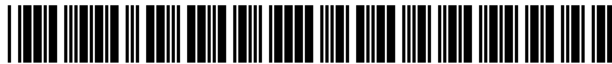


(12) **United States Patent**
Chiu et al.

(10) **Patent No.: US 9,735,312 B2**
(45) **Date of Patent: Aug. 15, 2017**

(54) **SEMICONDUCTOR LIGHT EMITTING DEVICE AND METHOD OF FABRICATING THE SAME**

(71) Applicant: **EPISTAR CORPORATION**, Hsinchu (TW)

(72) Inventors: **Hsin-Chih Chiu**, Hsinchu (TW); **Chih-Chiang Lu**, Hsinchu (TW); **Chun-Yu Lin**, Hsinchu (TW); **Ching-Huai Ni**, Hsinchu (TW); **Yi-Ming Chen**, Hsinchu (TW); **Tzu-Chieh Hsu**, Hsinchu (TW); **Ching-Pei Lin**, Hsinchu (TW)

(73) Assignee: **EPISTAR CORPORATION**, Hsinchu (TW)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/442,319**

(22) PCT Filed: **Jul. 3, 2013**

(86) PCT No.: **PCT/CN2013/078766**
§ 371 (c)(1),
(2) Date: **Feb. 19, 2016**

(87) PCT Pub. No.: **WO2014/071745**
PCT Pub. Date: **May 15, 2014**

(65) **Prior Publication Data**

US 2016/0204305 A1 Jul. 14, 2016

(30) **Foreign Application Priority Data**

Nov. 12, 2012 (CN) 2012 1 0451045

(51) **Int. Cl.**
H01L 33/02 (2010.01)
H01L 25/075 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H01L 33/0025*** (2013.01); ***H01L 21/00*** (2013.01); ***H01L 25/0753*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC H01L 33/0025; H01L 25/0753; H01L 33/0062; H01L 33/46; H01L 33/387;
(Continued)

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,606,572 A 2/1997 Swirhun et al.
6,956,241 B2 * 10/2005 Sugawara H01L 33/20 257/103
(Continued)

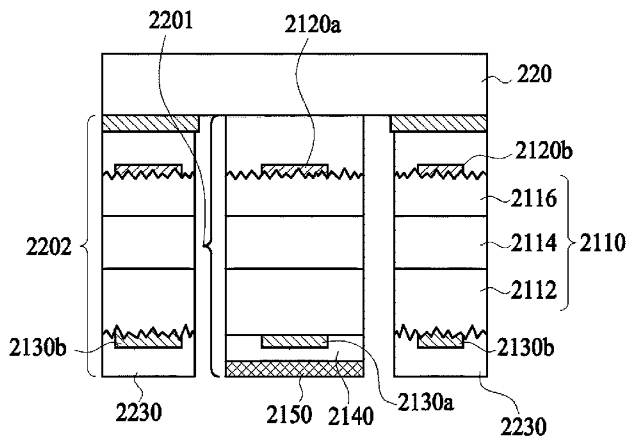
FOREIGN PATENT DOCUMENTS

CN 1848471 A 10/2006
CN 101083253 A 12/2007
(Continued)

Primary Examiner — Fernando L Toledo
Assistant Examiner — Adam S Bowen
(74) *Attorney, Agent, or Firm* — Muncy, Geissler, Olds & Lowe, P.C.

(57) **ABSTRACT**

A method of manufacturing a semiconductor light-emitting device, comprises the steps of providing a first substrate; providing multiple epitaxial units on the first substrate, wherein the plurality of epitaxial units comprises: multiple first epitaxial units, wherein each of the first epitaxial units has a first geometric shape and a first area; and multiple second epitaxial units, wherein each of the second epitaxial units has a second geometric shape and a second area; providing a second substrate with a surface; transferring the multiple second epitaxial units to the surface of the second substrate; and dividing the first substrate to form multiple first semiconductor light-emitting devices, wherein each of the first semiconductor light-emitting devices has the first epitaxial unit; wherein the first geometric shape is different
(Continued)



from the second geometric shape, or the first area is different from the second area.

29 Claims, 25 Drawing Sheets

(51) **Int. Cl.**

H01L 33/00	(2010.01)
H01L 33/38	(2010.01)
H01L 33/46	(2010.01)
H01L 33/62	(2010.01)
H01L 33/22	(2010.01)
H01L 21/00	(2006.01)

(52) **U.S. Cl.**
CPC ***H01L 33/0062*** (2013.01); ***H01L 33/0079*** (2013.01); ***H01L 33/22*** (2013.01); ***H01L 33/387*** (2013.01); ***H01L 33/46*** (2013.01); ***H01L 33/62*** (2013.01); *H01L 33/0095* (2013.01); *H01L 33/382* (2013.01); *H01L 2924/0002* (2013.01)

(58) **Field of Classification Search**
CPC H01L 33/62; H01L 21/00; H01L 33/22; H01L 33/0079; H01L 33/0095; H01L 2924/0002; H01L 33/382
USPC 257/94
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,180,099	B2 *	2/2007	Ogihara	B41J 2/45 257/72
7,432,117	B2 *	10/2008	Chu	H01L 33/0079 257/E33.065
2002/0079500	A1 *	6/2002	Liu	H01L 33/145 257/82
2004/0259331	A1 *	12/2004	Ogihara	H01L 21/2007 438/462
2009/0108286	A1 *	4/2009	Lin	H01L 33/382 257/103
2009/0218941	A1 *	9/2009	Nakamura	H01L 51/057 313/506
2010/0283069	A1 *	11/2010	Rogers	H01L 27/1214 257/98
2011/0151602	A1 *	6/2011	Speier	H01L 33/0079 438/26

FOREIGN PATENT DOCUMENTS

CN	101345277	A	1/2009
CN	102376826	A	3/2012
JP	2006319311	A	11/2006
JP	2012199405	A	10/2012
TW	200742123	A	11/2007
TW	I335088		12/2010
TW	201205859	A1	2/2012

