **1230** having a relatively high index of refraction, and the insulation layer **1270** and the reflective layer **1250***b* having a relatively low index of refraction. The reflective layer **1250***b* may cover 50% or more of the area of the first LED stack **1230**, or most of the first LED stack **1230**, thereby improving luminous efficacy.

[0399] The ohmic contact layer **1250***a* and the reflective layer **1250***b* may be metal layers, which may include Au. The reflective layer **1250***b* may be formed of a metal having relatively high reflectance with respect to light generated from the first LED stack **1230**, for example, red light. On the other hand, the reflective layer **1250***b* may be formed of a metal having relatively low reflectance with respect to light generated from the second LED stack **1330** and the third LED stack **1430**, for example, green light or blue light, to reduce interference of light having been generated from the second and third LED stacks **1330** and **1430** and traveling toward the support substrate **1510**.

[0400] The insulation layer **1270** is interposed between the support substrate **1510** and the first LED stack **1230** and has openings that expose the first LED stack **1230**. The ohmic contact layer **1250***a* is connected to the first LED stack **1230** in the openings of the insulation layer **1270**.

[0401] The ohmic electrode **1290** is disposed on the upper surface of the first LED stack **1230**. In order to reduce ohmic contact resistance of the ohmic electrode **1290**, the ohmic contact portion **1230***a* may protrude from the upper surface of the first LED stack **1230**. The ohmic electrode **1290** may be disposed on the ohmic contact portion **1230***a*.

[0402] The second-p transparent electrode **1350** forms ohmic contact with the p-type semiconductor layer of the second LED stack **1330**. The second-p transparent electrode **1350** may include a metal layer or a conducive oxide layer that is transparent to red light and green light.

[0403] The third-p transparent electrode **1450** forms ohmic contact with the p-type semiconductor layer of the third LED stack **1430**. The third-p transparent electrode **1450** may include a metal layer or a conducive oxide layer that is transparent to red light, green light, and blue light.

[0404] The reflective electrode **1250**, the second-p transparent electrode **1350**, and the third-p transparent electrode **1450** may assist in current spreading through ohmic contact with the p-type semiconductor layer of corresponding LED stack.

[0405] The first color filter **1370** may be interposed between the first LED stack **1230** and the second LED stack **1330**. The second color filter **1470** may be interposed between the second LED stack **1330** and the third LED stack **1430**. The first color filter **1370** transmits light generated from the first LED stack **1230** while reflecting light generated from the second LED stack **1330**. The second color filter **1470** transmits light generated from the first and second LED stacks **1230** and **1330**, while reflecting light generated from the third LED stack **1430**. As such, light generated from the first LED stack **1230** can be emitted outside through the second LED stack **1330** and the third LED stack **1430**, and light generated from the second LED stack **1330** can be emitted outside through the third LED stack **1430**. Further, light generated from the second LED stack **1330** may be prevented from entering the first LED stack **1230**, and light generated from the third LED stack **1430** may be prevented from entering the second LED stack **1330**, thereby preventing light loss.

[0406] In some exemplary embodiments, the first color filter **1370** may reflect light generated from the third LED stack **1430**.

[0407] The first and second color filters **1370** and **1470** may be, for example, a low pass filter that transmits light in a low frequency band, that is, in a long wavelength band, a band pass filter that transmits light in a predetermined wavelength band, or a band stop filter that prevents light in a predetermined wavelength band from passing therethrough. In particular, each of the first and second color filters **1370** and **1470** may include a distributed Bragg reflector (DBR). The distributed Bragg reflector may be formed by alternately stacking insulation layers having different indices of refraction one above another, for example, TiO_2 and SiO_2. In addition, the stop band of the distributed Bragg reflector can be controlled by adjusting the thicknesses of TiO_2 and SiO_2 layers. The low pass filter and the band pass filter may also be formed by alternately stacking insulation layers having different indices of refraction one above another.

[0408] The first bonding layer **1530** couples the first LED stack **1230** to the support substrate **1510**. As shown in FIG. **36**, the reflective electrode **1250** may adjoin the first bonding layer **1530**. The first bonding layer **1530** may be a light transmissive or opaque layer.

[0409] The second bonding layer **1550** couples the second LED stack **1330** to the first LED stack **1230**. As shown in FIG. **36**, the second bonding layer **1550** may adjoin the first LED stack **1230** and the first color filter **1370**. The ohmic electrode **1290** may be covered by the second bonding layer **1550**. The second bonding layer **1550** transmits light generated from the first LED stack **1230**. The second bonding layer **1550** may be formed of, for example, light transmissive spin-on-glass.

[0410] The third bonding layer **1570** couples the third LED stack **1430** to the second LED stack **1330**. As shown in FIG. **36**, the third bonding layer **1570** may adjoin the second LED stack **1330** and the second color filter **1470**. However, the inventive concepts are not limited thereto. For example, a transparent conductive layer may be disposed on the second LED stack **1330**. The third bonding layer **1570** transmits light generated from the first LED stack **1230** and the second LED stack **1330**. The third bonding layer **1570** may be formed of, for example, light transmissive spin-on-glass.

[0411] FIGS. **37**A, **37**B, **37**C, **37**D, and **37**E are schematic cross-sectional views illustrating a method of manufacturing a light emitting diode stack for a display according to an exemplary embodiment.

[0412] Referring to FIG. **37**A, a first LED stack **1230** is grown on a first substrate **1210**. The first substrate **1210** may be, for example, a GaAs substrate. The first LED stack **1230** may be formed of AlGaInP-based semiconductor layers and includes an n-type semiconductor layer, an active layer, and a p-type semiconductor layer.

[0413] An insulation layer **1270** is formed on the first LED stack **1230**, and is patterned to form opening(s). For example, a SiO_2 layer is formed on the first LED stack **1230** and a photoresist is deposited onto the SiO_2 layer, followed by photolithography and development to form a photoresist pattern. Then, the SiO_2 layer is patterned through the photoresist pattern used as an etching mask, thereby forming the insulation layer **1270**.

[0414] Then, an ohmic contact layer **1250***a* is formed in the opening(s) of the insulation layer **1270**. The ohmic contact layer **1250***a* may be formed by a lift-off process or the like. After the ohmic contact layer **1250***a* is formed, a reflective layer **1250***b* is formed to cover the ohmic contact layer **1250***a* and the insulation layer **1270**. The reflective layer **1250***b* may be formed by a lift-off process or the like. The reflective layer **1250***b* may cover a portion of the ohmic contact layer **1250***a* or the entirety thereof, as shown in FIG. **37**A. The ohmic contact layer **1250***a* and the reflective layer **1250***b* form a reflective electrode **1250**.

[0415] The reflective electrode **1250** forms ohmic contact with the p-type semiconductor layer of the first LED stack **1230**, and thus, will hereinafter be referred to as a first-p reflective electrode **1250**.

[0416] Referring to FIG. **37**B, a second LED stack **1330** is grown on a second substrate **1310**, and a second-p transparent electrode **1350** and a first color filter **1370** are formed on the second LED stack **1330**. The second LED stack **1330** may be formed of GaN-based semiconductor layers and include a GaInN well layer. The second substrate **1310** is a substrate on which GaN-based semiconductor layers may be grown thereon, and is different from the first substrate **1210**. The composition ratio of GaInN for the second LED stack **1330** may be determined such that the second LED stack **1330** emits green light. The second-p transparent electrode **1350** forms ohmic contact with the p-type semiconductor layer of the second LED stack **1330**.

[0417] Referring to FIG. **37**C, a third LED stack **1430** is grown on a third substrate **1410**, and a third-p transparent electrode **1450** and a second color filter **1470** are formed on the third LED stack **1430**. The third LED stack **1430** may be formed of GaN-based semiconductor layers and include a GaInN well layer. The third substrate **1410** is a substrate on which GaN-based semiconductor layers may be grown thereon, and is different from the first substrate **1210**. The composition ratio of GaInN for the third LED stack **1430** may be determined such that the third LED stack **1430** emits blue light. The third-p transparent electrode **1450** forms ohmic contact with the p-type semiconductor layer of the third LED stack **1430**.

[0418] The first color filter **1370** and the second color filter **1470** are substantially the same as those described with reference to FIG. **36**, and thus, repeated descriptions thereof will be omitted to avoid redundancy.

[0419] As such, the first LED stack **1230**, the second LED stack **1330** and the third LED stack **1430** may be grown on different substrates, and the formation sequence thereof is not limited to a particular sequence.

[0420] Referring to FIG. **37**D, the first LED stack **1230** is coupled to the support substrate **1510** via a first bonding layer **1530**. The first bonding layer **1530** may be previously formed on the support substrate **1510**, and the reflective electrode **1250** may be bonded to the first bonding layer **1530** to face the support substrate **1510**. The first substrate **1210** is removed from the first LED stack **1230** by chemical etching or the like. Accordingly, the upper surface of the n-type semiconductor layer of the first LED stack **1230** is exposed.

[0421] Then, an ohmic electrode **1290** is formed in the exposed region of the first LED stack **1230**. In order to reduce ohmic contact resistance of the ohmic electrode **1290**, the ohmic electrode **1290** may be subjected to heat treatment. The ohmic electrode **1290** may be formed in each pixel region so as to correspond to the pixel regions.

[0422] Referring to FIG. **37**E, the second LED stack **1330** is coupled to the first LED stack **1230**, on which the ohmic electrode **1290** is formed, via a second bonding layer **1550**. The first color filter **1370** is bonded to the second bonding layer **1550** to face the first LED stack **1230**. The second bonding layer **1550** may be previously formed on the first LED stack **1230** so that the first color filter **1370** may face and be bonded to the second bonding layer **1550**. The second substrate **31** may be separated from the second LED stack **1330** by a laser lift-off or chemical lift-off process.

[0423] Then, referring to FIG. **36** and FIG. **37**C, the third LED stack **1430** is coupled to the second LED stack **1330** via a third bonding layer **1570**. The second color filter **1470** is bonded to the third bonding layer **1570** to face the second LED stack **1330**. The third bonding layer **1570** may be previously disposed on the second LED stack **1330** so that the second color filter **1470** may face and be bonded to the third bonding layer **1570**. The third substrate **1410** may be separated from the third LED stack **1430** by a laser lift-off or chemical lift-off process. As such a light emitting diode stack for a display may be formed as shown in FIG. **36**, which has the n-type semiconductor layer of the third LED stack **1430** exposed to the outside.

[0424] A display apparatus according to an exemplary embodiment may be provided by patterning the stack of the first to third LED stacks **1230**, **1330**, and **1430** on the support substrate **1510** in pixel units, followed by connecting the first to third LED stacks to one another through interconnections. Hereinafter, a display apparatus according to exemplary embodiments will be described.

[0425] FIG. **38** is a schematic circuit diagram of a display apparatus according to an exemplary embodiment, and FIG. **39** is a schematic plan view of the display apparatus according to an exemplary embodiment.

[0426] Referring to FIG. **38** and FIG. **39**, a display apparatus according to an exemplary embodiment may be operated in a passive matrix manner.

[0427] For example, since the light emitting diode stack for a display of FIG. **36** includes the first to third LED stacks **1230**, **1330**, and **1430** stacked in the vertical direction, one pixel may include three light emitting diodes R, G, and B. A first light emitting diode R may correspond to the first LED stack **1230**, a second light emitting diode G may correspond to the second LED stack **1330**, and a third light emitting diode B may correspond to the third LED stack **1430**.

[0428] In FIGS. **38** and **39**, one pixel includes the first to third light emitting diodes R, G, and B, each of which corresponds to a subpixel. Anodes of the first to third light emitting diodes R, G, and B are connected to a common line, for example, a data line, and cathodes thereof are connected to different lines, for example, scan lines. More particularly, in a first pixel, the anodes of the first to third light emitting diodes R, G, and B are commonly connected to a data line Vdata**1** and the cathodes thereof are connected to scan lines Vscan**1**-**1**, Vscan**1**-**2**, and Vscan**1**-**3**, respectively. As such, the light emitting diodes R, G, and B in each pixel can be driven independently.

[0429] In addition, each of the light emitting diodes R, G, and B may be driven by a pulse width modulation or by changing the magnitude of electric current, thereby controlling the brightness of each subpixel.

[0430] Referring to FIG. **39**, a plurality of pixels is formed by patterning the light emitting diode stack **1000** of FIG. **36**, and each of the pixels is connected to the reflective electrodes **1250** and interconnection lines **1710**, **1730**, and **1750**. As shown in FIG. **38**, the reflective electrode **1250** may be used as the data line Vdata and the interconnection lines **1710**, **1730**, and **1750** may be formed as the scan lines.

[0431] The pixels may be arranged in a matrix form, in which the anodes of the light emitting diodes R, G, and B of each pixel are commonly connected to the reflective electrode **1250**, and the cathodes thereof are connected to the interconnection lines **1710**, **1730**, and **1750** separated from one another. Here, the interconnection lines **1710**, **1730**, and **1750** may be used as the scan lines Vscan.

[0432] FIG. **40** is an enlarged plan view of one pixel of the display apparatus of FIG. **39**, FIG. **41** is a schematic cross-sectional view taken along line A-A of FIG. **40**, and FIG. **42** is a schematic cross-sectional view taken along line B-B of FIG. **40**.

[0433] Referring to FIG. **39**, FIG. **40**, FIG. **41**, and FIG. **42**, in each pixel, a portion of the reflective electrode **1250**, the ohmic electrode **1290** formed on the upper surface of the first LED stack **1230** (see FIG. **43**H), a portion of the second-p transparent electrode **1350** (see also FIG. **43**H), a portion of the upper surface of the second LED stack **1330** (see FIG. **43**J), a portion of the third-p transparent electrode **1450** (see FIG. **43**H), and the upper surface of the third LED stack **1430** are exposed to the outside.

[0434] The third LED stack **1430** may have a roughened surface **1430***a* on the upper surface thereof. The roughened surface **1430***a* may be formed over the entirety of the upper surface of the third LED stack **1430** or may be formed in some regions thereof, as shown in FIG. **41**.

[0435] A lower insulation layer **1610** may cover a side surface of each pixel. The lower insulation layer **1610** may be formed of a light transmissive material, such as SiO_2. In this case, the lower insulation layer **1610** may cover the entire upper surface of the third LED stack **1430**. Alternatively, the lower insulation layer **1610** may include a distributed Bragg reflector to reflect light traveling towards the side surfaces of the first to third LED stacks **1230**, **1330**, and **1430**. In this case, the lower insulation layer **1610** partially exposes the upper surface of the third LED stack **1430**.

[0436] The lower insulation layer **1610** may include an opening **1610***a* which exposes the upper surface of the third LED stack **1430**, an opening **1610***b* which exposes the upper surface of the second LED stack **1330**, an opening **1610***c* (see FIG. **43**H) which exposes the ohmic electrode **1290** of the first LED stack **1230**, an opening **1610***d* which exposes the third-p transparent electrode **1450**, an opening **1610***e* which exposes the second-p transparent electrode **1350**, and openings **1610***f* which expose the first-p reflective electrode **1250**.