* cited by examiner

FIG. 1A

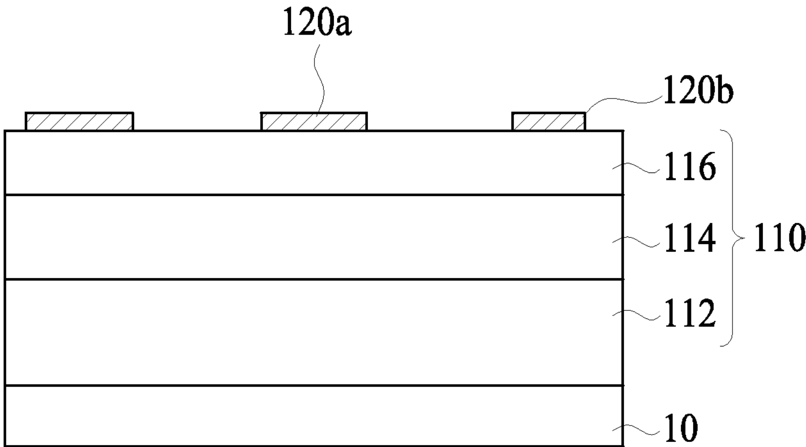


FIG. 1B

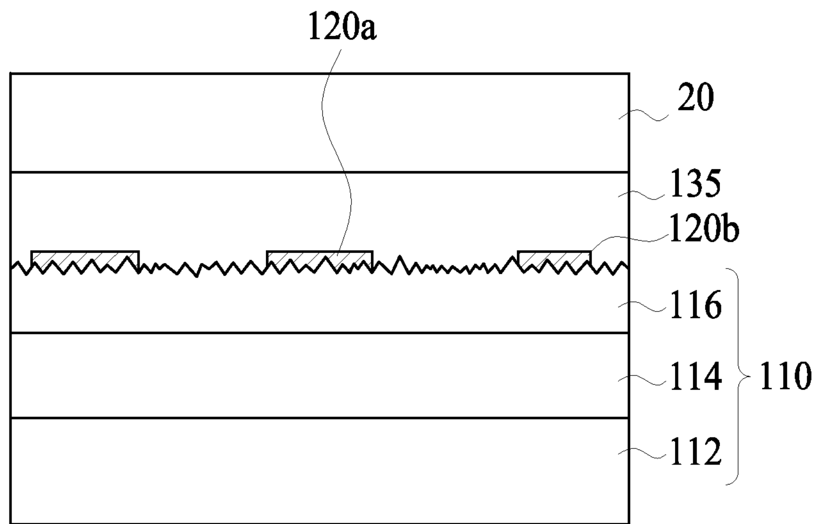


FIG. 1C

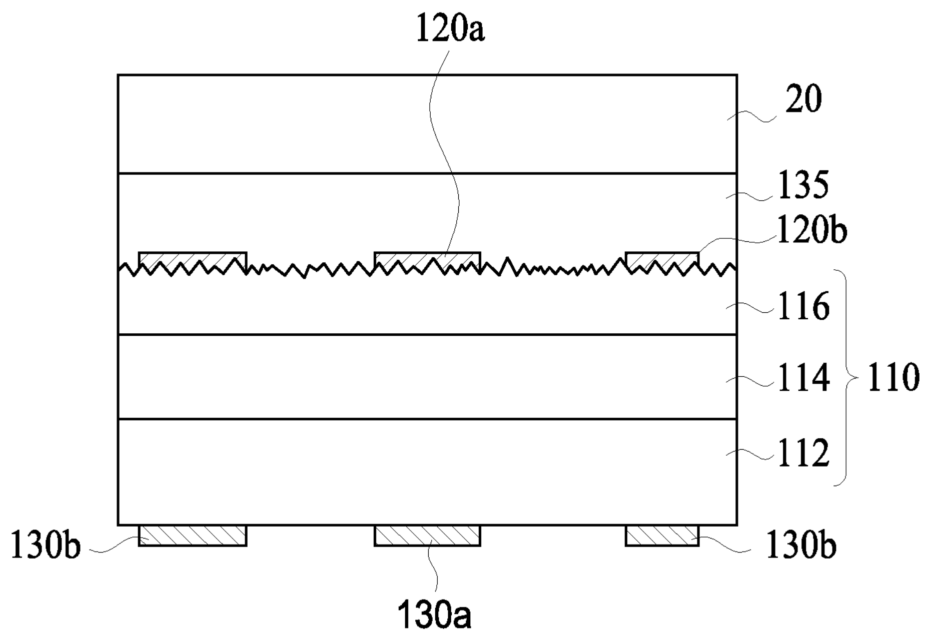


FIG. 1D

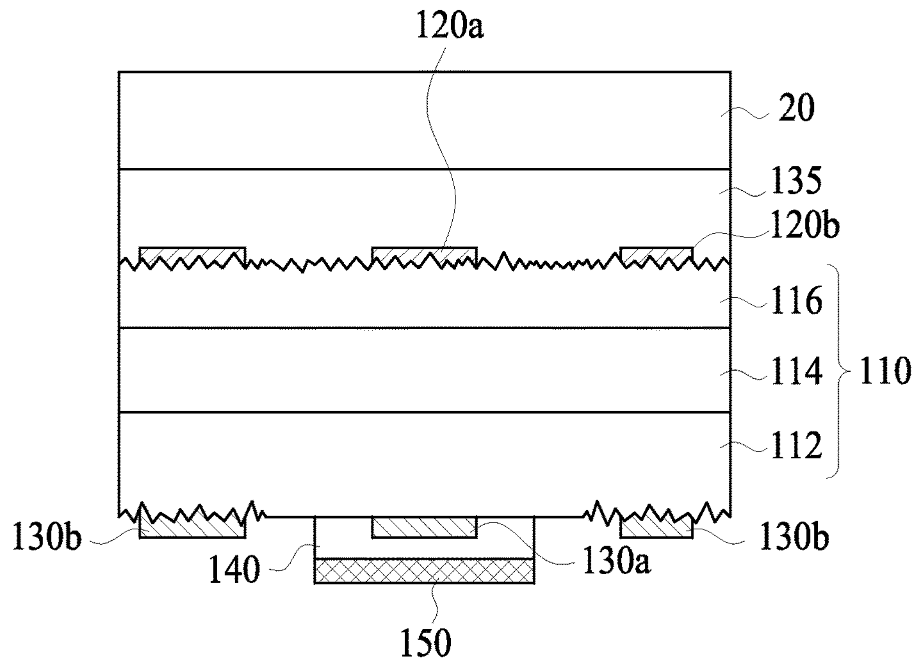


FIG. 1E

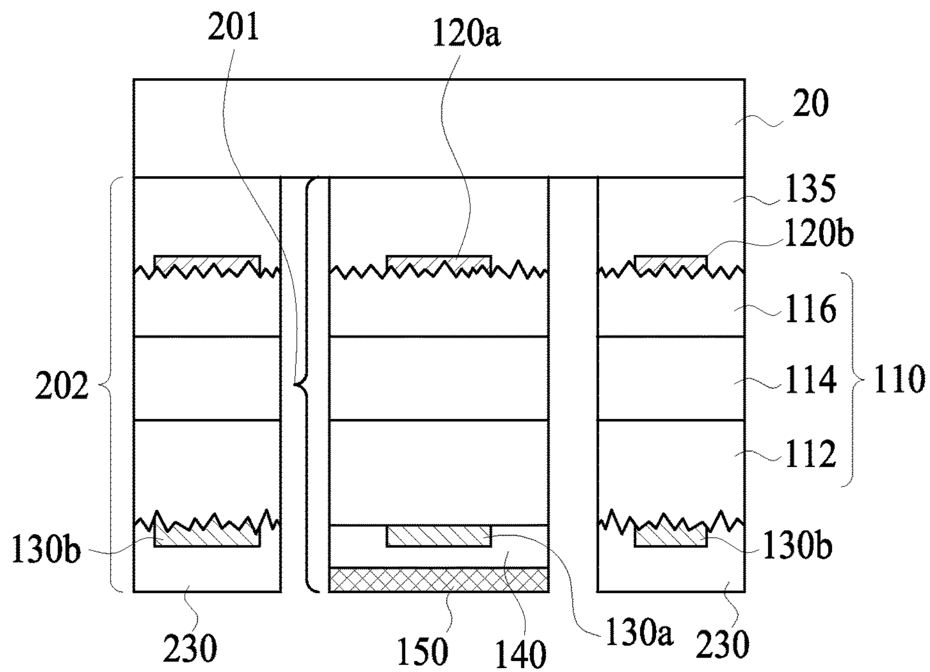


FIG. 1F

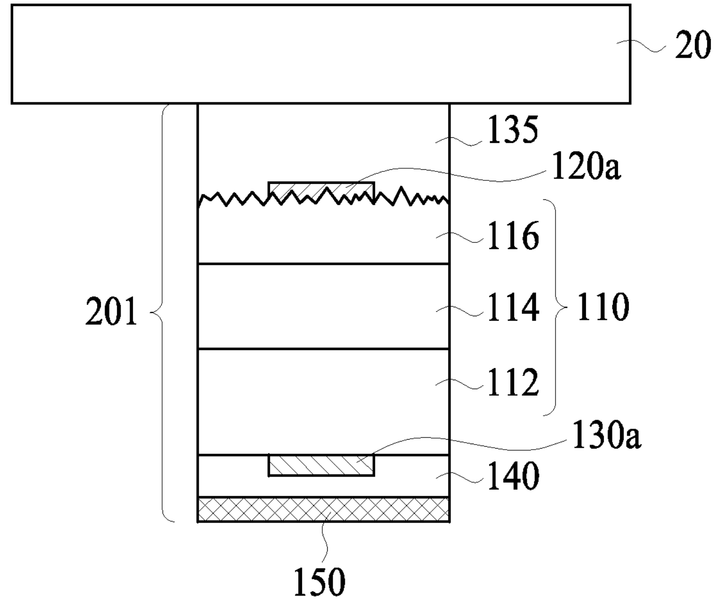


FIG. 1G

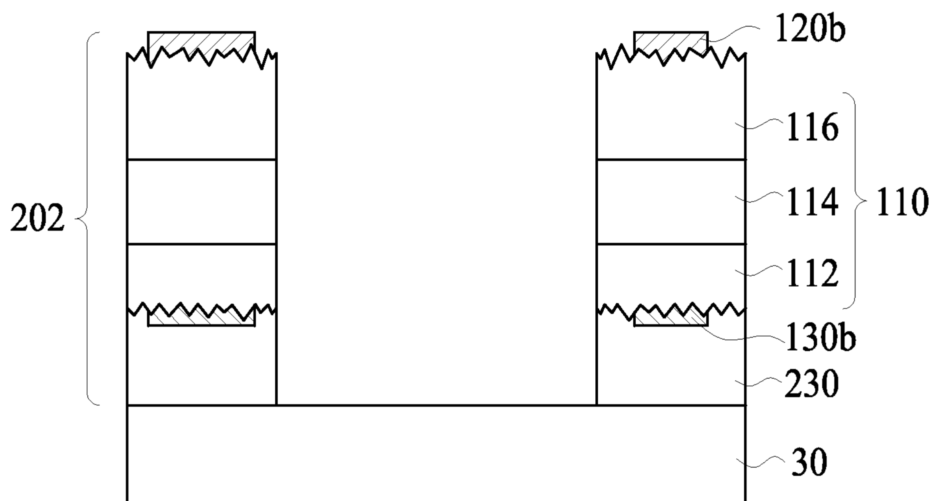


FIG. 1H

FIG. 2A

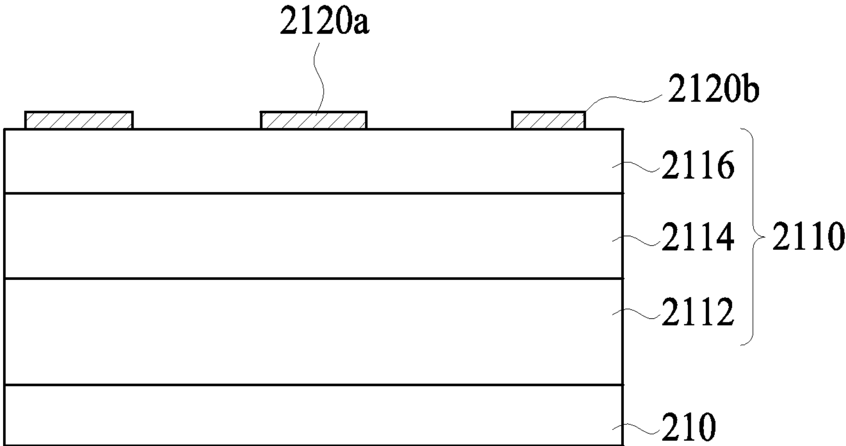


FIG. 2B

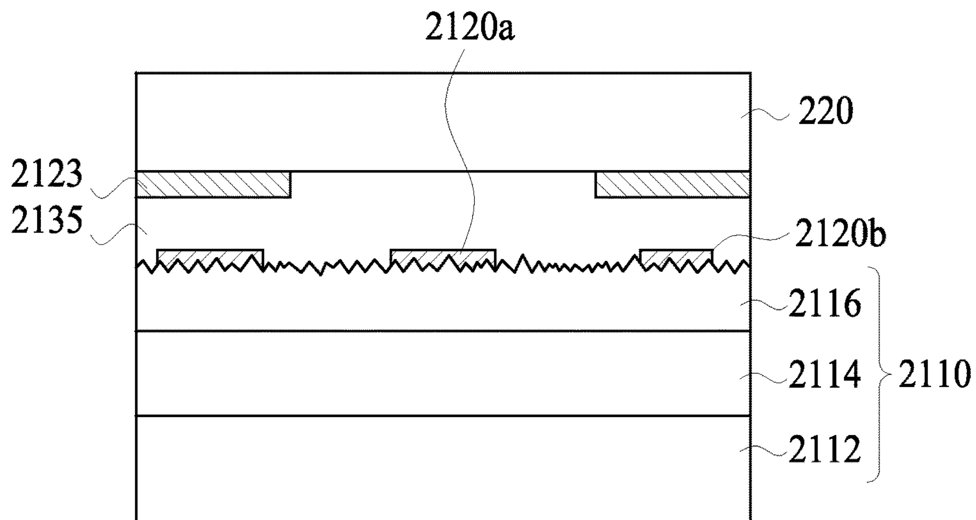


FIG. 2C

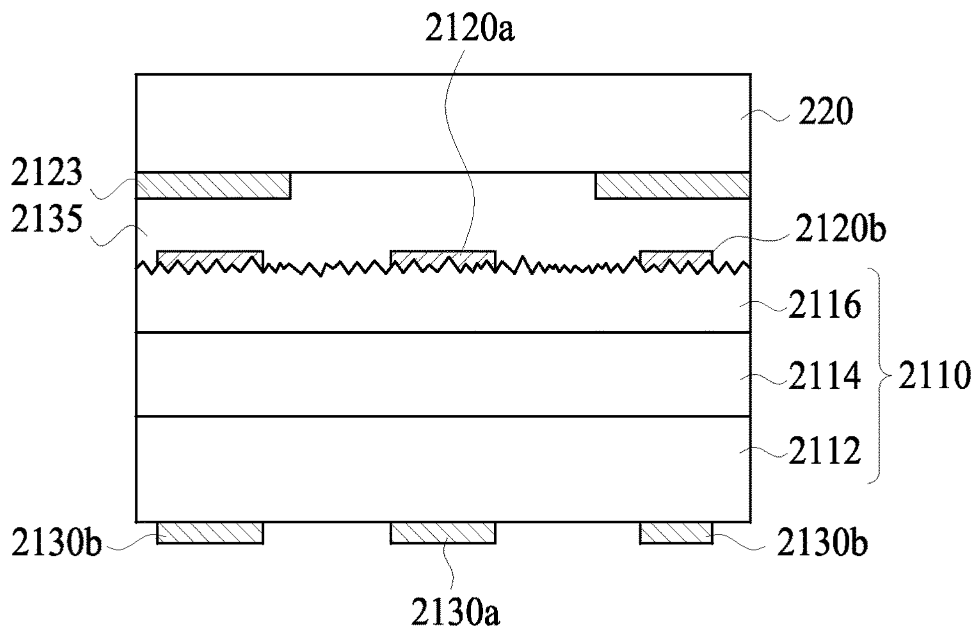


FIG. 2D

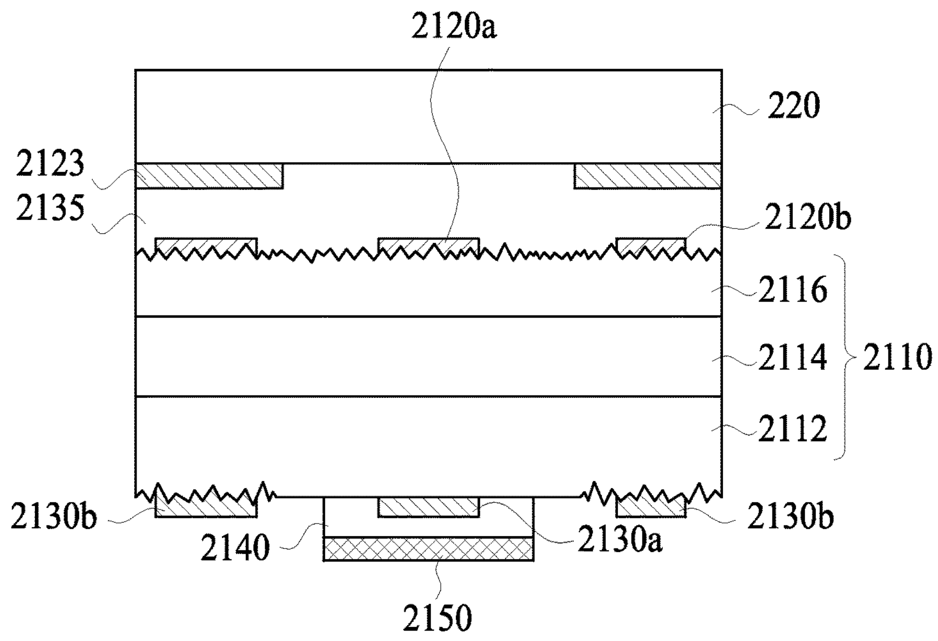