[0437] The interconnection lines **1710** and **1750** may be formed near the first to third LED stacks **1230**, **1330**, and **1430** on the support substrate **1510**, and may be disposed on the lower insulation layer **1610** to be insulated from the first-p reflective electrode **1250**. A connecting portion **1770***a* connects the third-p transparent electrode **1450** to the reflective electrode **1250**, and a connecting portion **1770***b* connects the second-p transparent electrode **1350** to the reflective electrode **1250**, such that the anodes of the first LED stack **1230**, the second LED stack **1330**, and the third LED stack **1430** are commonly connected to the reflective electrode **1250**.

[0438] A connecting portion **1710***a* connects the upper surface of the third LED stack **1430** to the interconnection line **1710**, and a connecting portion **1750***a* connects the ohmic electrode **1290** on the first LED stack **1230** to the interconnection line **1750**.

[0439] An upper insulation layer **1810** may be disposed on the interconnection lines **1710** and **1730** and the lower insulation layer **1610** to cover the upper surface of the third LED stack **1430**. The upper insulation layer **1810** may have an opening **1810***a* which partially exposes the upper surface of the second LED stack **1330**.

[0440] The interconnection line **1730** may be disposed on the upper insulation layer **1810**, and the connecting portion **1730***a* may connect the upper surface of the second LED stack **1330** to the interconnection line **1730**. The connecting portion **1730***a* may pass through an upper portion of the interconnection line **1750**, and is insulated from the interconnection line **1750** by the upper insulation layer **1810**.

[0441] Although the electrodes of each pixel according to the illustrated exemplary embodiment are described as being connected to the data line and the scan lines, various implementations are possible. In addition, although the interconnection lines **1710** and **1750** are described as being formed on the lower insulation layer **1610**, and the interconnection line **1730** is formed on the upper insulation layer **1810**, the inventive concepts are not limited thereto. For example, each of the interconnection lines **1710**, **1730**, and **1750** may be formed on the lower insulation layer **1610**, and covered by the upper insulation layer **1810**, which may have openings to expose the interconnection line **1730**. In this structure, the connecting portion **1730***a* may connect the upper surface of the second LED stack **1330** to the interconnection line **1730** through the openings of the upper insulation layer **1810**.

[0442] Alternatively, the interconnection lines **1710**, **1730**, and **1750** may be formed inside the support substrate **1510**, and the connecting portions **1710***a*, **1730***a*, and **1750***a* on the lower insulation layer **1610** may connect the ohmic electrode **1290**, the upper surface of the second LED stack **1330**, and the upper surface of the third LED stack **1430** to the interconnection lines **1710**, **1730**, and **1750**.

[0443] FIG. **43**A to FIG. **43**K are schematic plan views illustrating a method of manufacturing a display apparatus including the pixel of FIG. **40** according to an exemplary embodiment.

[0444] First, the light emitting diode stack **1000** described in FIG. **36** is prepared.

[0445] Then, referring to FIG. **43**A, a roughened surface **1430***a* may be formed on the upper surface of the third LED stack **1430**. The roughened surface **1430***a* may be formed on the upper surface of the third LED stack **1430** so as to correspond to each pixel region. The roughened surface **1430***a* may be formed by chemical etching, for example, photo-enhanced chemical etching (PEC) or the like.

[0446] The roughened surface **1430***a* may be partially formed in each pixel region by taking into account a region of the third LED stack **1430** to be etched in the subsequent process, without being limited thereto. Alternatively, the roughened surface **1430***a* may be formed over the entire upper surface of the third LED stack **1430**.

[0447] Referring to FIG. **43**B, a surrounding region of the third LED stack **1430** in each pixel is removed by etching to expose the third-p transparent electrode **1450**. As shown in FIG. **43**B, the third LED stack **1430** may be remained to have a rectangular shape or a square shape. The third LED stack **1430** may have a plurality of depressions along edges thereof.

[0448] Referring to FIG. **43**C, the upper surface of the second LED stack **1330** is exposed by removing the exposed third-p transparent electrode **1450** in areas other than one depression of the third LED stack **1430**. Accordingly, the upper surface of the second LED stack **1330** is exposed around the third LED stack **1430** and in other depressions excluding the depression in which the third-p transparent electrode **1450** partially remains.

[0449] Referring to FIG. **43**D, the second-p transparent electrode **1350** is exposed by removing the exposed second LED stack **1330** in areas other than another depression of the third LED stack **1430**.

[0450] Referring to FIG. **43**E, the ohmic electrode **1290** is exposed together with the upper surface of the first LED stack **1230** by removing the exposed second-p transparent electrode **1350** in areas other than still another depression of the third LED stack **1430**. In this case, the ohmic electrode **1290** may be exposed in one depression. Accordingly, the upper surface of the first LED stack **1230** is exposed around the third LED stack **1430**, and an upper surface of the ohmic electrode **1290** is exposed in at least one of the depressions formed in the third LED stack **1430**.

[0451] Referring to FIG. **43**F, the reflective electrode **1250** is exposed by removing an exposed portion of the first LED stack **1230** other than the ohmic electrode **1290** exposed in one depression. The reflective electrode **1250** is exposed around the third LED stack **1430**.

[0452] Referring to FIG. **43**G, linear interconnection lines are formed by patterning the reflective electrode **1250**. Here, the support substrate **1510** may be exposed. The reflective electrode **1250** may connect pixels arranged in one row to each other among pixels arranged in a matrix (see FIG. **39**).

[0453] Referring to FIG. **43**H, a lower insulation layer **1610** (see FIG. **41** and FIG. **42**) is formed to cover the pixels. The lower insulation layer **1610** covers the reflective electrode **1250** and side surfaces of the first to third LED stacks **1230**, **1330**, and **1430**. In addition, the lower insulation layer **1610** may at least partially cover the upper surface of the third LED stack **1430**. If the lower insulation layer **1610** is a transparent layer such as a SiO_2 layer, the lower insulation layer **1610** may cover the entire upper surface of the third LED stack **1430**. Alternatively, when the lower insulation layer **1610** includes a distributed Bragg reflector, the lower insulation layer **1610** may at least partially expose the upper surface of the third LED stack **1430** such that light may be emitted to the outside.

[0454] The lower insulation layer **1610** may include an opening **1610***a* which exposes the third LED stack **1430**, an opening **1610***b* which exposes the second LED stack **1330**, an opening **1610***c* which exposes the ohmic electrode **1290**, an opening **1610***d* which exposes the third-p transparent electrode **1450**, an opening **1610***e* which exposes the second-p transparent electrode **1350**, and an opening **1610***f* which exposes the reflective electrode **1250**. One or more openings **1610***f* may be formed to expose the reflective electrode **1250**.

[0455] Referring to FIG. **43**I, interconnection lines **1710**, **1750** and connecting portions **1710***a*, **1750***a*, **1770***a*, and **1770***b* are formed. These may be formed by a lift-off process or the like. The interconnection lines **1710** and **1750** are insulated from the reflective electrode **1250** by the lower insulation layer **1610**. The connecting portion **1710***a* electrically connects the third LED stack **1430** to the interconnection line **1710**, and the connecting portion **1750***a* electrically connects the ohmic electrode **1290** to the interconnection line **1750** such that the first LED stack **1230** is electrically connected to the interconnection line **1750**. The connecting portion **1770***a* electrically connects the third-p transparent electrode **1450** to the first-p reflective electrode **1250**, and the connecting portion **1770***b* electrically connects the second-p transparent electrode **1350** to the first-p reflective electrode **1250**.

[0456] Referring to FIG. **43**J, an upper insulation layer **1810** (see FIG. **41** and FIG. **42**) covers the interconnection lines **1710** and **1750** and the connecting portions **1710***a*, **1750***a*, **1770***a*, and **1770***b*. The upper insulation layer **1810** may also cover the entire upper surface of the third LED stack **1430**. The upper insulation layer **1810** has an opening **1810***a* which exposes the upper surface of the second LED stack **1330**. The upper insulation layer **1810** may be formed of, for example, silicon oxide or silicon nitride, and may include a distributed Bragg reflector. When the upper insulation layer **1810** includes the distributed Bragg reflector, the upper insulation layer **1810** may expose at least part of the upper surface of the third LED stack **1430** such that light may be emitted to the outside.

[0457] Referring to FIG. **43**K, an interconnection line **1730** and a connecting portion **1730***a* are formed. An interconnection line **1750** and a connecting portion **1750***a* may be formed by a lift-off process or the like. The interconnection line **1730** is disposed on the upper insulation layer **1810**, and is insulated from the reflective electrode **1250** and the interconnection lines **1710** and **1750**. The connecting portion **1730***a* electrically connects the second LED stack **1330** to the interconnection line **1730**. The connecting portion **1730***a* may pass through an upper portion of the interconnection line **1750** and is insulated from the interconnection line **1750** by the upper insulation layer **1810**.

[0458] As such, a pixel region as shown in FIG. **40** may be formed. In addition, as shown in FIG. **39**, a plurality of pixels may be formed on the support substrate **1510** and may be connected to one another by the first-p the reflective electrode **1250** and the interconnection lines **1710**, **1730**, and **1750** to be operated in a passive matrix manner.

[0459] Although the display apparatus above has been described as being configured to be operated in the passive matrix manner, the inventive concepts are not limited thereto. More particularly, a display apparatus according to some exemplary embodiments may be manufactured in various ways so as to be operated in the passive matrix manner using the light emitting diode stack shown in FIG. **36**.

[0460] For example, although the interconnection line **1730** is illustrated as being formed on the upper insulation layer **1810**, the interconnection line **1730** may be formed together with the interconnection lines **1710** and **1750** on the lower insulation layer **1610**, and the connecting portion **1730***a* may be formed on the upper insulation layer **1810** to connect the second LED stack **1330** to the interconnection line **1730**. Alternatively, the interconnection lines **1710**, **1730**, and **1750** may be disposed inside the support substrate **1510**.

[0461] FIG. **44** is a schematic circuit diagram of a display apparatus according to another exemplary embodiment. The display apparatus according to the illustrated exemplary embodiment may be driven in an active matrix manner.

[0462] Referring to FIG. **44**, the drive circuit according to an exemplary embodiment includes at least two transistors Tr**1**, Tr**2** and a capacitor. When a power source is connected to selection lines Vrow1 to Vrow**3**, and voltage is applied to data lines Vdata**1** to Vdata**3**, the voltage is applied to the corresponding light emitting diode. In addition, the corresponding capacitor is charged according to the values of Vdata1 to Vdata**3**. Since a turned-on state of a transistor Tr**2** can be maintained by the charged voltage of the capacitor, the voltage of the capacitor can be maintained and applied to the light emitting diodes LED**1** to LED**3** even when power supplied to Vrow1 is cut off. In addition, electric current flowing in the light emitting diodes LED**1** to LED**3** can be changed depending upon the values of Vdata**1** to Vdata**3**. Electric current can be continuously supplied through Vdd, such that light may be emitted continuously.

[0463] The transistors Tr**1**, Tr**2** and the capacitor may be formed inside the support substrate **1510**. For example, thin film transistors formed on a silicon substrate may be used for active matrix driving.

[0464] The light emitting diodes LED**1** to LED**3** may correspond to the first to third LED stacks **1230**, **1330**, and **1430** stacked in one pixel, respectively. The anodes of the first to third LED stacks are connected to the transistor Tr**2** and the cathodes thereof are connected to the ground.

[0465] Although FIG. **44** shows the circuit for active matrix driving according to an exemplary embodiment, other various types of circuits may be used. In addition, although the anodes of the light emitting diodes LED**1** to LED**3** are described as being connected to different transistors Tr**2**, and the cathodes thereof are described as being connected to the ground, the inventive concepts are not limited thereto, and the anodes of the light emitting diodes may be connected to current supplies Vdd and the cathodes thereof may be connected to different transistors.

[0466] FIG. **45** is a schematic plan view of a pixel of a display apparatus according to another exemplary embodiment. The pixel described herein may be one of a plurality of pixels arranged on the support substrate **1511**.

[0467] Referring to FIG. **45**, the pixels according to the illustrated exemplary embodiment are substantially similar to the pixels described with reference to FIG. **39** to FIG. **42**, except that the support substrate **1511** is a thin film transistor panel including transistors and capacitors, and the reflective electrode is disposed in a lower region of the first LED stack.

[0468] The cathode of the third LED stack is connected to the support substrate **1511** through the connecting portion **1711***a*. For example, as shown in FIG. **45**, the cathode of the third LED stack may be connected to the ground through electrical connection to the support substrate **1511**. The cathodes of the second LED stack and the first LED stack may also be connected to the ground through electrical connection to the support substrate **1511** via the connecting portions **1731***a* and **1751***a*.

[0469] The reflective electrode is connected to the transistors Tr**2** (see FIG. **44**) inside the support substrate **1511**. The third-p transparent electrode and the second-p transparent electrode are also connected to the transistors Tr2 (see FIG. **44**) inside the support substrate **1511** through the connecting portions **1771***a* and **1731***b*.

[0470] In this manner, the first to third LED stacks are connected to one another, thereby constituting a circuit for active matrix driving, as shown in FIG. **44**.

[0471] Although FIG. **45** shows electrical connection of a pixel for active matrix driving according to an exemplary embodiment, the inventive concepts are not limited thereto, and the circuit for the display apparatus can be modified into various circuits for active matrix driving in various ways.

[0472] In addition, while the reflective electrode **1250**, the second-p transparent electrode **1350**, and the third-p transparent electrode **1450** of FIG. **36** are described as forming ohmic contact with the corresponding p-type semiconductor layer of each of the first LED stack **1230**, the second LED stack **1330**, and the third LED stack **1430**, and the ohmic electrode **1290** forms ohmic contact with the n-type semiconductor layer of the first LED stack **1230**, the n-type semiconductor layer of each of the second LED stack **1330** and the third LED stack **1430** is not provided with a separate ohmic contact layer. When the pixels have a small size of 200 μm or less, there is less difficulty in current spreading even without formation of a separate ohmic contact layer in the n-type semiconductor layer. However, according to some exemplary embodiments, a transparent electrode layer may be disposed on the n-type semiconductor layer of each of the LED stacks in order to secure current spreading.

[0473] In addition, although the first to third LED stacks **1230**, **1330**, and **1430** are coupled to each other via bonding layers **1530**, **1550**, and **1570**, the inventive concepts are not limited thereto, and the first to third LED stacks **1230**, **1330**, and **1430** may be connected to one another in various sequences and using various structures.