FIG. 2E

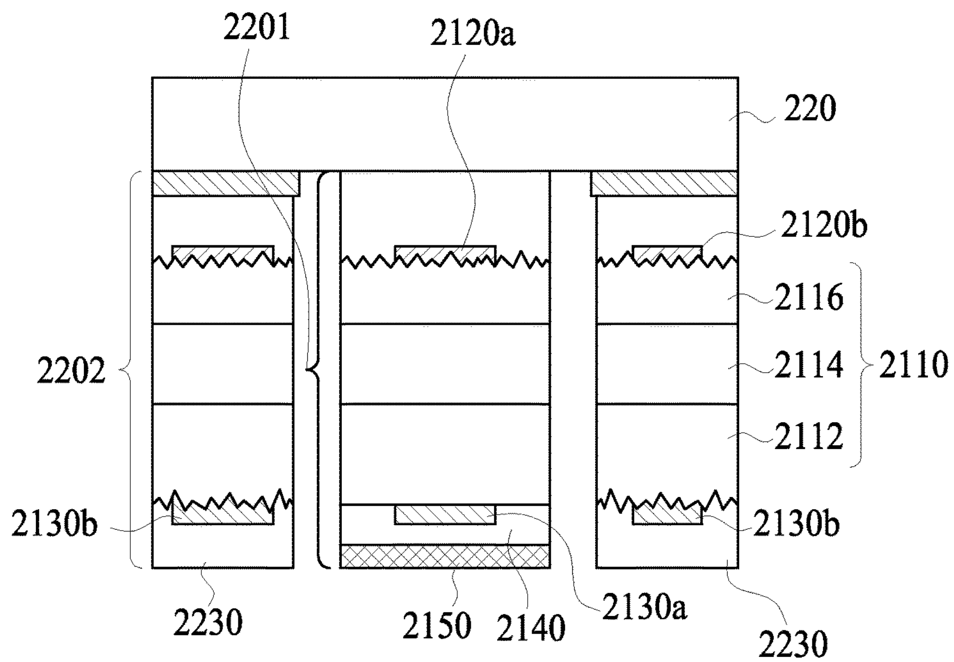


FIG. 2F

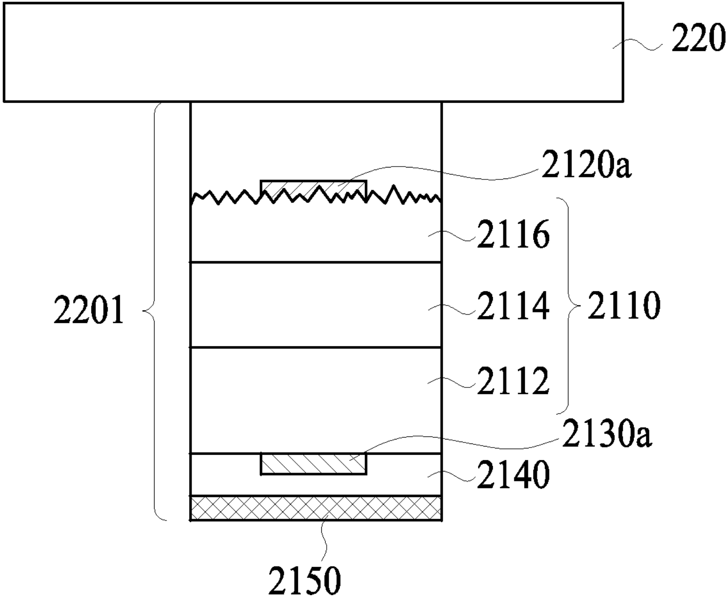


FIG. 2G

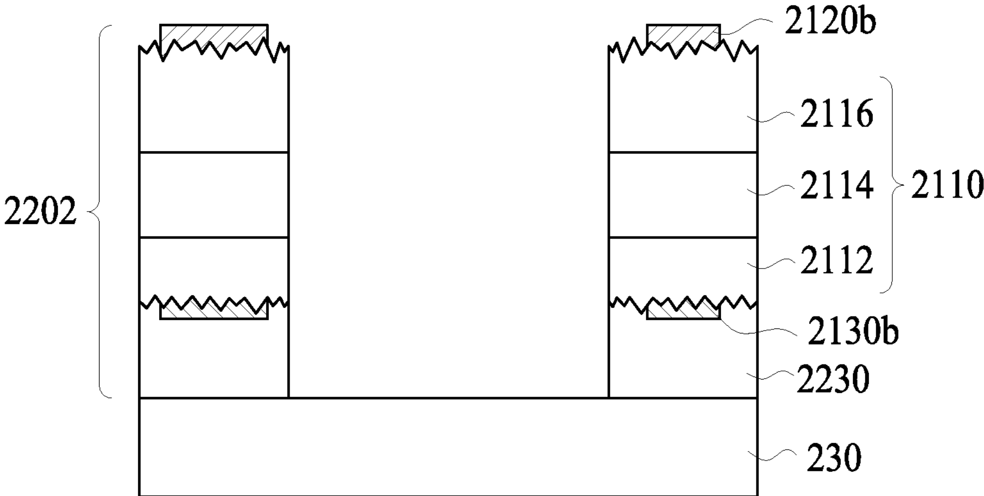


FIG. 2H

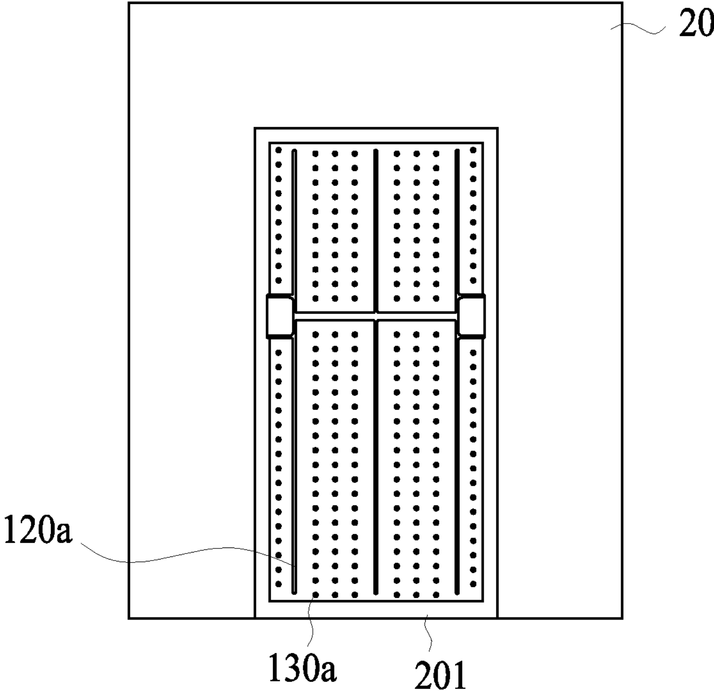


FIG. 3A

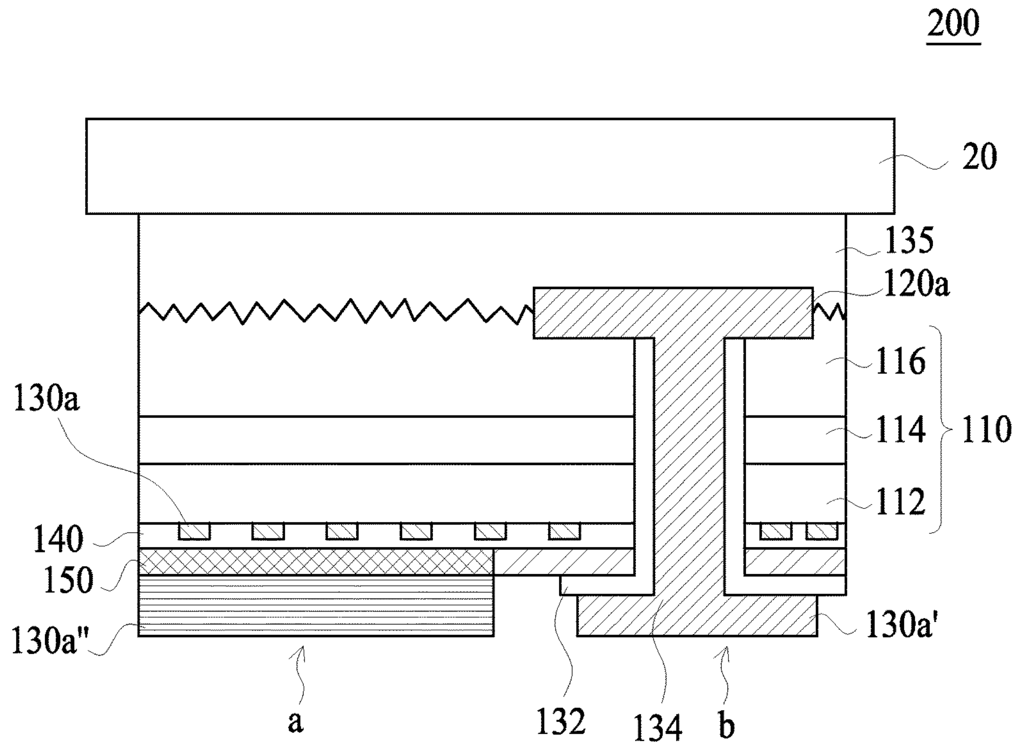


FIG. 3B