[0474] According to exemplary embodiments, since it is possible to form a plurality of pixels at the wafer level using the light emitting diode stack **1000** for a display, individual mounting of light emitting diodes may be obviated. In addition, the light emitting diode stack according to the exemplary embodiments has the structure in which the first to third LED stacks **1230**, **1330**, and **1430** are stacked in the vertical direction, thereby securing an area for subpixels in a limited pixel area. Furthermore, the light emitting diode stack according to the exemplary embodiments allows light generated from the first LED stack **1230**, the second LED stack **1330**, and the third LED stack **1430** to be emitted outside therethrough, thereby reducing light loss.

[0475] FIG. **46** is a schematic cross-sectional view of a light emitting diode stack for a display according to an exemplary embodiment.

[0476] Referring to FIG. **46**, the light emitting diode stack **2000** includes a support substrate **2510**, a first LED stack **2230**, a second LED stack **2330**, a third LED stack **2430**, a reflective electrode **2250**, an ohmic electrode **2290**, a second-p transparent electrode **2350**, a third-p transparent electrode **2450**, an insulation layer **2270**, a first bonding layer **2530**, a second bonding layer **2550**, and a third bonding layer **2570**. In addition, the first LED stack **2230** may include an ohmic contact portion **2230***a* for ohmic contact.

[0477] In general, light may be generated from the first LED stack by the light emitted from the second LED stack, and light may be generated from the second LED stack by the light emitted from the third LED stack. As such, a color filter may be interposed between the second LED stack and the first LED stack, and between the third LED stack and the second LED stack.

[0478] However, while the color filters may prevent interference of light, forming color filters increases manufacturing complexity. A display apparatus according to exemplary embodiments may suppress generation of secondary light between the LED stacks without arrangement of the color filters therebetween.

[0479] Accordingly, in some exemplary embodiments, interference of light between the LED stacks can be reduced by controlling the bandgap of each of the LED stacks, which will be described in more detail below.

[0480] The support substrate **2510** supports the semiconductor stacks **2230**, **2330**, and **2430**. The support substrate **2510** may include a circuit on a surface thereof or therein, but the inventive concepts are not limited thereto. The support substrate **2510** may include, for example, a Si substrate, a Ge substrate, a sapphire substrate, a patterned sapphire substrate, a glass substrate, or a patterned glass substrate.

[0481] Each of the first LED stack **2230**, the second LED stack **2330**, and the third LED stack **2430** includes an n-type semiconductor layer, a p-type semiconductor layer, and an active layer interposed therebetween. The active layer may have a multi-quantum well structure.

[0482] Light L1 generated from the first LED stack **2230** has a longer wavelength than light L2 generated from the second LED stack **2330**, which has a longer wavelength than light L3 generated from the third LED stack **2430**. However, the inventive concepts are limited thereto, and when the light emitting diode stack includes micro LEDs, light generated from the first, second, and third LED stacks **2230**, **2330**, and **2440** may have any wavelength range without adversely affecting operation due to its small form factor.

[0483] The first LED stack **2230** may be an inorganic light emitting diode configured to emit red light, the second LED stack **2330** may be an inorganic light emitting diode configured to emit green light, and the third LED stack **2430** may be an inorganic light emitting diode configured to emit blue light. The first LED stack **2230** may include a GaInP-based well layer, and each of the second LED stack **2330** and the third LED stack **2430** may include a GaInN-based well layer.

[0484] Although the light emitting diode stack **2000** of FIG. **46** is illustrated as including three LED stacks **2230**, **2330**, and **2430**, the inventive concepts are not limited to a particular number of LED stacks one over the other. For example, an LED stack for emitting yellow light may be further added between the first LED stack **2230** and the second LED stack **2330**.

[0485] Both surfaces of each of the first to third LED stacks **2230**, **2330**, and **2430** are an n-type semiconductor layer and a p-type semiconductor layer, respectively. In FIG. **46**, each of the first to third LED stacks **2230**, **2330**, and **2430** is described as having an n-type upper surface and a p-type lower surface. Since the third LED stack **2430** has an n-type upper surface, a roughened surface may be formed on the upper surface of the third LED stack **2430** through chemical etching or the like. However, the inventive concepts are not limited thereto, and the semiconductor types of the upper and lower surfaces of each of the LED stacks can be formed alternatively.

[0486] The first LED stack **2230** is disposed near the support substrate **2510**, the second LED stack **2330** is disposed on the first LED stack **2230**, and the third LED stack **2430** is disposed on the second LED stack. Since the first LED stack **2230** emits light having a longer wavelength than the second and third LED stacks **2330** and **2430**, light L1 generated from the first LED stack **2230** can be emitted to the outside through the second and third LED stacks **2330** and **2430**. In addition, since the second LED stack **2330** emits light having a longer wavelength than the third LED stack **2430**, light L2 generated from the second LED stack **2330** can be emitted to the outside through the third LED stack **2430**. Light L3 generated in the third LED stack **2430** is directly emitted outside from the third LED stack **2430**.

[0487] In an exemplary embodiment, the n-type semiconductor layer of the first LED stack **2230** may have a bandgap wider than the bandgap of the active layer of the first LED stack **2230**, and narrower than the bandgap of the active layer of the second LED stack **2330**. Accordingly, a portion of light generated from the second LED stack **2330** may be absorbed by the n-type semiconductor layer of the first LED stack **2230** before reaching the active layer of the first LED stack **2230**. As such, the intensity of light generated in the active layer of the first LED stack **2230** may be reduced by the light generated from the second LED stack **2330**.

[0488] In addition, the n-type semiconductor layer of the second LED stack **2330** has a bandgap wider than the bandgap of the active layer of each of the first LED stack **2230** and the second LED stack **2330**, and narrower than the bandgap of the active layer of the third LED stack **2430**. Accordingly, a portion of light generated from the third LED stack **2430** may be absorbed by the n-type semiconductor layer of the second LED stack **2330** before reaching the active layer of the second LED stack **2330**. As such, the intensity of light generated in the second LED stack **2330** or the first LED stack **2230** may be reduced by the light generated from the third LED stack **2430**.

[0489] The p-type semiconductor layer and the n-type semiconductor layer of the third LED stack **2430** has wider bandgaps than the active layers of the first LED stack **2230** and the second LED stack **2330**, thereby transmitting light generated from the first and second LED stacks **2230** and **2330** therethrough.

[0490] According to an exemplary embodiment, it is possible to reduce interference of light between the LED stacks **2230**, **2330**, and **2430** by adjusting the bandgaps of the n-type semiconductor layers or the p-type semiconductor layers of the first and second LED stacks **2230** and **2330**, which may obviate the need for other components, such as color filters. For example, the intensity of light generated from the second LED stack **2330** and emitted to the outside may be about 10 times or more than the intensity of the light generated from the first LED stack **2230** by the light generated from the second LED stack **2330**. Likewise, the intensity of light generated from the third LED stack **2430** and emitted to the outside may be about 10 times or more the intensity of the light generated from the second LED stack **2330** caused by the light generated from the third LED stack **2430**. In this case, the intensity of the light generated from the third LED stack **2430** and emitted to the outside may be about 10 times or more the intensity of the light generated from the first LED stack **2230** caused by the light generated from the third LED stack **2430**. Accordingly, it is possible to realize a display apparatus free from color contamination caused by interference of light.

[0491] The reflective electrode **2250** forms ohmic contact with the p-type semiconductor layer of the first LED stack **2230** and reflects light generated from the first LED stack **2230**. For example, the reflective electrode **2250** may include an ohmic contact layer **2250*a*** and a reflective layer **2250*b***.

[0492] The ohmic contact layer **2250*a*** partially contacts the p-type semiconductor layer of the first LED stack **2230**. In order to prevent absorption of light by the ohmic contact layer **2250*a***, a region in which the ohmic contact layer **2250*a*** contacts the p-type semiconductor layer may not exceed about 50% of the total area of the p-type semiconductor layer. The reflective layer **2250*b*** covers the ohmic contact layer **2250*a*** and the insulation layer **2270**. As shown in FIG. **46**, the reflective layer **2250*b*** may cover substantially the entire ohmic contact layer **2250*a***, without being limited thereto. Alternatively, the reflective layer **2250*b*** may cover a portion of the ohmic contact layer **2250*a***.

[0493] Since the reflective layer **2250*b*** covers the insulation layer **2270**, an omnidirectional reflector can be formed by the stacked structure of the first LED stack **2230** having a relatively high index of refraction and the insulation layer **2270** having a relatively low index of refraction, and the reflective layer **2250*b***. The reflective layer **2250*b*** may cover about 50% or more of the area of the first LED stack **2230** or most of the first LED stack **2230**, thereby improving luminous efficacy.

[0494] The ohmic contact layer **2250*a*** and the reflective layer **2250*b*** may be formed of metal layers, which may include Au. The reflective layer **2250*b*** may include metal having relatively high reflectance with respect to light generated from the first LED stack **2230**, for example, red light. On the other hand, the reflective layer **2250*b*** may include metal having relatively low reflectance with respect to light generated from the second LED stack **2330** and the third LED stack **2430**, for example, green light or blue light, to reduce interference of light having been generated from the second and third LED stacks **2330**, **2430** and traveling toward the support substrate **2510**.

[0495] The insulation layer **2270** is interposed between the support substrate **2510** and the first LED stack **2230**, and has openings that expose the first LED stack **2230**. The ohmic contact layer **2250*a*** is connected to the first LED stack **2230** in the openings of the insulation layer **2270**.

[0496] The ohmic electrode **2290** is disposed on the upper surface of the first LED stack **2230**. In order to reduce ohmic contact resistance of the ohmic electrode **2290**, the ohmic contact portion **2230*a*** may protrude from the upper surface of the first LED stack **2230**. The ohmic electrode **2290** may be disposed on the ohmic contact portion **2230*a***.

[0497] The second-p transparent electrode **2350** forms ohmic contact with the p-type semiconductor layer of the second LED stack **2330**. The second-p transparent electrode **2350** may be formed of a metal layer or a conducive oxide layer that is transparent to red light and green light.

[0498] The third-p transparent electrode **2450** forms ohmic contact with the p-type semiconductor layer of the third LED stack **2430**. The third-p transparent electrode **2450** may be formed of a metal layer or a conducive oxide layer that is transparent to red light, green light, and blue light.

[0499] The reflective electrode **2250**, the second-p transparent electrode **2350**, and the third-p transparent electrode **2450** may assist in current spreading through ohmic contact with the p-type semiconductor layer of corresponding LED stacks.

[0500] The first bonding layer **2530** couples the first LED stack **2230** to the support substrate **2510**. As shown in FIG. **46**, the reflective electrode **2250** may adjoin the first bonding layer **2530**. The first bonding layer **2530** may be a light transmissive or opaque layer.

[0501] The second bonding layer **2550** couples the second LED stack **2330** to the first LED stack **2230**. As shown in FIG. **46**, the second bonding layer **2550** may adjoin the first LED stack **2230** and the second-p transparent electrode **2350**. The ohmic electrode **2290** may be covered by the second bonding layer **2550**. The second bonding layer **2550** transmits light generated from the first LED stack **2230**. The second bonding layer **2550** may be formed of a light transmissive bonding material, for example, a light transmissive organic bonding agent or light transmissive spin-on-glass. Examples of the light transmissive organic bonding agent may include SU8, poly(methyl methacrylate) (PMMA), polyimide, Parylene, benzocyclobutene (BCB), and the like. In addition, the second LED stack **2330** may be bonded to the first LED stack **2230** by plasma bonding or the like.

[0502] The third bonding layer **2570** couples the third LED stack **2430** to the second LED stack **2330**. As shown in FIG. **46**, the third bonding layer **2570** may adjoin the second LED stack **2330** and the third-p transparent electrode **2450**. However, the inventive concepts are not limited thereto. For example, a transparent conductive layer may be disposed on the second LED stack **2330**. The third bonding layer **2570** transmits light generated from the first LED stack **2230** and the second LED stack **2330**, and may be formed of, for example, light transmissive spin-on-glass.

[0503] Each of the second bonding layer **2550** and the third bonding layer **2570** may transmit light generated from the third LED stack **2430** and light generated from the second LED stack **2330**.

[0504] FIG. **47**A to FIG. **47**E are schematic cross-sectional views illustrating a method of manufacturing a light emitting diode stack for a display according to an exemplary embodiment.

[0505] Referring to FIG. **47**A, a first LED stack **2230** is grown on a first substrate **2210**. The first substrate **2210** may be, for example, a GaAs substrate. The first LED stack **2230** is formed of AlGaInP-based semiconductor layers, and includes an n-type semiconductor layer, an active layer, and a p-type semiconductor layer. In some exemplary embodiments, the n-type semiconductor layer may have an energy bandgap capable absorbing light generated from the second LED stack **2330**, and the p-type semiconductor layer may have an energy bandgap capable absorbing light generated from the second LED stack **2330**.

[0506] An insulation layer **2270** is formed on the first LED stack **2230** and patterned to form opening(s) therein. For example, a SiO_2 layer is formed on the first LED stack **2230**, and a photoresist is deposited onto the SiO_2 layer, followed by photolithography and development to form a photoresist pattern. Then, the SiO_2 layer is patterned through the photoresist pattern used as an etching mask, thereby forming the insulation layer **2270** having the opening(s).

[0507] Then, an ohmic contact layer **2250***a* is formed in the opening(s) of the insulation layer **2270**. The ohmic contact layer **2250***a* may be formed by a lift-off process or the like. After the ohmic contact layer **2250***a* is formed, a reflective layer **2250***b* is formed to cover the ohmic contact layer **2250***a* and the insulation layer **2270**. The reflective layer **2250***b* may be formed by a lift-off process or the like. The reflective layer **2250***b* may cover a portion of the ohmic contact layer **2250***a* or the entirety thereof. The ohmic contact layer **2250***a* and the reflective layer **2250***b* form a reflective electrode **2250**.

[0508] The reflective electrode **2250** forms ohmic contact with the p-type semiconductor layer of the first LED stack **2230**, and thus, will hereinafter be referred to as a first-p reflective electrode **2250**.

[0509] Referring to FIG. **47**B, a second LED stack **2330** is grown on a second substrate **2310**, and a second-p transparent electrode **2350** is formed on the second LED stack **2330**. The second LED stack **2330** may be formed of GaN-based semiconductor layers and may include a GaInN well layer. The second substrate **2310** is a substrate on which GaN-based semiconductor layers may be grown thereon, and is different from the first substrate **2210**. The composition ratio of GaInN for the second LED stack **2330** may be determined such that the second LED stack **2330** emits green light. The second-p transparent electrode **2350** forms ohmic contact with the p-type semiconductor layer of the second LED stack **2330**. The second LED stack **2330** may include an n-type semiconductor layer, an active layer, and a p-type semiconductor layer. In some exemplary embodiments, the n-type semiconductor layer of the second LED stack **2330** may have an energy bandgap capable of absorbing light generated from the third LED stack **2430**, and the p-type semiconductor layer of the second LED stack **2330** may have an energy bandgap capable of absorbing light generated from the third LED stack **2430**.