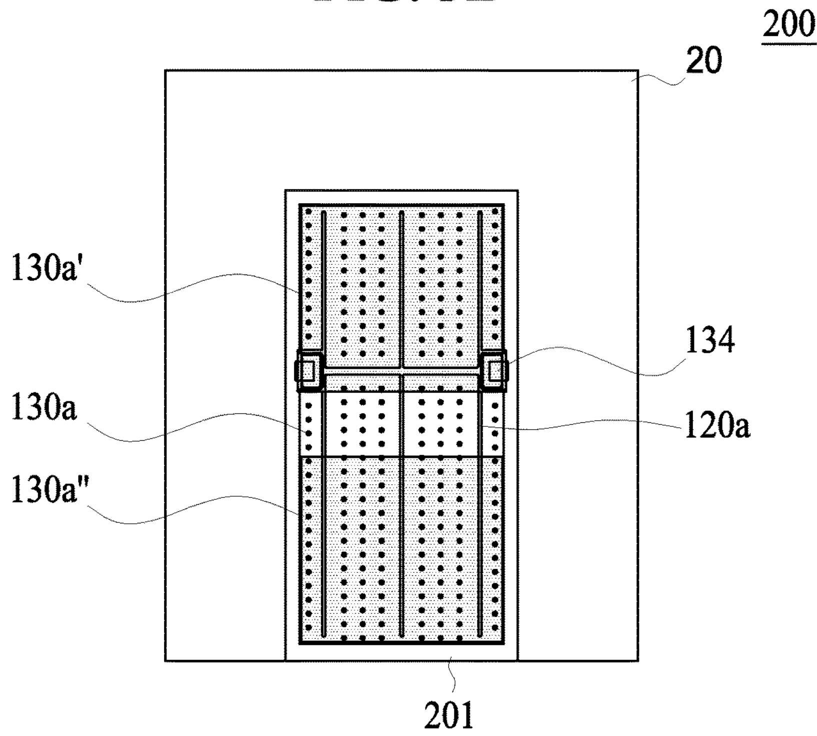


FIG. 3C

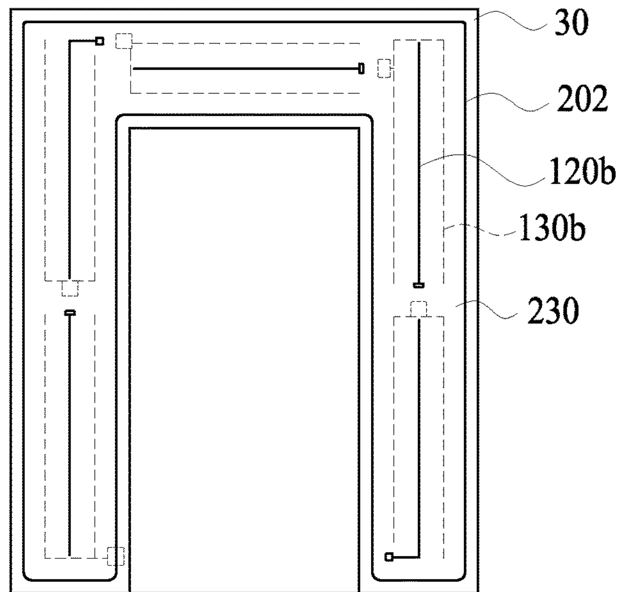


FIG. 4A

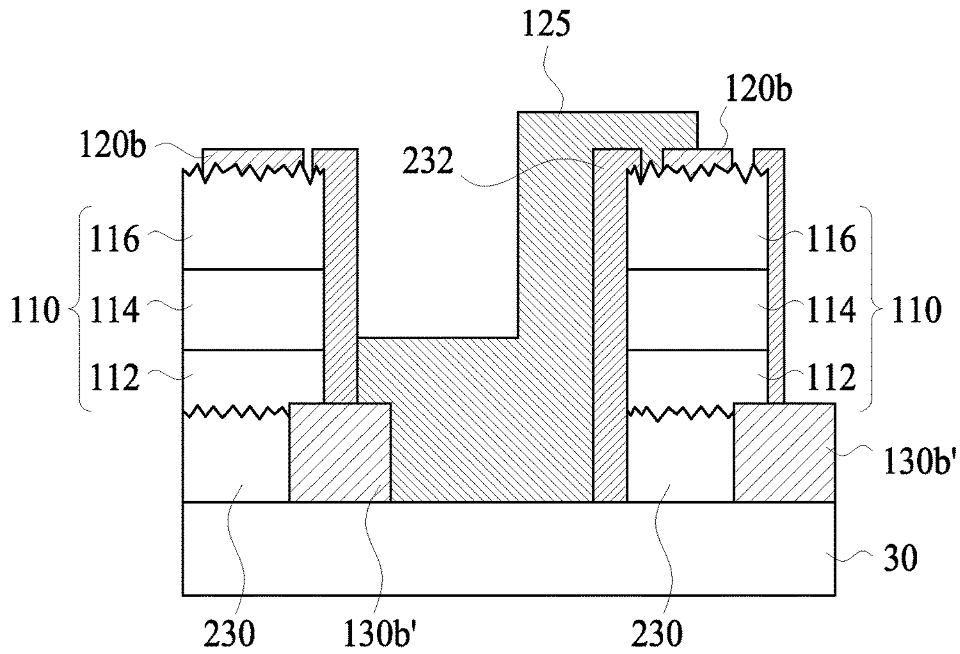


FIG. 4B

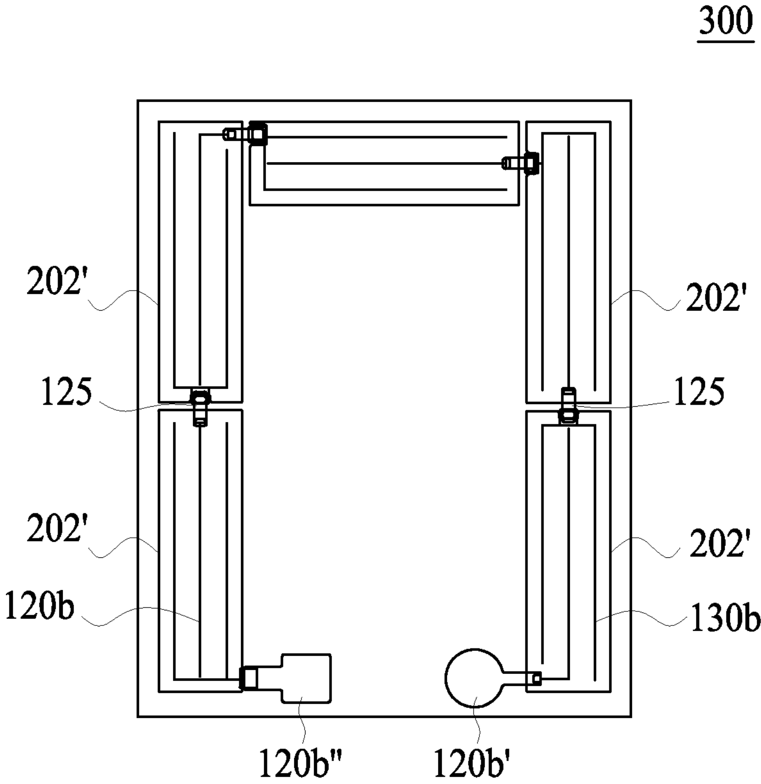


FIG. 4C

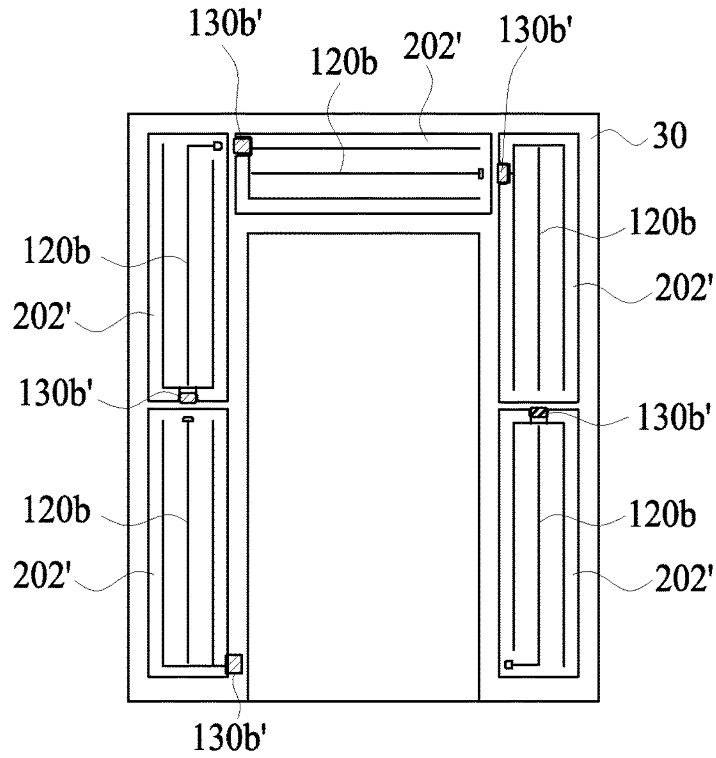


FIG. 5A

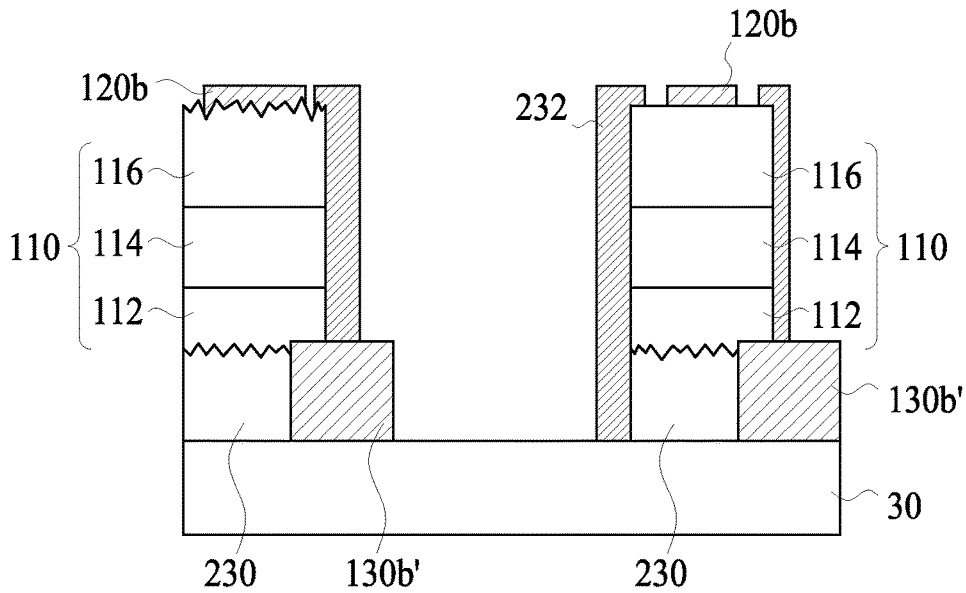


FIG. 5B