[0510] Referring to FIG. **47**C, a third LED stack **2430** is grown on a third substrate **2410**, and a third-p transparent electrode **2450** is formed on the third LED stack **2430**. The third LED stack **2430** may be formed of GaN-based semiconductor layers and may include a GaInN well layer. The third substrate **2410** is a substrate on which GaN-based semiconductor layers may be grown thereon, and is different from the first substrate **2210**. The composition ratio of GaInN for the third LED stack **2430** may be determined such that the third LED stack **2430** emits blue light. The third-p transparent electrode **2450** forms ohmic contact with the p-type semiconductor layer of the third LED stack **2430**.

[0511] As such, the first LED stack **2230**, the second LED stack **2330**, and the third LED stack **2430** are grown on different substrates, and the formation sequence thereof is not limited to a particular sequence.

[0512] Referring to FIG. **47**D, the first LED stack **2230** is coupled to the support substrate **2510** via a first bonding layer **2530**. The first bonding layer **2530** may be previously formed on the support substrate **2510** and the reflective electrode **2250** may be bonded to the first bonding layer **2530** to face the support substrate **2510**. The first substrate **2210** is removed from the first LED stack **2230** by chemical etching or the like. Accordingly, the upper surface of the n-type semiconductor layer of the first LED stack **2230** is exposed.

[0513] Then, an ohmic electrode **2290** is formed in the exposed region of the first LED stack **2230**. In order to reduce ohmic contact resistance of the ohmic electrode **2290**, the ohmic electrode **2290** may be subjected to heat treatment. The ohmic electrode **2290** may be formed in each pixel region so as to correspond to the pixel regions.

[0514] Referring to FIG. **47**E, the second LED stack **2330** is coupled to the first LED stack **2230**, on which the ohmic electrode **2290** is formed, via a second bonding layer **2550**. The second-p transparent electrode **2350** is bonded to the second bonding layer **2550** to face the first LED stack **2230**. The second bonding layer **2550** may be previously formed on the first LED stack **2230** such that the second-p transparent electrode **2350** may face and be bonded to the second bonding layer **2550**. The second substrate **2310** may be separated from the second LED stack **2330** by a laser lift-off or chemical lift-off process.

[0515] Then, referring to FIG. **46** and FIG. **47**C, the third LED stack **2430** is coupled to the second LED stack **2330** via a third bonding layer **2570**. The third-p transparent electrode **2450** is bonded to the third bonding layer **2570** to face the second LED stack **2330**. The third bonding layer **2570** may be previously formed on the second LED stack **2330** such that the third-p transparent electrode **2450** may face and be bonded to the third bonding layer **2570**. The third substrate **2410** may be separated from the third LED stack **2430** by a laser lift-off or chemical lift-off process. As such, the light emitting diode stack for a display as shown in FIG. **46** may be formed, which has the n-type semiconductor layer of the third LED stack **2430** exposed to the outside.

[0516] A display apparatus may be formed by patterning the stack of the first to third LED stacks **2230**, **2330**, and **2430** disposed on the support substrate **2510** in pixel units, followed by connecting the first to third LED stacks **2230**, **2330**, and **2430** to one another through interconnections. However, the inventive concepts are not limited thereto. For example, a display apparatus may be manufactured by dividing the stack of the first to third LED stacks **2230**, **2330**, and **2430** into individual units, and transferring the first to third LED stacks **2230**, **2330**, and **2430** to other support substrates, such as a printed circuit board.

[0517] FIG. **48** is a schematic circuit diagram of a display apparatus according to an exemplary embodiment. FIG. **49** is a schematic plan view of the display apparatus according to an exemplary embodiment.

[0518] Referring to FIG. **48** and FIG. **49**, the display apparatus according to an exemplary embodiment may be implemented to be driven in a passive matrix manner.

[0519] The light emitting diode stack for a display shown in FIG. **46** has the structure including the first to third LED stacks **2230**, **2330**, and **2430** stacked in the vertical direction. Since one pixel includes three light emitting diodes R, G, and B, a first light emitting diode R may correspond to the first LED stack **2230**, a second light emitting diode G may correspond to the second LED stack **2330**, and a third light emitting diode B may correspond to the third LED stack **2430**.

[0520] Referring to FIGS. **48** and **49**, one pixel includes the first to third light emitting diodes R, G, and B, each of which may correspond to a subpixel. Anodes of the first to third light emitting diodes R, G, and B are connected to a common line, for example, a data line, and cathodes thereof are connected to different lines, for example, scan lines. For example, in a first pixel, the anodes of the first to third light emitting diodes R, G, and B are commonly connected to a data line Vdata**1**, and the cathodes thereof are connected to scan lines Vscan**1**-**1**, Vscan**1**-**2**, and Vscan**1**-**3**, respectively. As such, the light emitting diodes R, G, and B in each pixel can be driven independently.

[0521] In addition, each of the light emitting diodes R, G, and B may be driven by a pulse width modulation or by changing the magnitude of electric current to control the brightness of each subpixel.

[0522] Referring to FIG. **49**, a plurality of pixels is formed by patterning the stack of FIG. **46**, and each of the pixels is connected to the reflective electrodes **2250** and interconnection lines **2710**, **2730**, and **2750**. As shown in FIG. **48**, the reflective electrode **2250** may be used as the data line Vdata and the interconnection lines **2710**, **2730**, and **2750** may be formed as the scan lines.

[0523] The pixels may be arranged in a matrix form, in which the anodes of the light emitting diodes R, G, and B of each pixel are commonly connected to the reflective electrode **2250**, and the cathodes thereof are connected to the interconnection lines **2710**, **2730**, and **2750** separated from one another. Here, the interconnection lines **2710**, **2730**, and **2750** may be used as the scan lines Vscan.

[0524] FIG. **50** is an enlarged plan view of one pixel of the display apparatus of FIG. **49**. FIG. **51** is a schematic cross-sectional view taken along line A-A of FIG. **50**, and FIG. **52** is a schematic cross-sectional view taken along line B-B of FIG. **50**.

[0525] Referring to FIGS. **49** to **52**, in each pixel, a portion of the reflective electrode **2250**, the ohmic electrode **2290** formed on the upper surface of the first LED stack **2230** (see FIG. **53**H), a portion of the second-p transparent electrode **2350** (see FIG. **53**H), a portion of the upper surface of the second LED stack **2330** (see FIG. **53**J), a portion of the third-p transparent electrode **2450** (see FIG. **53**H), and the upper surface of the third LED stack **2430** are exposed to the outside.

[0526] The third LED stack **2430** may have a roughened surface **2430***a* on the upper surface thereof. The roughened surface **2430***a* may be formed over the entirety of the upper surface of the third LED stack **2430** or may be formed in some regions thereof.

[0527] A lower insulation layer **2610** may cover a side surface of each pixel. The lower insulation layer **2610** may be formed of a light transmissive material, such as SiO_2. In this case, the lower insulation layer **2610** may cover substantially the entire upper surface of the third LED stack **2430**. Alternatively, the lower insulation layer **2610** may include a distributed Bragg reflector to reflect light traveling towards the side surfaces of the first to third LED stacks **2230**, **2330**, and **2430**. In this case, the lower insulation layer **2610** may partially expose the upper surface of the third LED stack **2430**. Still alternatively, the lower insulation layer **2610** may be a black-based insulation layer that absorbs light. Furthermore, an electrically floating metallic reflective layer may be further formed on the lower insulation layer **2610** to reflect light emitted through the side surfaces of the first to third LED stacks **2230**, **2330**, and **2430**.

[0528] The lower insulation layer **2610** may include an opening **2610***a* which exposes the upper surface of the third LED stack **2430**, an opening **2610***b* which exposes the upper surface of the second LED stack **2330**, an opening **2610***c* (see FIG. **53**H) which exposes the ohmic electrode **2290** of the first LED stack **2230**, an opening **2610***d* which exposes the third-p transparent electrode **2450**, an opening **2610***e* which exposes the second-p transparent electrode **2350**, and openings **2610***f* which expose the first-p reflective electrode **2250**.

[0529] The interconnection lines **2710** and **2750** may be formed near the first to third LED stacks **2230**, **2330**, and **2430** on the support substrate **2510**, and may be disposed on the lower insulation layer **2610** to be insulated from the first-p reflective electrode **2250**. A connecting portion **2770***a* connects the third-p transparent electrode **2450** to the reflective electrode **2250**, and a connecting portion **2770***b* connects the second-p transparent electrode **2350** to the reflective electrode **2250**, such that the anodes of the first LED stack **2230**, the second LED stack **2330**, and the third LED stack **2430** are commonly connected to the reflective electrode **2250**.

[0530] A connecting portion **2710***a* connects the upper surface of the third LED stack **2430** to the interconnection line **2710**, and a connecting portion **2750***a* connects the ohmic electrode **2290** on the first LED stack **2230** to the interconnection line **2750**.

[0531] An upper insulation layer **2810** may be disposed on the interconnection lines **2710** and **2730** and the lower insulation layer **2610** to cover the upper surface of the third LED stack **2430**. The upper insulation layer **2810** may have an opening **2810***a* which partially exposes the upper surface of the second LED stack **2330**.

[0532] The interconnection line **2730** may be disposed on the upper insulation layer **2810**, and the connecting portion **2730***a* may connect the upper surface of the second LED stack **2330** to the interconnection line **2730**. The connecting portion **2730***a* may pass through an upper portion of the interconnection line **2750** and is insulated from the interconnection line **2750** by the upper insulation layer **2810**.

[0533] Although the electrodes of each pixel are described as being connected to the data line and the scan lines, the inventive concepts are not limited thereto. Further, while the interconnection lines **2710** and **2750** are described as being formed on the lower insulation layer **2610** and the interconnection line **2730** is described as being formed on the upper insulation layer **2810**, the inventive concepts are not limited thereto. For example, all of the interconnection lines **2710**, **2730**, and **2750** may be formed on the lower insulation layer **2610**, and may be covered by the upper insulation layer **2810**, which may have openings that expose the interconnection line **2730**. In this manner, the connecting portion **2730***a* may connect the upper surface of the second LED stack **2330** to the interconnection line **2730** through the openings of the upper insulation layer **2810**.

[0534] Alternatively, the interconnection lines **2710**, **2730**, and **2750** may be formed inside the support substrate **2510**, and the connecting portions **2710***a*, **2730***a*, and **2750***a* on the lower insulation layer **2610** may connect the ohmic electrode **2290**, the upper surface of the first LED stack **2230**, and the upper surface of the third LED stack **2430** to the interconnection lines **2710**, **2730**, and **2750**.

[0535] According to an exemplary embodiment, light L1 generated from the first LED stack **2230** is emitted to the outside through the second and third LED stacks **2330** and **2430**, and light L2 generated from the second LED stack **2330** is emitted to the outside through the third LED stack **2430**. Furthermore, a portion of light L3 generated from the third LED stack **2430** may enter the second LED stack **2330**, and a portion of light L2 generated from the second LED stack **2330** may enter the first LED stack **2230**. Furthermore, a secondary light may be generated from the second LED stack **2330** by the light L3, and a secondary light may also be generated from the first LED stack **2230** by the light L2. However, such secondary light may have a low intensity.

[0536] FIG. **53**A to FIG. **53**K are schematic plan views illustrating a method of manufacturing a display apparatus according to an exemplary embodiment. Hereinafter, the following descriptions will be given with reference to the pixel of FIG. **50**.

[0537] First, the light emitting diode stack **2000** described in FIG. **46** is prepared.

[0538] Referring to FIG. **53**A, a roughened surface **2430***a* may be formed on the upper surface of the third LED stack **2430**. The roughened surface **2430***a* may be formed on the upper surface of the third LED stack **2430** to correspond to each pixel region. The roughened surface **2430***a* may be formed by chemical etching, for example, photo-enhanced chemical etching (PEC) or the like.

[0539] The roughened surface **2430***a* may be partially formed in each pixel region by taking into account a region of the third LED stack **2430** to be etched in the subsequent process, without being limited thereto. Alternatively, the roughened surface **2430***a* may be formed over the entire upper surface of the third LED stack **2430**.

[0540] Referring to FIG. **53**B, a surrounding region of the third LED stack **2430** in each pixel is removed by etching to expose the third-p transparent electrode **2450**. As shown in FIG. **53**B, the third LED stack **2430** may be remained to have a rectangular shape or a square shape. The third LED stack **2430** may have a plurality of depressions formed along edges thereof.

[0541] Referring to FIG. **53**C, the upper surface of the second LED stack **2330** is exposed by removing the exposed third-p transparent electrode **2450** in areas other than in one depression. Accordingly, the upper surface of the second LED stack **2330** is exposed around the third LED stack **2430** and in other depressions other than the depression where the third-p transparent electrode **2450** is partially remained.

[0542] Referring to FIG. **53**D, the second-p transparent electrode **2350** is exposed by removing the exposed second LED stack **2330** exposed in areas other than one depression.

[0543] Referring to FIG. **53**E, the ohmic electrode **2290** is exposed together with the upper surface of the first LED stack **2230** by removing the exposed second-p transparent electrode **2350** in areas other than in one depression. Here, the ohmic electrode **2290** may be exposed in one depression. Accordingly, the upper surface of the first LED stack **2230** is exposed around the third LED stack **2430**, and an upper surface of the ohmic electrode **2290** is exposed in at least one of the depressions formed in the third LED stack **2430**.

[0544] Referring to FIG. **53**F, the reflective electrode **2250** is exposed by removing an exposed portion of the first LED stack **2230** in areas other than in one depression. As such, the reflective electrode **2250** is exposed around the third LED stack **2430**.

[0545] Referring to FIG. **53**G, linear interconnection lines are formed by patterning the reflective electrode **2250**. Here, the support substrate **2510** may be exposed. The reflective electrode **2250** may connect pixels arranged in one row to each other among pixels arranged in a matrix (see FIG. **49**).

[0546] Referring to FIG. **53**H, a lower insulation layer **2610** (see FIG. **51** and FIG. **52**) is formed to cover the pixels. The lower insulation layer **2610** covers the reflective electrode **2250** and side surfaces of the first to third LED stacks **2230**, **2330**, and **2430**. In addition, the lower insulation layer **2610** may partially cover the upper surface of the third LED stack **2430**. If the lower insulation layer **2610** is a transparent layer such as a SiO_2 layer, the lower insulation layer **2610** may cover substantially the entire upper surface of the third LED stack **2430**. Alternatively, the lower insulation layer **2610** may include a distributed Bragg reflector. In this case, the lower insulation layer **2610** may partially expose the upper surface of the third LED stack **2430** to allow light to be emitted to the outside.

[0547] The lower insulation layer **2610** may include an opening **2610***a* which exposes the third LED stack **2430**, an opening **2610***b* which exposes the second LED stack **2330**, an opening **2610***c* which exposes the ohmic electrode **2290**, an opening **2610***d* which exposes the third-p transparent electrode **2450**, an opening **2610***e* which exposes the second-p transparent electrode **2350**, and an opening **2610***f* which exposes the reflective electrode **2250**. The opening **2610***f* that exposes the reflective electrode **2250** may be formed singularly or in plural.

[0548] Referring to FIG. **53**I, interconnection lines **2710** and **2750**, and connecting portions **2710***a*, **2750***a*, **2770***a*, and **2770***b* are formed by a lift-off process or the like. The interconnection lines **2710** and **2750** are insulated from the reflective electrode **2250** by the lower insulation layer **2610**. The connecting portion **2710***a* electrically connects the third LED stack **2430** to the interconnection line **2710**, and the connecting portion **2750***a* electrically connects the ohmic electrode **2290** to the interconnection line **2750** such that the first LED stack **2230** is electrically connected to the interconnection line **2750**. The connecting portion **2770***a* electrically connects the third-p transparent electrode **2450** to the first-p reflective electrode **2250**, and the connecting portion **2770***b* electrically connects the second-p transparent electrode **2350** to the first-p reflective electrode **2250**.

[0549] Referring to FIG. **53**J, an upper insulation layer **2810** (see FIG. **51** and FIG. **52**) covers the interconnection lines **2710**, **2750** and the connecting portions **2710***a*, **2750***a*, **2770***a*, and **2770***b*. The upper insulation layer **2810** may also cover substantially the entire upper surface of the third LED stack **2430**. The upper insulation layer **2810** has an opening **2810***a* which exposes the upper surface of the second LED stack **2330**. The upper insulation layer **2810** may be formed of, for example, silicon oxide or silicon nitride, and may include a distributed Bragg reflector. When the upper insulation layer **2810** includes the distributed Bragg reflector, the upper insulation layer **2810** may expose at least a part of the upper surface of the third LED stack **2430** to allow light to be emitted to the outside.

[0550] Referring to FIG. **53**K, an interconnection line **2730** and a connecting portion **2730***a* are formed. An interconnection line **2750** and a connecting portion **2750***a* may be formed by a lift-off process or the like. The interconnection line **2730** is disposed on the upper insulation layer **2810**, and is insulated from the reflective electrode **2250** and the interconnection lines **2710** and **2750**. The connecting portion **2730***a* electrically connects the second LED stack **2330** to the interconnection line **2730**. The connecting portion **2730***a* may pass through an upper portion of the interconnection line **2750**, and is insulated from the interconnection line **2750** by the upper insulation layer **2810**.

[0551] As such, a pixel region shown in FIG. **50** may be formed. In addition, as shown in FIG. **49**, a plurality of pixels may be formed on the support substrate **2510** and may be connected to one another by the first-p the reflective electrode **2250** and the interconnection lines **2710**, **2730** and **2750**, to be operated in a passive matrix manner.

[0552] Although the above describes a method of manufacturing a display apparatus that may be operated in the passive matrix manner, the inventive concepts are not limited thereto. More particularly, the display apparatus according to exemplary embodiments may be manufactured in various ways so as to be operated in the passive matrix manner using the light emitting diode stack shown in FIG. **46**.

[0553] For example, while the interconnection line **2730** is described as being formed on the upper insulation layer **2810**, the interconnection line **2730** may be formed together with the interconnection lines **2710** and **2750** on the lower insulation layer **2610**, and the connecting portion **2730***a* may be formed on the upper insulation layer **2810** to connect the second LED stack **2330** to the interconnection line **2730**. Alternatively, the interconnection lines **2710**, **2730**, **2750** may be disposed inside the support substrate **2510**.

[0554] FIG. **54** is a schematic circuit diagram of a display apparatus according to another exemplary embodiment. The circuit diagram of FIG. **54** relates to a display apparatus driven in an active matrix manner.

[0555] Referring to FIG. **54**, the drive circuit according to an exemplary embodiment includes at least two transistors Tr**1**, Tr**2** and a capacitor. When a power source is connected to selection lines Vrowl to Vrow**3** and voltage is applied to data lines Vdata**1** to Vdata**3**, the voltage is applied to the corresponding light emitting diode. In addition, the corresponding capacitors are charged according to the values of Vdata**1** to Vdata**3**. Since a turned-on state of the transistor Tr**2** can be maintained by the charged voltage of the capacitor, the voltage of the capacitor can be maintained and applied to the light emitting diodes LED**1** to LED**3**, even when power supplied to Vrowl is cut off. In addition, electric current flowing in the light emitting diodes LED**1** to LED**3** can be changed depending upon the values of Vdata**1** to Vdata**3**. Electric current can be continuously supplied through Vdd, and thus, light may be emitted continuously.

[0556] The transistors Tr**1**, Tr**2** and the capacitor may be formed inside the support substrate **2510**. For example, thin film transistors formed on a silicon substrate may be used for active matrix driving.

[0557] Here, the light emitting diodes LED**1** to LED**3** may correspond to the first to third LED stacks **2230**, **2330**, and **2430** stacked in one pixel, respectively. The anodes of the first to third LED stacks **2230**, **2330**, and **2430** are connected to the transistor Tr**2** and the cathodes thereof are connected to the ground.

[0558] Although FIG. **54** shows the circuit for active matrix driving according to an exemplary embodiment, other types of circuits may be variously used. In addition, although the anodes of the light emitting diodes LED**1** to LED**3** are described as being connected to different transistors Tr**2** and the cathodes thereof are described as being connected to the ground, the anodes of the light emitting diodes may be connected to current supplies Vdd and the cathodes thereof may be connected to different transistors in some exemplary embodiments.

[0559] FIG. **55** is a schematic plan view of a display apparatus according to another exemplary embodiment. Hereinafter, the following description will be given with reference to one pixel among a plurality of pixels arranged on the support substrate **2511**.

[0560] Referring to FIG. **55**, the pixel according to an exemplary embodiment are substantially similar to the pixel described with reference to FIG. **49** to FIG. **52**, except that the support substrate **2511** is a thin film transistor panel including transistors and capacitors and the reflective electrode **2250** is disposed in a lower region of the first LED stack **2230**.

[0561] The cathode of the third LED stack **2430** is connected to the support substrate **2511** through the connecting portion **2711***a*. For example, as shown in FIG. **54**, the cathode of the third LED stack **2430** may be connected to the ground through electrical connection to the support substrate **2511**. The cathodes of the second LED stack **2330** and the first LED stack **2230** may also be connected to the ground through electrical connection to the support substrate **2511** via the connecting portions **2731***a* and **2751***a*.

[0562] The reflective electrode is connected to the transistors Tr2 (see FIG. **54**) inside the support substrate **2511**. The third-p transparent electrode and the second-p transparent electrode are also connected to the transistors Tr**2** (see FIG. **54**) inside the support substrate **2511** through the connecting portions **2711***b* and **2731***b*.

[0563] In this manner, the first to third LED stacks are connected to one another, thereby forming a circuit for active matrix driving, as shown in FIG. **54**.

[0564] Although FIG. **55** shows a pixel having an electrical connection for active matrix driving according to an exemplary embodiment, the inventive concepts are not limited thereto, and the circuit for the display apparatus can be modified into various circuits for active matrix driving in various ways.

[0565] In addition, the reflective electrode **2250**, the second-p transparent electrode **2350**, and the third-p transparent electrode **2450** of FIG. **46** are described as forming ohmic contact with the p-type semiconductor layer of each of the first LED stack **2230**, the second LED stack **2330**, and the third LED stack **2430**, and the ohmic electrode **2290** is described as forming ohmic contact with the n-type semiconductor layer of the first LED stack **2230**, the n-type semiconductor layer of each of the second LED stack **2330**, and the third LED stack **2430** is not provided with a separate ohmic contact layer. Although there is less difficulty in current spreading even without formation of a separate ohmic contact layer in the n-type semiconductor layer when the pixels have a small size of 200 μm or less, however, a transparent electrode layer may be disposed on the n-type semiconductor layer of each of the LED stacks in order to secure current spreading according to some exemplary embodiments.

[0566] In addition, although FIG. **46** shows the coupling of the first to third LED stacks **2230**, **2330**, and **2430** to one another via a bonding layers, the inventive concepts are not limited thereto, and the first to third LED stacks **2230**, **2330**, and **2430** may be connected to one another in various sequences and using various structures.

[0567] According to exemplary embodiments, since it is possible to form a plurality of pixels at the wafer level using the light emitting diode stack **2000** for a display, the need for individual mounting of light emitting diodes may be obviated. In addition, the light emitting diode stack according to exemplary embodiments has the structure in which the first to third LED stacks **2230**, **2330**, and **2430** are stacked in the vertical direction, and thus, an area for subpixels may be secured in a limited pixel area. Furthermore, the light emitting diode stack according to the exemplary embodiments allows light generated from the first LED stack **2230**, the second LED stack **2330**, and the third LED stack **2430** to be emitted outside therethrough, thereby reducing light loss.

[0568] FIG. **56** is a schematic plan view of a display apparatus according to an exemplary embodiment, and FIG. **57** is a schematic cross-sectional view of a light emitting diode pixel for a display according to an exemplary embodiment.

[0569] Referring to FIG. **56** and FIG. **57**, the display apparatus includes a circuit board **3510** and a plurality of pixels **3000**. Each of the pixels **3000** includes a substrate **3210** and first to third subpixels R, G, and B disposed on the substrate **3210**.

[0570] The circuit board **3510** may include a passive circuit or an active circuit. The passive circuit may include, for example, data lines and scan lines. The active circuit may include, for example, a transistor and a capacitor. The circuit board **3510** may have a circuit on a surface thereof or therein. The circuit board **3510** may include, for example, a glass substrate, a sapphire substrate, a Si substrate, or a Ge substrate.

[0571] The substrate **3210** supports first to third subpixels R, G, and B. The substrate **3210** is continuous over the plurality of pixels **3000** and electrically connects the subpixels R, G, and B to the circuit board **3510**. For example, the substrate **3210** may be a GaAs substrate.

[0572] The first subpixel R includes a first LED stack **3230**, the second subpixel G includes a second LED stack **3330**, and the third subpixel B includes a third LED stack **3430**. The first subpixel R is configured to allow the first LED stack **3230** to emit light, the second subpixel G is configured to allow the second LED stack **3330** to emit light, and the third subpixel B is configured to allow the third LED stack **3430** to emit light. The first to third LED stacks **3230**, **3330**, and **3430** may be driven independently.

[0573] The first LED stack **3230**, the second LED stack **3330**, and the third LED stack **3430** are stacked to overlap one another in the vertical direction. Here, as shown in FIG. **57**, the second LED stack **3330** may be disposed in a portion of the first LED stack **3230**. For example, the second LED stack **3330** may be disposed towards one side on the first LED stack **3230**. The third LED stack **3430** may be disposed in a portion of the second LED stack **3330**. For example, the third LED stack **3430** may be disposed towards one side on the second LED stack **3330**. Although FIG. **57** shows that the third LED stack **3430** is disposed towards right side, the inventive concepts are not limited thereto. Alternatively, the third LED stack **3430** may be disposed towards the left side of the second LED stack **3330**.

[0574] Light R generated from the first LED stack **3230** may be emitted through a region not covered by the second LED stack **3330**, and light G generated from the second LED stack **3330** may be emitted through a region not covered by the third LED stack **3430**. More particularly, light generated from the first LED stack **3230** may be emitted to the outside without passing through the second LED stack **3330** and the third LED stack **3430**, and light generated from the second LED stack **3330** may be emitted to the outside without passing through the third LED stack **3430**.

[0575] The region of the first LED stack **3230** through which the light R is emitted, the region of the second LED stack **3330** through which the light G is emitted, and the region of the third LED stack **3340** may have different areas, and the intensity of light emitted from each of the LED stacks **3230**, **3330**, and **3430** may be adjusted by adjusting the areas thereof.

[0576] However, the inventive concepts are not limited thereto. Alternatively, light generated from the first LED stack **3230** may be emitted to the outside after passing through the second LED stack **3330** or after passing through the second LED stack **3330** and the third LED stack **3430**, and light generated from the second LED stack **3330** may be emitted to the outside after passing through the third LED stack **3430**.

[0577] Each of the first LED stack **3230**, the second LED stack **3330**, and the third LED stack **3430** may include a first conductivity type (for example, n-type) semiconductor layer, a second conductivity type (for example, p-type) semiconductor layer, and an active layer interposed therebetween. The active layer may have a multi-quantum well structure. The first to third LED stacks **3230**, **3330**, and **3430** may include different active layers to emit light having different wavelengths. For example, the first LED stack **3230** may be an inorganic light emitting diode configured to emit red light, the second LED stack **3330** may be an inorganic light emitting diode configured to emit green light, and the third LED stack **3430** may be an inorganic light emitting diode configured to emit blue light. To this end, the first LED stack **3230** may include an AlGaInP-based well layer, the second LED stack **3330** may include an AlGaInP or AlGaInN-based well layer, and the third LED stack **3430** may include an AlGaInN-based well layer. However, the inventive concepts are not limited thereto. The wavelengths of light generated from the first LED stack **3230**, the second LED stack **3330**, and the third LED stack **3430** may be varied. For example, the first LED stack **3230**, the second LED stack **3330**, and the third LED stack **3430** may emit green light, red light, and blue light, respectively, or may emit green light, blue light, and red light, respectively.

[0578] In addition, a distributed Bragg reflector may be interposed between the substrate **3210** and the first LED stack **3230** to prevent loss of light generated from the first LED stack **3230** through absorption by the substrate **3210**. For example, a distributed Bragg reflector formed by alternately stacking AlAs and AlGaAs semiconductor layers one above another may be interposed therebetween.

[0579] FIG. **58** is a schematic circuit diagram of a display apparatus according to an exemplary embodiment.

[0580] Referring to FIG. **58**, the display apparatus according to an exemplary embodiment may be driven in an active matrix manner. As such, the circuit board may include an active circuit.

[0581] For example, the drive circuit may include at least two transistors Tr**1**, Tr**2** and a capacitor. When a power source is connected to selection lines Vrowl to Vrow**3** and voltage is applied to data lines Vdata**1** to Vdata**3**, the voltage is applied to the corresponding light emitting diode. In addition, the corresponding capacitors are charged according to the values of Vdata**1** to Vdata**3**. Since a turned-on state of the transistor Tr**2** can be maintained by the charged voltage of the capacitor, the voltage of the capacitor can be maintained and applied to the light emitting diodes LED**1** to LED**3** even when power supplied to Vrowl is cut off. In addition, electric current flowing in the light emitting diodes LED**1** to LED**3** can be changed depending upon the values of Vdata**1** to Vdata**3**. Electric current can be continuously supplied through Vdd, and thus, light may be emitted continuously.