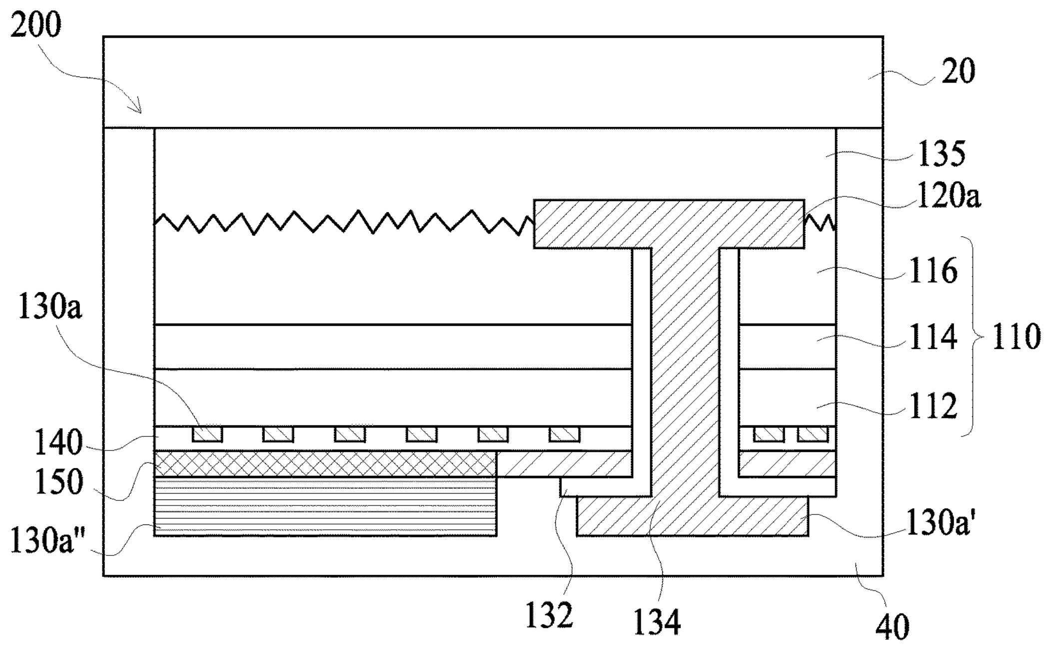


FIG. 6A

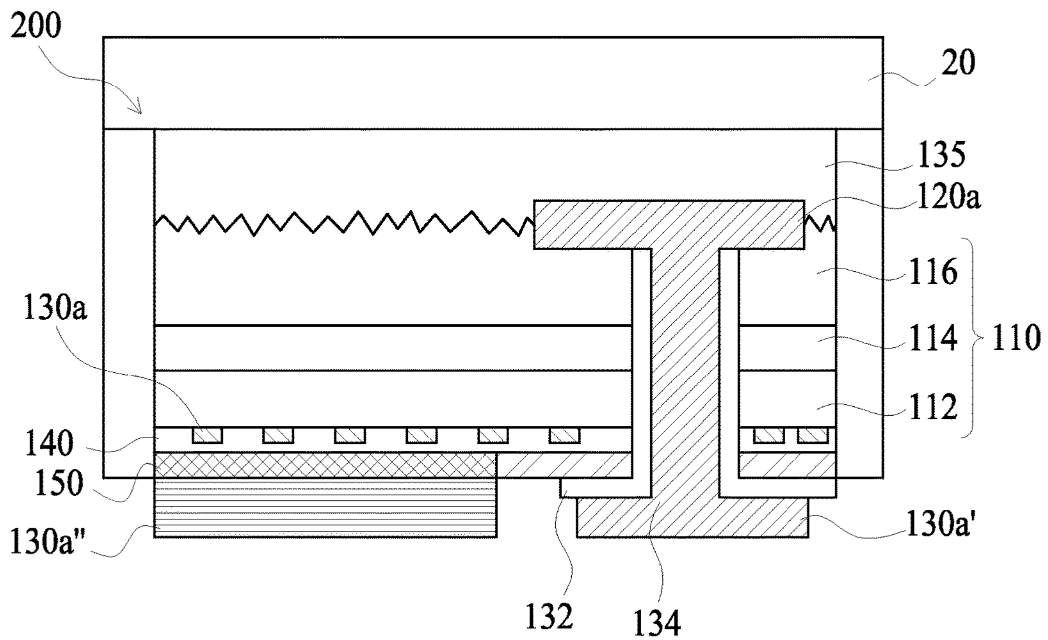


FIG. 6B

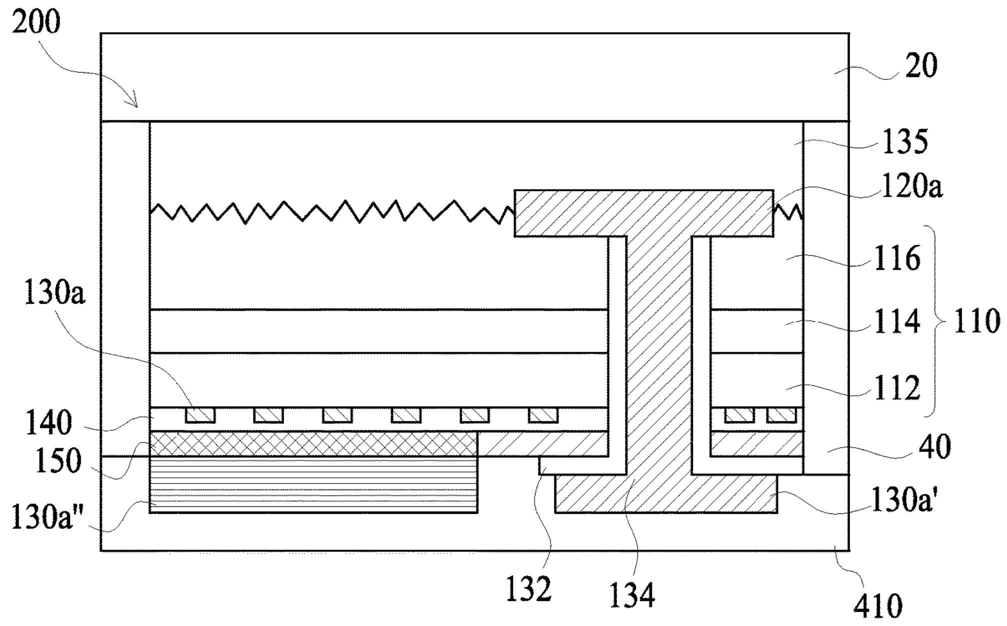


FIG. 6C

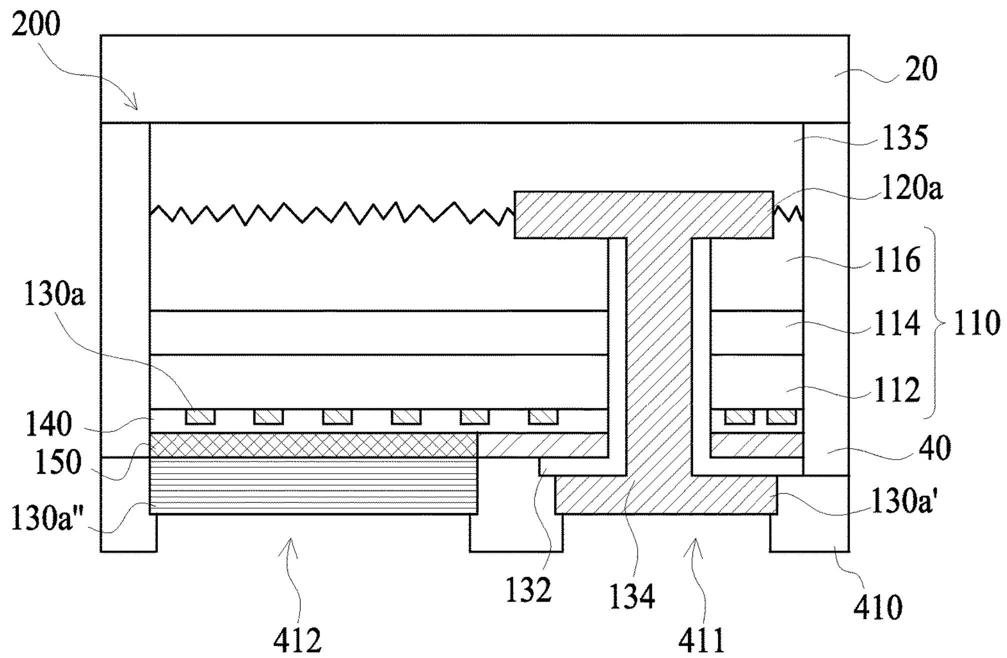


FIG. 6D

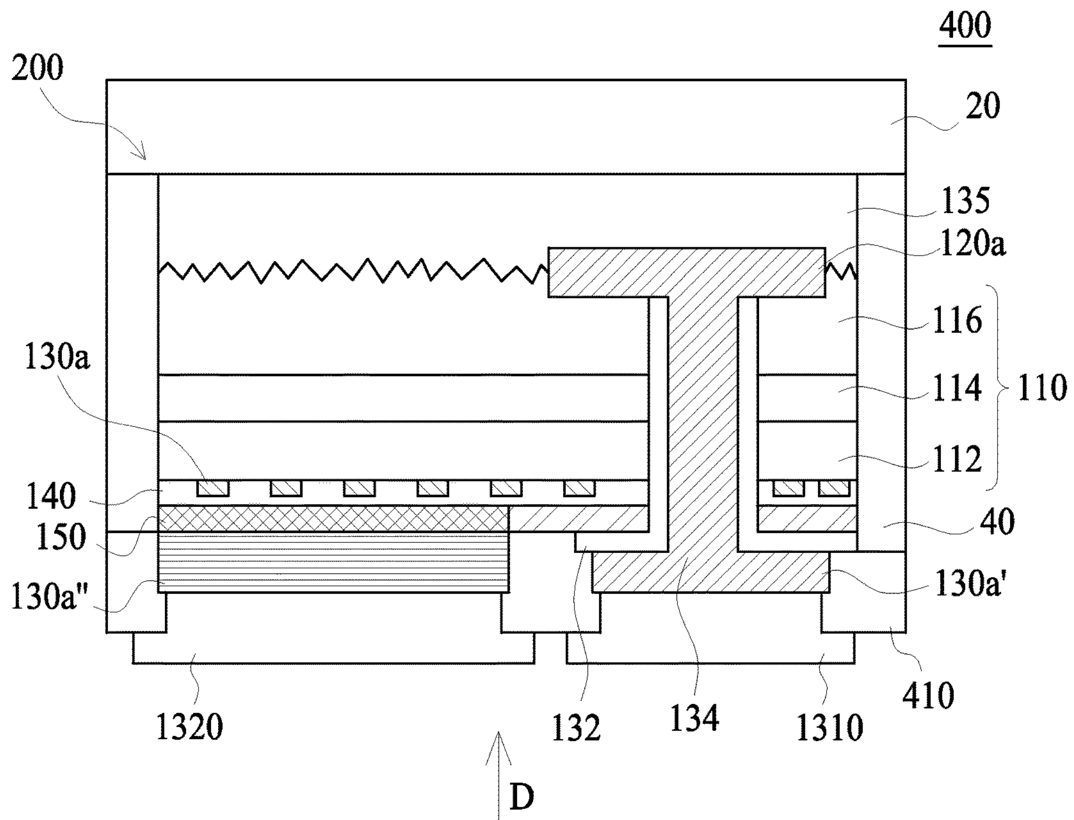


FIG. 6E

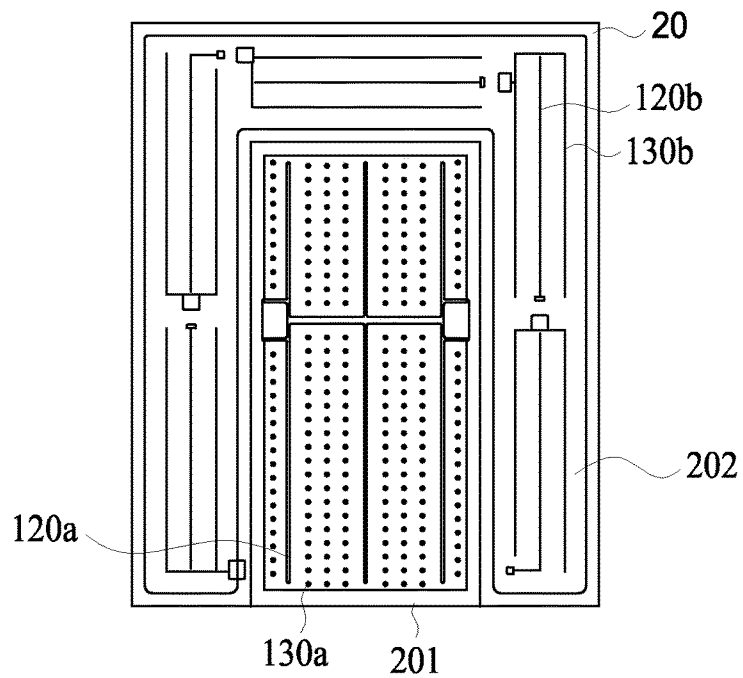


FIG. 7

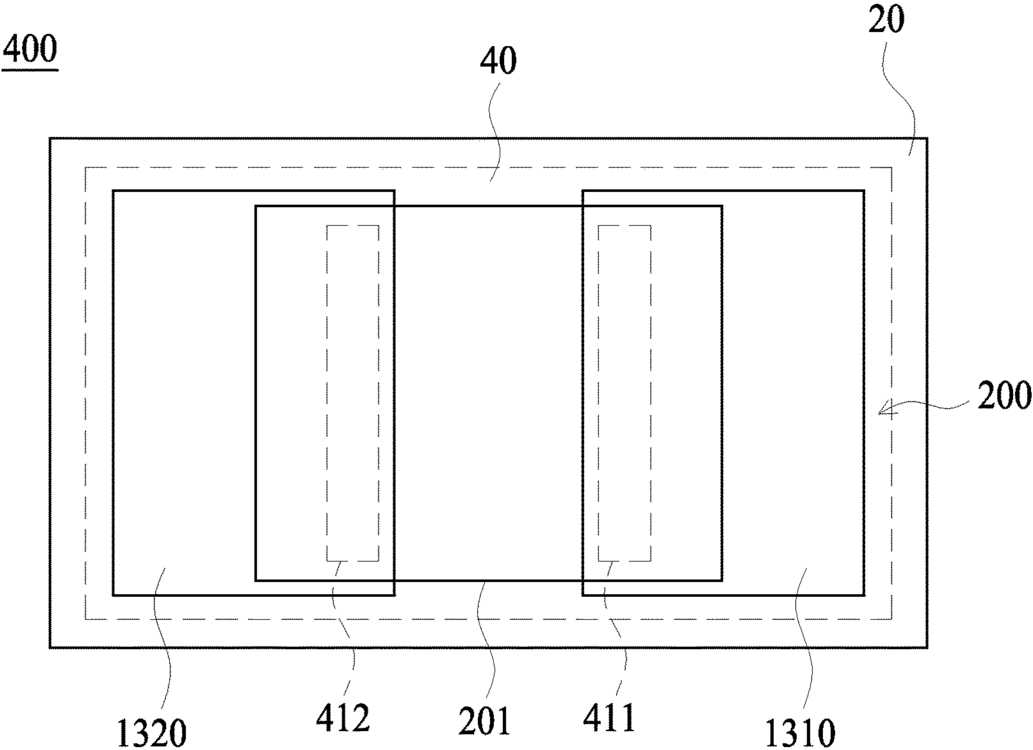


FIG. 8

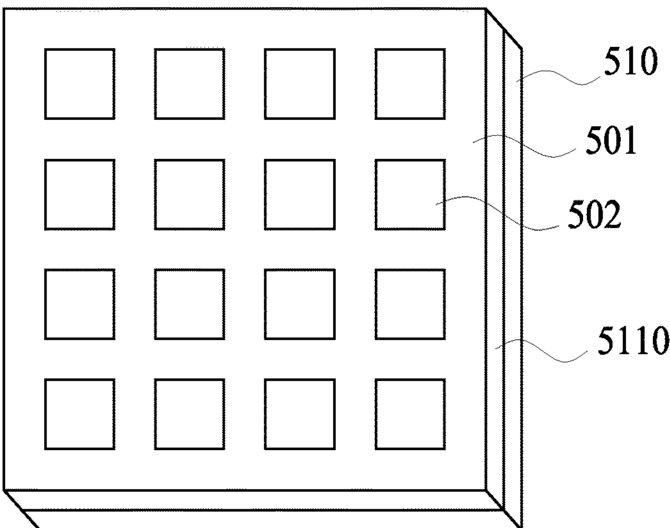


FIG. 9

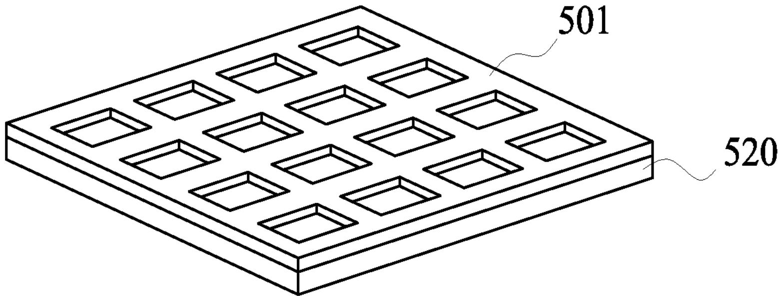


FIG. 10A

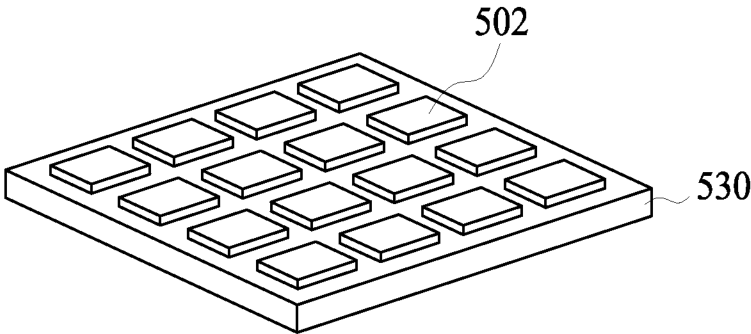


FIG. 10B

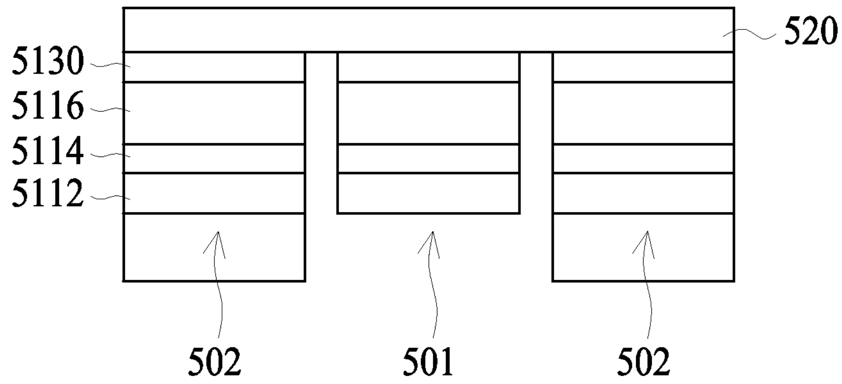


FIG. 11A

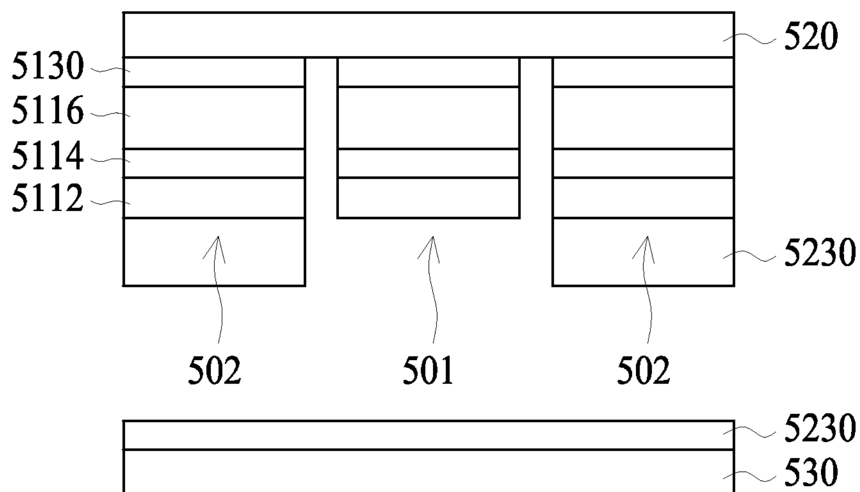