[0582] The transistors Tr**1**, Tr**2** and the capacitor may be formed inside the support substrate **3510**. Here, the light emitting diodes LED**1** to LED**3** may correspond to the first to third LED stacks **3230**, **3330**, and **3430** stacked in one pixel, respectively. The anodes of the first to third LED stacks **3230**, **3330**, and **3430** are connected to the transistor Tr**2** and the cathodes thereof are connected to the ground. The cathodes of the first to third LED stacks **3230**, **3330**, and **3430**, for example, may be commonly connected to the ground.

[0583] Although FIG. **58** shows the circuit for active matrix driving according to an exemplary embodiment, other types of circuits may also be used. In addition, although the anodes of the light emitting diodes LED**1** to LED**3** are described as being connected to different transistors Tr**2** and the cathodes thereof are described as being connected to the ground, the anodes of the light emitting diodes may be commonly connected and the cathodes thereof may be connected to different transistors in some exemplary embodiments.

[0584] Although the active circuit for active matrix driving is illustrated above, the inventive concepts are not limited thereto, and the pixels according to an exemplary embodiment may be driven in a passive matrix manner. As such, the circuit board **3510** may include data lines and scan lines arranged thereon, and each of the subpixels may be connected to the data line and the scan line. In an exemplary embodiment, the anodes of the first to third LED stacks **3230**, **3330**, and **3430** may be connected to different data lines and the cathodes thereof may be commonly connected to a scan line. In another exemplary embodiments, the anodes of the first to third LED stacks **3230**, **3330**, and **3430** may be connected to different scan lines and the cathodes thereof may be commonly connected to a data line.

[0585] In addition, each of the LED stacks **3230**, **3330**, and **3430** may be driven by a pulse width modulation or by changing the magnitude of electric current, thereby controlling the brightness of each subpixel. Furthermore, the brightness may be adjusted by adjusting the areas of the first to third LED stacks **3230**, **3330**, and **3430**, and the areas of the regions of the LED stacks **3230**, **3330**, and **3430** through which light R, G, and B is emitted. For example, an LED stack emitting light having low visibility, for example, the first LED stack **3230**, has a larger area than the second LED stack **3330** or the third LED stack **3430**, and thus, can emit light with a higher intensity under the same current density. In addition, since the area of the second LED stack **3330** is larger than the area of the third LED stack **3430**, the second LED stack **3330** can emit light with a higher intensity under the same current density than the third LED stack **3430**. In this manner, light output can be adjusted based on the visibility of light emitted from the first to third LED stacks **3230**, **3330**, and **3430** by adjusting the areas of the first LED stack **3230**, the second LED stack **3330**, and the third LED stack **3430**.

[0586] FIG. **59**A and FIG. **59**B are a top view and a bottom view of one pixel of a display apparatus according to an exemplary embodiment, and FIG. **60**A, FIG. **60**B, FIG. **60**C, and FIG. **60**D are schematic cross-sectional views taken along lines A-A, B-B, C-C, and D-D of FIG. **59**A, respectively.

[0587] In the display apparatus, pixels are arranged on a circuit board **3510** (see FIG. **56**) and each of the pixel includes a substrate **3210** and subpixels R, G, and B. The substrate **3210** may be continuous over the plurality of pixels. Hereinafter, a configuration of a pixel according to an exemplary embodiment will be described.

[0588] Referring to FIG. **59**A, FIG. **59**B, FIG. **60**A, FIG. **60**B, FIG. **60**C, and FIG. **60**D, the pixel includes a substrate **3210**, a distributed Bragg reflector **3220**, an insulation layer **3250**, through-hole vias **3270***a*, **3270***b*, **3270***c*, a first LED stack **3230**, a second LED stack **3330**, a third LED stack **3430**, a first-1 ohmic electrode **3290***a*, a first-2 ohmic electrode **3290***b*, a second-1 ohmic electrode **3390**, a second-2 ohmic electrode **3350**, a third-1 ohmic electrode **3490**, a third-2 ohmic electrode **3450**, a first bonding layer **3530**, a second bonding layer **3550**, an upper insulation layer **3610**, connectors **3710**, **3720**, **3730**, a lower insulation layer **3750**, and electrode pads **3770***a*, **3770***b*, **3770***c*, **3770***d*.

[0589] Each of subpixels R, G, and B includes the LED stacks **3230**, **3330**, and **3430** and ohmic electrodes. In addition, anodes of the first to third subpixels R, G, and B may be electrically connected to the electrode pads **3770***a*, **3770***b*, and **3770***c*, respectively, and cathodes thereof may be electrically connected to the electrode pad **3770***d*, thereby allowing the first to third subpixels R, G, and B to be driven independently.

[0590] The substrate **3210** supports the LED stacks **3230**, **3330**, and **3430**. The substrate **3210** may be a growth substrate on which AlGaInP-based semiconductor layers may be grown thereon, for example, a GaAs substrate. In particular, the substrate **3210** may be a semiconductor substrate exhibiting n-type conductivity.

[0591] The first LED stack **3230** includes a first conductivity type semiconductor layer **3230***a* and a second conductivity type semiconductor layer **3230***b*, the second LED stack **3330** includes a first conductivity type semiconductor layer **3330***a* and a second conductivity type semiconductor layer **3330***b*, and the third LED stack **3430** includes a first conductivity type semiconductor layer **3430***a* and a second conductivity type semiconductor layer **3430***b*. An active layer may be interposed between the first conductivity type semiconductor layer **3230***a*, **3330***a*, or **3430***a* and the second conductivity type semiconductor layer **3230***b*, **3330***b*, or **3430***b*.

[0592] According to an exemplary embodiment, each of the first conductivity type semiconductor layers **3230***a*, **3330***a*, **3430***a* may be an n-type semiconductor layer, and each of the second conductivity type semiconductor layers **3230***b*, **3330***b*, **3430***b* may be a p-type semiconductor layer. A roughened surface may be formed on an upper surface of each of the first conductivity type semiconductor layers **3230***a*, **3330***a*, **3430***a* by surface texturing. However, the inventive concepts are not limited thereto and the first and second conductivity types can be changed vice versa.

[0593] The first LED stack **3230** is disposed near the support substrate **3510**, the second LED stack **3330** is disposed on the first LED stack **3230**, and the third LED stack **3430** is disposed on the second LED stack **3330**. The second LED stack **3330** is disposed in some region on the first LED stack **3230**, so that the first LED stack **3230** partially overlaps the second LED stack **3330**. The third LED stack **3430** is disposed in some region on the second LED stack **3330**, so that the second LED stack **3330** partially overlaps the third LED stack **3430**. Accordingly, light generated from the first LED stack **3230** can be emitted to the outside without passing through the second and third LED stacks **3330** and **3430**. In addition, light generated from the second LED stack **3330** can be emitted to the outside without passing through the third LED stack **3430**.

[0594] Materials for the first LED stack **3230**, the second LED stack **3330**, and the third LED stack **3430** are substantially the same as those described with reference to FIG. **57**, and thus, detailed descriptions thereof will be omitted to avoid redundancy.

[0595] The distributed Bragg reflector **3220** is interposed between the substrate **3210** and the first LED stack **3230**. The distributed Bragg reflector **3220** may include a semiconductor layer grown on the substrate **3210**. For example, the distributed Bragg reflector **3220** may be formed by alternately stacking AlAs layers and AlGaAs layers. The distributed Bragg reflector **3220** may include a semiconductor layer that electrically connects the substrate **3210** to the first conductivity type semiconductor layer **3230***a* of the first LED stack **3230**.

[0596] Through-hole vias **3270***a*, **3270***b*, **3270***c* are formed through the substrate **3210**. The through-hole vias **3270***a*, **3270***b*, **3270***c* may be formed to pass through the first LED stack **3230**. The through-hole vias **3270***a*, **3270***b*, **3270***c* may be formed of conductive pastes or by plating.

[0597] The insulation layer **3250** is disposed between the through-hole vias **3270***a*, **3270***b*, and **3270***c* and an inner wall of a through-hole formed through the substrate **3210** and the first LED stack **3230** to prevent short circuit between the first LED stack **3230** and the substrate **3210**.

[0598] The first-1 ohmic electrode **3290***a* forms ohmic contact with the first conductivity type semiconductor layer **3230***a* of the first LED stack **3230**. The first-1 ohmic electrode **3290***a* may be formed of, for example, Au—Te or Au—Ge alloys.

[0599] In order to form the first-1 ohmic electrode **3290***a*, the second conductivity type semiconductor layer **3230***b* and the active layer may be partially removed to expose the first conductivity type semiconductor layer **3230***a*. The first-1 ohmic electrode **3290***a* may be disposed apart from the region where the second LED stack **3330** is disposed. Furthermore, the first-1 ohmic electrode **3290** may include a pad region and an extension, and the connector **3710** may be connected to the pad region of the first-1 ohmic electrode **3290**, as shown in FIG. **59**A.

[0600] The first-2 ohmic electrode **3290***b* forms ohmic contact with the second conductivity type semiconductor layer **3230***b* of the first LED stack **3230**. As shown in FIG. **59**A, the first-2 ohmic electrode **3290***b* may be formed to partially surround the first-1 ohmic electrode **3290***a* in order to assist in current spreading. The first-2 ohmic electrode **3290***b* may not include the extension. The first-2 ohmic electrode **3290***b* may be formed of, for example, Au—Zn or Au—Be alloys. Furthermore, the first-2 ohmic electrode **3290***b* may have a single layer or multiple layers structure.

[0601] The first-2 ohmic electrode **3290***b* may be connected to the through-hole via **3270***a* such that the through-hole via **3270***a* can be electrically connected to the second conductivity type semiconductor layer **3230***b*.

[0602] The second-1 ohmic electrode **3390** forms ohmic contact with the first conductivity type semiconductor layer

3330*a* of the second LED stack **3330**. The second-1 ohmic electrode **3390** may also include a pad region and an extension. As shown in FIG. **59**A, the connector **3710** may electrically connect the second-1 ohmic electrode **3390** to the first-1 ohmic electrode **3290***a*. The second-1 ohmic electrode **3390** may be disposed apart from the region where the third LED stack **3430** is disposed.

[0603] The second-2 ohmic electrode **3350** forms ohmic contact with the second conductivity type semiconductor layer **3330***b* of the second LED stack **3330**. The second-2 ohmic electrode **3350** may include a reflective layer **3350***a* and a barrier layer **3350***b*. The reflective layer **3350***a* reflects light generated from the second LED stack **3330** to improve luminous efficacy of the second LED stack **3330**. The barrier layer **3350***b* may act as a connection pad, which provides the reflective layer **3350***a*, and is connected to the connector **3720**. Although the second-2 ohmic electrode **3350** is described as including a metal layer in this exemplary embodiment, the inventive concepts are not limited thereto. For example, the second-2 ohmic electrode **3350** may be formed of a transparent conductive oxide, such as a conducive oxide semiconductor layer.

[0604] The third-1 ohmic electrode **3490** forms ohmic contact with the first conductivity type semiconductor layer **3430***a* of the third LED stack **3430**. The third-1 ohmic electrode **3490** may also include a pad region and an extension, and the connector **3710** may connect the third-1 ohmic electrode **3490** to the first-1 ohmic electrode **3290***a*, as shown in FIG. **59**A.

[0605] The third-2 ohmic electrode **3450** may form ohmic contact with the second conductivity type semiconductor layer **3430***b* of the third LED stack **3430**. The third-2 ohmic electrode **3450** may include a reflective layer **3450***a* and a barrier layer **3450***b*. The reflective layer **3450***a* reflects light generated from the third LED stack **3430** to improve luminous efficacy of the third LED stack **3430**. The barrier layer **3450***b* may act as a connection pad, which provides the reflective layer **3450***a*, and is connected to the connector **3730**. Although the third-2 ohmic electrode **3450** is described as including a metal layer, the inventive concepts are not limited thereto. Alternatively, the third-2 ohmic electrode **3450** may be formed of a transparent conductive oxide, such as a conducive oxide semiconductor layer.

[0606] The first-2 ohmic electrode **3290***b*, the second-2 ohmic electrode **3350**, and the third-2 ohmic electrode **3450** may form ohmic contact with the p-type semiconductor layers of the corresponding LED stacks to assist in current spreading, and the first-1 ohmic electrode **3290***a*, the second-1 ohmic electrode **3390**, and the third-1 ohmic electrode **3490** may form ohmic contact with the n-type semiconductor layers of the corresponding LED stacks to assist in current spreading.

[0607] The first bonding layer **3530** couples the second LED stack **3330** to the first LED stack **3230**. As shown in the drawings, the second-2 ohmic electrode **3350** may adjoin the first bonding layer **3530**. The first bonding layer **3530** may be a light transmissive layer or an opaque layer. The first bonding layer **3530** may be formed of an organic material or an inorganic material. Examples of the organic material may include SUB, poly(methyl methacrylate) (PMMA), polyimide, Parylene, benzocyclobutene (BCB), or others, and examples of the inorganic material may include Al_2O_3, SiO_2, SiN_x, or others. The organic material layer may be bonded under high vacuum, and the inorganic material layer may be bonded under high vacuum after flattening the surface of the first bonding layer by, for example, chemical mechanical polishing, followed by adjusting surface energy through plasma treatment. The first bonding layer **3530** may be formed of spin-on-glass or may be a metal bonding layer formed of AuSn or the like. For the metal bonding layer, an insulation layer may be disposed on the first LED stack **3230** to secure electrical insulation between the first LED stack **3230** and the metal bonding layer. Furthermore, a reflective layer may be further disposed between the first bonding layer **3530** and the first LED stack **3230** to prevent light generated from the first LED stack **3230** from entering the second LED stack **3330**.

[0608] The second bonding layer **3550** couples the second LED stack **3330** to the third LED stack **3430**. The second bonding layer **3550** may be interposed between the second LED stack **3330** and the third-2 ohmic electrode **3450** to bond the second LED stack **3330** to the third-2 ohmic electrode **3450**. The second bonding layer **3550** may be formed of substantially the same bonding material as the first bonding layer **3530**. Furthermore, an insulation layer and/or a reflective layer may be further disposed between the second LED stack **3330** and the second bonding layer **3550**.

[0609] When the first bonding layer **3530** and the second bonding layer **3550** are formed of a light transmissive material, and the second-2 ohmic electrode **3350** and the third-2 ohmic electrode **3450** are formed of a transparent oxide material, some fractions of light generated from the first LED stack **3230** may be emitted through the second LED stack **3330** after passing through the first bonding layer **3530** and the second-2 ohmic electrode **3350**, and may also be emitted through the third LED stack **3430** after passing through the second bonding layer **3550** and the third-2 ohmic electrode **3450**. In addition, some fractions of light generated from the second LED stack **3330** may be emitted through the third LED stack **3430** after passing through the second bonding layer **3550** and the third-2 ohmic electrode **3450**.

[0610] In this case, light generated from the first LED stack **3230** should be prevented from being absorbed by the second LED stack **3330** while passing through the second LED stack **3330**. As such, light generated from the first LED stack **3230** may have a smaller bandgap than the second LED stack **3330**, and thus, may have a longer wavelength than light generated from the second LED stack **3330**.

[0611] In addition, in order to prevent light generated from the second LED stack **3330** from being absorbed by the third LED stack **3430** while passing through the third LED stack **3430**, light generated from the second LED stack **3330** may have a longer wavelength than light generated from the third LED stack **3430**.

[0612] When the first bonding layer **3530** and the second bonding layer **3550** are formed of opaque materials, the reflective layers are interposed between the first LED stack **3230** and the first bonding layer **3530**, and between the second LED stack **3330** and the second bonding layer **3550**, respectively, to reflect light having been generated from the first LED stack **3230** and entering the first bonding layer **3530**, and light having been generated from the second LED stack **3330** and entering the second bonding layer **3550**. The reflected light may be emitted through the first LED stack **3230** and the second LED stack **3330**.

[0613] The upper insulation layer **3610** may cover the first to third LED stacks **3230**, **3330**, and **3430**. In particular, the upper insulation layer **3610** may cover side surfaces of the second LED stack **3330** and the third LED stack **3430**, and may also cover the side surface of the first LED stack **3230**.

[0614] The upper insulation layer **3610** has openings that expose the first to third the through-hole vias **3270***a*, **3270***b*, **3270***c*, and openings that expose the first conductivity type semiconductor layer **3330***a* of the second LED stack **3330**, the first conductivity type semiconductor layer **3430***a* of the third LED stack **3430**, the second-2 ohmic electrode **3350**, and the third-2 ohmic electrode **3450**.

[0615] The upper insulation layer **3610** may be formed of any insulation material, for example, silicon oxide or silicon nitride, without being limited thereto.

[0616] The connector **3710** electrically connects the first-1 ohmic electrode **3290***a*, the second-1 ohmic electrode **3390**, and the third-1 ohmic electrode **3490** to one another. The connector **3710** is formed on the upper insulation layer **3610**, and is insulated from the second conductivity type semiconductor layer **3430***b* of the third LED stack **3430**, the second conductivity type semiconductor layer **3330***b* of the second LED stack **3330**, and the second conductivity type semiconductor layer **3230***b* of the first LED stack **3230**.

[0617] The connector **3710** may be formed of substantially the same material as the second-1 ohmic electrode **3390** and the third-1 ohmic electrode **3490**, and thus, may be formed together with the second-1 ohmic electrode **3390** and the third-1 ohmic electrode **3490**. Alternatively, the connector **3710** may be formed of a different conductive material from the second-1 ohmic electrode **3390** or the third-1 ohmic electrode **3490**, and thus, may be separately formed in a different process from the second-1 ohmic electrode **3390** and/or the third-1 ohmic electrode **3490**.

[0618] The connector **3720** may electrically connect the second-1 ohmic electrode **3350**, for example, the barrier layer **3350***b*, to the second through-hole via **3270***b*. The connector **3730** electrically connects the third-1 ohmic electrode, for example, the barrier layer **3450***b*, to the third through-hole via **3270***c*. The connector **3720** may be electrically insulated from the first LED stack **3230** by the upper insulation layer **3610**. The connector **3730** may also be electrically insulated from the second LED stack **3330** and the first LED stack **3230** by the upper insulation layer **3610**.

[0619] The connectors **3720**, **3730** may be formed together by the same process. The connector **3720**, **3730** may also be formed together with the connector **3710**. Furthermore, the connectors **3720**, **3730** may be formed of substantially the same material as the second-1 ohmic electrode **3390** and the third-1 ohmic electrode **3490**, and may be formed together therewith. Alternatively, the connectors **3720**, **3730** may be formed of a different conductive material from the second-1 ohmic electrode **3390** or the third-1 ohmic electrode **3490**, and thus may be separately formed by a different process from the second-1 ohmic electrode **3390** and/or the third-1 ohmic electrode **3490**.

[0620] The lower insulation layer **3750** covers a lower surface of the substrate **3210**. The lower insulation layer **3750** may include openings which expose the first to third through-hole vias **3270***a*, **3270***b*, **3270***c* at a lower side of the substrate **3210**, and may also include openings which expose the lower surface of the substrate **3210**.

[0621] The electrode pads **3770***a*, **3770***b*, **3770***c*, and **3770***d* are disposed on the lower surface of the substrate **3210**. The electrode pads **3770***a*, **3770***b*, and **3770***c* are connected to the through-hole vias **3270***a*, **3270***b*, and **3270***c* through the openings of the insulation layer **3750**, and the electrode pad **3770***d* is connected to the substrate **3210**.

[0622] The electrode pads **3770***a*, **3770***b*, and **3770***c* are provided to each pixel to be electrically connected to the first to third LED stacks **3230**, **3330**, and **3430** of each pixel, respectively. Although the electrode pad **3770***d* may also be provided to each pixel, the substrate **3210** is continuously disposed over a plurality of pixels, which may obviate the need for providing the electrode pad **3770***d* to each pixel.

[0623] The electrode pads **3770***a*, **3770***b*, **3770***c*, **3770***d* are bonded to the circuit board **3510**, thereby providing a display apparatus.

[0624] Next, a method of manufacturing the display apparatus according to an exemplary embodiment will be described.

[0625] FIG. **61**A to FIG. **68**B are schematic plan views and cross-sectional views illustrating a method of manufacturing the display apparatus according to an exemplary embodiment. Each of the cross-sectional views is taken along a line shown in each corresponding plan view.

[0626] Referring to FIGS. **61**A and **61**B, a first LED stack **3230** is grown on a substrate **3210**. The substrate **3210** may be, for example, a GaAs substrate. The first LED stack **3230** is formed of AlGaInP-based semiconductor layers, and includes a first conductivity type semiconductor layer **3230***a*, an active layer, and a second conductivity type semiconductor layer **3230***b*. A distributed Bragg reflector **3220** may be formed prior to growth of the first LED stack **3230**. The distributed Bragg reflector **3220** may have a stack structure formed by repeatedly stacking, for example, AlAs/AlGaAs layers.

[0627] Then, grooves are formed on the first LED stack **3230** and the substrate **3210** through photolithography and etching. The grooves may be formed to pass through the substrate **3210** or may be formed to a predetermined depth in the substrate **3210**, as shown in FIG. **61**B.

[0628] Then, an insulation layer **3250** is formed to cover sidewalls of the grooves and through-hole vias **3270***a*, **3270***b*, **3270***c* are formed to fill the grooves. The through-hole vias **3270***a*, **3270***b*, and **3270***c* may be formed by, for example, forming an insulation layer to cover the sidewalls of the grooves, filling the groove with a conductive material layer or conductive pastes through plating, and removing the insulation and the conductive material layer from an upper surface of the first LED stack **3230** through chemical mechanical polishing.

[0629] Referring to FIG. **62**A and FIG. **62**B, a second LED stack **3330** and a second-2 ohmic electrode **3350** may be coupled to the first LED stack **3230** via the first bonding layer **3530**.

[0630] The second LED stack **3330** is grown on a second substrate, and the second-2 ohmic electrode **3350** is formed on the second LED stack **3330**. The second LED stack **3330** is formed of AlGaInP-based or AlGaInN-based semiconductor layers, and may include a first conductivity type semiconductor layer **3330***a*, an active layer, and a second conductivity type semiconductor layer **3330***b*. The second substrate may be a substrate on which AlGaInP-based semiconductor layers may be grown thereon, for example, a GaAs substrate, or a substrate on which AlGaInN-based semiconductor layers may be grown thereon, for example, a sapphire substrate. The composition ratio of Al, Ga, and In for the second LED stack **3330** may be determined such that the second LED stack **3330** can emit green light. The second-2 ohmic electrode **3350** forms ohmic contact with the second conductivity type semiconductor layer **3330***b*, for example, a p-type semiconductor layer. The second-2 ohmic electrode **3350** may include a reflective layer **3350***a*, which reflects light generated from the second LED stack **3330**, and a barrier layer **3350***b*.

[0631] The second-2 ohmic electrode **3350** is disposed to face the first LED stack **3230** and is coupled to the first LED stack **3230** by the first bonding layer **3530**. Thereafter, the second substrate is removed from the second LED stack **3330** to expose the first conductivity type semiconductor layer **3330***a* by chemical etching or laser lift-off. A roughened surface may be formed on the exposed first conductivity type semiconductor layer **3330***a* by surface texturing.

[0632] According to an exemplary embodiment, an insulation layer and a reflective layer may be further formed on the first LED stack **3230** before formation of the first bonding layer **3530**.

[0633] Referring to FIG. **63**A and FIG. **63**B, a third LED stack **3430** and a third-2 ohmic electrode **3450** may be coupled to the second LED stack **3330** via the second bonding layer **3550**.

[0634] The third LED stack **3430** is grown on a third substrate, and the third-2 ohmic electrode **3450** is formed on the third LED stack **3430**. The third LED stack **3430** is formed of AlGaInN-based semiconductor layers, and may include a first conductivity type semiconductor layer **3430***a*, an active layer, and a second conductivity type semiconductor layer **3430***b*. The third substrate is a substrate on which GaN-based semiconductor layers may be grown thereon, and is different from the first substrate **3210**. The composition ratio of AlGaInN for the third LED stack **3430** may be determined such that the third LED stack **3430** can emit blue light. The third-2 ohmic electrode **3450** forms ohmic contact with the second conductivity type semiconductor layer **3430***b*, for example, a p-type semiconductor layer. The third-2 ohmic electrode **3450** may include a reflective layer **3450***a*, which reflects light generated from the third LED stack **3430**, and a barrier layer **3450***b*.

[0635] The third-2 ohmic electrode **3450** is disposed to face the second LED stack **3330** and is coupled to the second LED stack **3330** by the second bonding layer **3550**. Thereafter, the third substrate is removed from the third LED stack **3430** to expose the first conductivity type semiconductor layer **3430***a* by chemical etching or laser lift-off. A roughened surface may be formed on the exposed first conductivity type semiconductor layer **3430***a* by surface texturing.

[0636] According to an exemplary embodiment, an insulation layer and a reflective layer may be further formed on the second LED stack **3330** before formation of the second bonding layer **3550**.

[0637] Referring to FIG. **64**A and FIG. **64**B, in each of pixel regions, the third LED stack **3430** is patterned to remove the third LED stack **3430** other than in the third subpixel B. In a region of the third subpixel B, an indentation is formed on the third LED stack **3430** to expose the barrier layer **3450***b* through the indentation.

[0638] Then, in regions other than the third subpixel B, the third-2 ohmic electrode **3450** and the second bonding layer **3550** are removed to expose the second LED stack **3330**. As such, the third-2 ohmic electrode **3450** is restrictively placed near the region of the third subpixel B.

[0639] In each pixel region, the second LED stack **3330** is patterned to remove the second LED stack **3330** in regions other than the second subpixel G. In the region of the second subpixel G, the second LED stack **3330** partially overlaps the third LED stack **3430**.

[0640] By patterning the second LED stack **3330**, the second-2 ohmic electrode **3350** is exposed. The second LED stack **3330** may include an indentation, and the second-2 ohmic electrode **3350**, for example, the barrier layer **3350***b*, may be exposed through the indentation.

[0641] Thereafter, the second-2 ohmic electrode **3350** and the first bonding layer **3530** are removed to expose the first LED stack **3230**. As such, the second-2 ohmic electrode **3350** is disposed near the region of the second subpixel G. On the other hand, the first to third through-hole vias **3270***a*, **3270***b*, and **3270***c* are also exposed together with the first LED stack **3230**.

[0642] In each pixel region, the first conductivity type semiconductor layer **3230***a* is exposed by patterning the second conductivity type semiconductor layer **3230***b* of the first LED stack **3230**. As shown in FIG. **64**A, the first conductivity type semiconductor layer **3230***a* may be exposed in an elongated shape, without being limited thereto.

[0643] Furthermore, the pixel regions are divided from one another by patterning the first LED stack **3230**. As such, a region of the first subpixel R is defined. Here, the distributed Bragg reflector **3220** may also be divided. Alternatively, the distributed Bragg reflector **3220** may be continuously disposed over the plurality of pixels, rather than being divided. Further, the first conductivity type semiconductor layer **3230***a* may also be continuously disposed over the plurality of pixels.

[0644] Referring to FIG. **65**A and FIG. **65**B, a first-1 ohmic electrode **3290***a* and a first-2 ohmic electrode **3290***b* are formed on the first LED stack **3230**. The first-1 ohmic electrode **3290***a* may be formed of, for example, Au—Te or Au—Ge alloys on the exposed first conductivity type semiconductor layer **3230***a*. The first-2 ohmic electrode **3290***b* may be formed of, for example, Au—Be or Au—Zn alloys on the second conductivity type semiconductor layer **3230***b*. The first-2 ohmic electrode **3290***b* may be formed prior to the first-1 ohmic electrode **3290***a*, or vice versa. The first-2 ohmic electrode **3290***b* may be connected to the first through-hole via **3270***a*. On the other hand, the first-1 ohmic electrode **3290***a* may include a pad region and an extension, which may extend from the pad region towards the first through-hole via **3270***a*.

[0645] For current spreading, the first-2 ohmic electrode **3290***b* may be disposed to at least partially surround the first-1 ohmic electrode **3290***a*. Although each of the first-1 ohmic electrode **3290***a* and the first-2 ohmic electrode **3290***b* is being illustrated as having an elongated shape in FIG. **65**A, the inventive concepts are not limited thereto. Alternatively, each of the first-1 ohmic electrode **3290***a* and the first-2 ohmic electrode **3290***b* may have a circular shape, for example.

[0646] Referring to FIG. **66**A and FIG. **66**B, an upper insulation layer **3610** is formed to cover the first to third LED stacks **3230**, **3330**, **3430**. The upper insulation layer **3610** may cover the first-1 ohmic electrode **3290***a* and the first-2 ohmic electrode **3290***b*. The upper insulation layer **3610** may also cover side surfaces of the first to third LED stacks **3230**, **3330**, and **3430**, and a side surface of the distributed Bragg reflector **3220**.

[0647] The upper insulation layer **3610** may have an opening **3610***a* which exposes the first-1 ohmic electrode **3290***a*, openings **3610***b*, **3610***c* which expose the barrier layers **3350***b*, **3450***b*, openings **3610***d*, **3610***e* which expose the second and third through-hole vias **3270***b*, **3270***c*, and openings **3610***f*, **3610***g* which expose the first conductivity type semiconductor layers **3330***a*, **3430***a* of the second LED stack **3330** and the third LED stack **3430**.

[0648] Referring to FIG. **67**A and FIG. **67**B, a second-1 ohmic electrode **3390**, a third-1 ohmic electrode **3490** and connectors **3710**, **3720**, **3730** are formed. The second-1 ohmic electrode **3390** is formed in the opening **3610***f* to form ohmic contact with the first conductivity type semiconductor layer **3330***a*, and the third-1 ohmic electrode **3490** is formed in the opening **3610***g* to form ohmic contact with the first conductivity type semiconductor layer **3430***a*.

[0649] The connector **3710** electrically connects the second-1 ohmic electrode **3390** and the third-1 ohmic electrode **3490** to the first-1 ohmic electrode **3290***a*. The connector **3710** may be connected to, for example, the first-1 ohmic electrode **3290***a* exposed in the opening **3610***a*. The connector **3710** is formed on the upper insulation layer **3610** to be insulated from the second conductivity type semiconductor layers **3230***b*, **3330***b*, and **3430***b*.

[0650] The connector **3720** electrically connects the second-2 ohmic electrode **3350** to the second through-hole via **3270***b*, and the connector **3730** electrically connects the third-2 ohmic electrode **3450** to the third through-hole via **3270***c*. The connectors **3720**, **3730** are disposed on the upper insulation layer **3610** to prevent short circuit to the first to third LED stacks **3230**, **3330**, and **3430**.

[0651] The second-1 ohmic electrode **3390**, the third-1 ohmic electrode **3490**, and the connectors **3710**, **3720**, **3730** may be formed of substantially the same material by the same process. However, the inventive concepts are not limited thereto. Alternatively, the second-1 ohmic electrode **3390**, the third-1 ohmic electrode **3490**, and the connectors **3710**, **3720**, **3730** may be formed of different materials by different processes.

[0652] Thereafter, referring to FIG. **68**A and FIG. **68**B, a lower insulation layer **3750** is formed on a lower surface of the substrate **3210**. The lower insulation layer **3750** has openings which expose the first to third the through-hole vias **3270***a*, **3270***b*, **3270***c*, and may also have opening(s) which expose the lower surface of the substrate **3210**.

[0653] Electrode pads **3770***a*, **3770***b*, **3770***c*, **3770***d* are formed on the lower insulation layer **3750**. The electrode pads **3770***a*, **3770***b*, **3770***c* are connected to the first to third the through-hole vias **3270***a*, **3270***b*, **3270***c*, respectively, and the electrode pad **3770***d* is connected to the substrate **3210**.

[0654] Accordingly, the electrode pad **3770***a* is electrically connected to the second conductivity type semiconductor layer **3230***b* of the first LED stack **3230** through the first through-hole via **3270***a*, the electrode pad **3770***b* is electrically connected to the second conductivity type semiconductor layer **3330***b* of the second LED stack **3330** through the second through-hole via **3270***b*, and the electrode pad **3770***c* is electrically connected to the second conductivity type semiconductor layer **3430***b* of the third LED stack **3430** through the third through-hole via **3270***c*. The first conductivity type semiconductor layers **3230***a*, **3330***a*, **3430***a* of the first to third LED stacks **3230**, **3330**, **3430** are commonly electrically connected to the electrode pad **3770***d*.

[0655] In this manner, a display apparatus according to an exemplary embodiment may be formed by bonding the electrode pads **3770***a*, **3770***b*, **3770***c*, **3770***d* of the substrate **3210** to the circuit board **3510** shown in FIG. **56**. As described above, the circuit board **3510** may include an active circuit or a passive circuit, whereby the display apparatus can be driven in an active matrix manner or in a passive matrix manner.

[0656] FIG. **69** is a cross-sectional view of a light emitting diode pixel for a display according to another exemplary embodiment.

[0657] Referring to FIG. **69**, the light emitting diode pixel **3001** of the display apparatus according to an exemplary embodiment is generally similar to the light emitting diode pixel **3000** of the display apparatus of FIG. **57**, except that the second LED stack **3330** covers most of the first LED stack **3230** and the third LED stack **3430** covers most of the second LED stack **3330**. In this manner, light generated from the first subpixel R is emitted to the outside after substantially passing through the second LED stack **3330** and the third LED stack **3430**, and light generated from the second LED stack **3330** is emitted to the outside after substantially passing through the third LED stack **3430**.

[0658] The first LED stack **3230** may include an active layer having a narrower bandgap than the second LED stack **3330** and the third LED stack **3430** to emit light having a longer wavelength than the second LED stack **3330** and the third LED stack **3430**, and the second LED stack **3330** may include an active layer having a narrower bandgap than the third LED stack **3430** to emit light having a longer wavelength than the third LED stack **3430**.

[0659] FIG. **70** is an enlarged top view of one pixel of a display apparatus according to an exemplary embodiment, and FIG. **71**A and FIG. **71**B are cross-sectional views taken along lines G-G and H-H of FIG. **70**, respectively.

[0660] Referring to FIG. **70**, FIG. **71**A, and FIG. **71**B, the pixel according to an exemplary embodiment is generally similar to the pixel of FIG. **59**, FIG. **60**A, FIG. **60**B, and FIG. **60**C, except that the second LED stack **3330** covers most of the first LED stack **3230** and the third LED stack **3430** covers most of the second LED stack **3330**. The first to third through-hole vias **3270***a*, **3270***b*, **3270***c* may be disposed outside the second LED stack **3330** and the third LED stack **3430**.

[0661] In addition, a portion of the first-1 ohmic electrode **3290***a* and a portion of the second-1 ohmic electrode **3390** may be disposed under the third LED stack **3430**. As such, the first-1 ohmic electrode **3290***a* may be formed before the second LED stack **3330** is coupled to the first LED stack **3230**, and the second-1 ohmic electrode **3390** may also be formed before the third LED stack **3430** is coupled to the second LED stack **3330**.

[0662] Furthermore, light generated from the first LED stack **3230** is emitted to the outside after substantially passing through the second LED stack **3330** and the third LED stack **3430**, and light generated from the second LED stack **3330** is emitted to the outside after substantially passing through the third LED stack **3430**. Accordingly, the first bonding layer **3530** and the second bonding layer **3550** are formed of light transmissive materials, and the second-2 ohmic electrode **3350** and the third-2 ohmic electrode **3450** are composed of transparent conductive layers.

[0663] On the other hand, as shown in FIGS. **71**A and **71**B, an indentation may be formed on the third LED stack

3430 to expose the third-2 ohmic electrode **3450**, and an indentation is continuously formed on the third LED stack **3430** and the second LED stack **3330** to expose the second-2 ohmic electrode **3350**. The second-2 ohmic electrode **3350** and the third-2 ohmic electrode **3450** are electrically connected to the second through-hole via **3270***b*, and the third through-hole via **3270***c* through the connectors **3720**, **3730**, respectively.

[0664] Furthermore, the indentation may be formed on the third LED stack **3430** to expose the second-1 ohmic electrode **3390** formed on the first conductivity type semiconductor layer **3330***a* of the second LED stack **3330**, and the indentation may be continuously formed on the third LED stack **3430** and the second LED stack **3330** to expose the first-1 ohmic electrode **3290***a* formed on the first conductivity type semiconductor layer **3230***a* of the first LED stack **3230**. The connector **3710** may connect the first-1 ohmic electrode **3290***a* and the second-1 ohmic electrode **3390** to the third-1 ohmic electrode **3490**. The third-1 ohmic electrode **3490** may be formed together with the connector **3710** and may be connected to the pad regions of the first-1 ohmic electrode **3290***a* and the second-1 ohmic electrode **3390**.

[0665] The first-1 ohmic electrode **3290***a* and the second-1 ohmic electrode **3390** are partially disposed under the third LED stack **3430**, but the inventive concepts are not limited thereto. For example, the portions of the first-1 ohmic electrode **3290***a* and the second-1 ohmic electrode **3390** disposed under the third LED stack **3430** may be omitted. Furthermore, the second-1 ohmic electrode **3390** may be omitted and the connector **3710** may form ohmic contact with the first conductivity type semiconductor layer **3330***a*.

[0666] According to exemplary embodiments, a plurality of pixels may be formed at the wafer level through wafer bonding, and thus, the process of individually mounting light emitting diodes may be obviated or substantially reduced.

[0667] Furthermore, since the through-hole vias **3270***a*, **3270***b*, **3270***c* are formed in the substrate **3210** and used as current paths, the substrate **3210** may not need to be removed. Accordingly, a growth substrate used for growth of the first LED stack **3230** can be used as the substrate **3210** without being removed from the first LED stack **3230**.

[0668] Although certain exemplary embodiments and implementations have been described herein, other embodiments and modifications will be apparent from this description. Accordingly, the inventive concepts are not limited to such embodiments, but rather to the broader scope of the appended claims and various obvious modifications and equivalent arrangements as would be apparent to a person of ordinary skill in the art.

What is claimed is:

1. A light emitting diode (LED) stack for a display, comprising:

a first LED sub-unit having a first surface and a second surface;

a second LED sub-unit disposed on the first surface of the first LED sub-unit;

a third LED sub-unit disposed on the second LED sub-unit;

a reflective electrode disposed on the second side of the second LED sub-unit and forming ohmic contact with the first LED sub-unit; and

an ohmic electrode interposed between the first LED sub-unit and the second LED sub-unit and forming ohmic contact with the first LED sub-unit,

wherein:

the second LED sub-unit and the third LED sub-unit are configured to transmit light generated from the first LED sub-unit; and

the third LED sub-unit is configured to transmit light generated from the second LED sub-unit.

2. The LED stack for a display of claim **1**, wherein the first, second, and third LED sub-units comprise first, second, and third LED stacks, respectively.

3. The LED stack for a display of claim **1**, wherein the LED stack comprises a micro LED having a surface area less than about 200 square μm.

4. The LED stack for a display of claim **1**, wherein the reflective electrode and the ohmic electrode have different reflective indices from each other.

5. The LED stack for a display of claim **2**, wherein the first, second, and third LED stacks are configured to emit red light, green light, and blue light, respectively.

6. The LED stack for a display of claim **2**, further comprising:

a first color filter interposed between the first LED stack and the second LED stack, and configured to transmit light generated from the first LED stack and reflect light generated from the second LED stack; and

a second color filter interposed between the second LED stack and the third LED stack, and configured to transmit light generated from the first and second LED stacks and reflect light generated from the third LED stack.

7. The LED stack for a display of claim **6**, wherein each of the first color filter and the second color filter comprises at least one of a low pass filter, a band pass filter, and a band stop filter.

8. The LED stack for a display of claim **7**, wherein each of the first and second color filters comprises a distributed Bragg reflector.

9. The LED stack for a display of claim **2**, further comprising:

a support substrate;

a first bonding layer interposed between the support substrate and the first LED stack;

a second bonding layer interposed between the first LED stack and the second LED stack; and

a third bonding layer interposed between the second LED stack and the third LED stack,

wherein:

the second bonding layer is configured to transmit light generated from the first LED stack; and

the third bonding layer is configured to transmit light generated from the first and second LED stacks.

10. The LED stack for a display of claim **9**, wherein:

the first bonding layer adjoins the reflective electrode; and

the second bonding layer adjoins the ohmic electrode.

11. The LED stack for a display of claim **10**, further comprising:

a second transparent electrode forming ohmic contact with a p-type semiconductor layer of the second LED stack; and

a third-p transparent electrode forming ohmic contact with a p-type semiconductor layer of the third LED stack.

12. The LED stack for a display of claim **11**, wherein the second bonding layer adjoins an n-type semiconductor layer of the first LED stack, and the third bonding layer adjoins an n-type semiconductor layer of the second LED stack.

13. The LED stack for a display of claim **12**, further comprising:

a first color filter interposed between the first LED stack and the second LED stack and configured to transmit light generated from the first LED stack and reflect light generated from the second LED stack; and

a second color filter interposed between the second LED stack and the third LED stack, and configured to transmit light generated from the first and second LED stacks and reflect light generated from the third LED stack,

wherein the first color filter is disposed on the second bonding layer and the second color filter is disposed on the third bonding layer.

14. A display apparatus comprising a plurality of pixels arranged on a support substrate,

wherein at least some of the pixels comprise the LED stack of claim **2**.

15. The display apparatus of claim **14**, wherein:

each of the first, second, and third LED stacks comprises a p-type semiconductor layer and an n-type semiconductor layer;

each of the p-type semiconductor layers of the first, second, and third LED stacks is electrically connected to a common line; and

each of the n-type semiconductor layers of the first, second, and third LED stacks is electrically connected to different lines from each other.

16. The display apparatus of claim **15**, wherein the common line comprises a data line and the different lines comprise scan lines.

17. The display apparatus of claim **14**, further comprising:

a lower insulation layer covering side surfaces of the first, second, and third LED stacks,

the lower insulation layer comprising openings exposing the ohmic electrode, the reflective electrode, the second LED stack, and the third LED stack.

18. The display apparatus of claim **17**, wherein the lower insulation layer comprises a distributed Bragg reflector configured to reflect red, green, and blue light.

19. The display apparatus of claim **15**, wherein the reflective electrode comprises the common line and is continuously disposed over the plurality of pixels.

20. The display apparatus of claim **14**, wherein the reflective electrode is disposed within each pixel region.

* * * * *

专利名称(译)	用于显示器的LED单元和具有该LED单元的显示装置		
公开(公告)号	US20190165038A1	公开(公告)日	2019-05-30
申请号	US16/198796	申请日	2018-11-22
申请(专利权)人(译)	汉城VIOSYS CO. , LTD.		
当前申请(专利权)人(译)	汉城VIOSYS CO. , LTD.		
[标]发明人	CHAE JONG HYEON LEE CHUNG HOON JANG SEONG GYU KIM CHANG YEON LEE HO JOON		
发明人	CHAE, JONG HYEON LEE, CHUNG HOON JANG, SEONG GYU KIM, CHANG YEON LEE, HO JOON		
IPC分类号	H01L27/15 H01L33/40 H01L33/50 H01L33/10 H01L33/30		
CPC分类号	H01L27/156 H01L33/405 H01L33/504 H01L33/10 H01L33/30 H01L25/0756 H01L33/06 H01L33/08 H01L33/385 H01L33/42 H01L33/0093 H01L27/3209		
优先权	62/590810 2017-11-27 US 62/590854 2017-11-27 US 62/590870 2017-11-27 US 62/621503 2018-01-24 US 62/635284 2018-02-26 US		
外部链接	Espacenet USPTO		

摘要(译)

用于显示器的发光二极管（LED）堆叠包括具有第一表面和第二表面的第一LED子单元，设置在第一LED子单元的第一表面上的第二LED子单元，第三LED子单元 - 单元设置在第二LED子单元上，反射电极设置在第二LED子单元的第二侧上并与第一LED子单元形成欧姆接触，以及欧姆电极插入在第一LED子单元之间第二LED子单元，与第一LED子单元形成欧姆接触，第二LED子单元和第三LED子单元用于传输第一LED子单元产生的光，第三LED子单元被配置为传输从第二LED子单元产生的光。