FIG. 11B

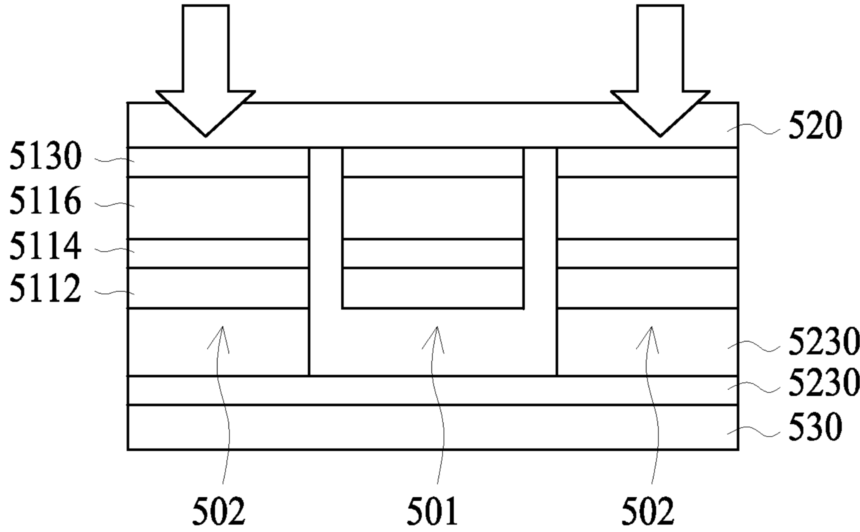


FIG. 11C

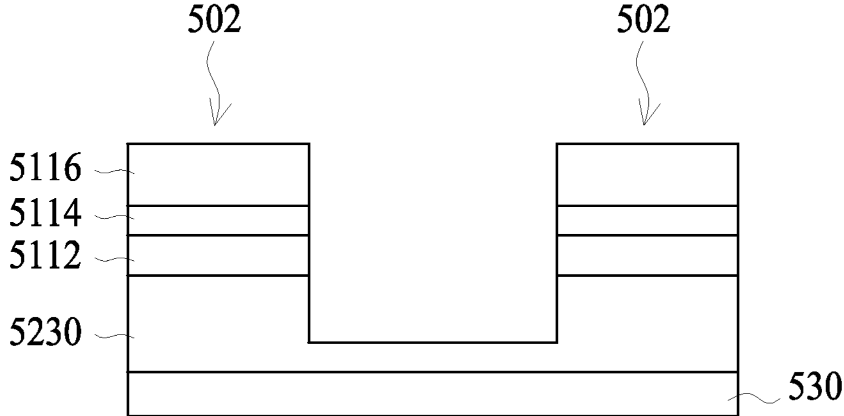


FIG. 11D

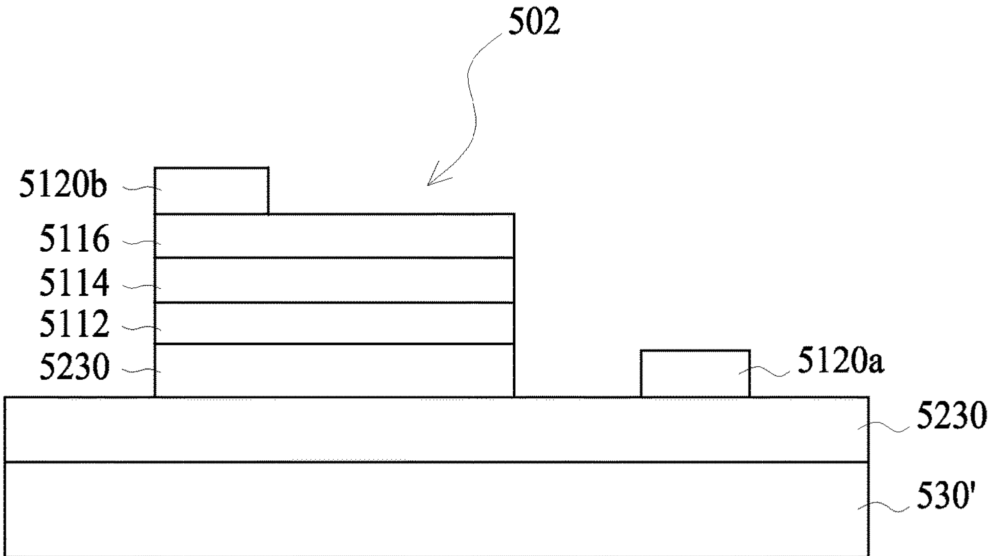


FIG. 11E

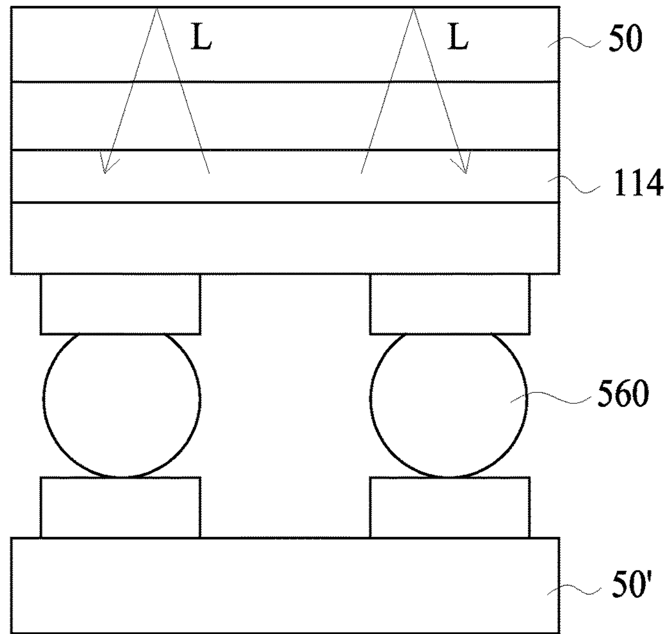


FIG. 12A

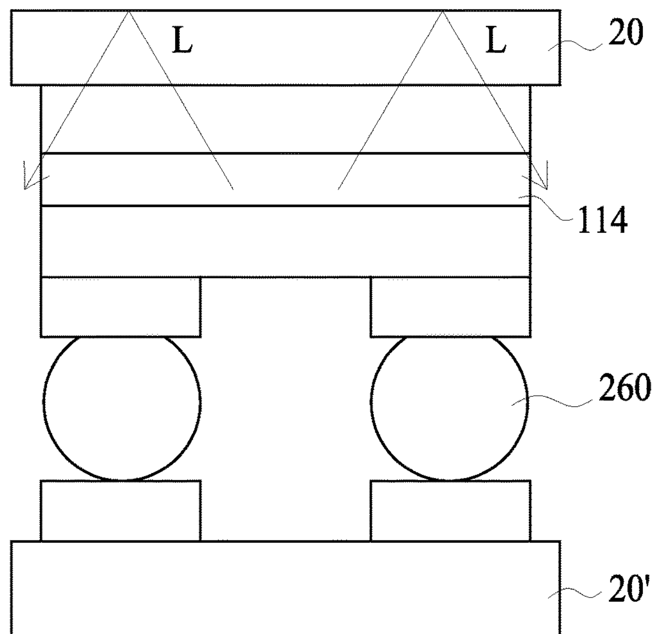


FIG. 12B

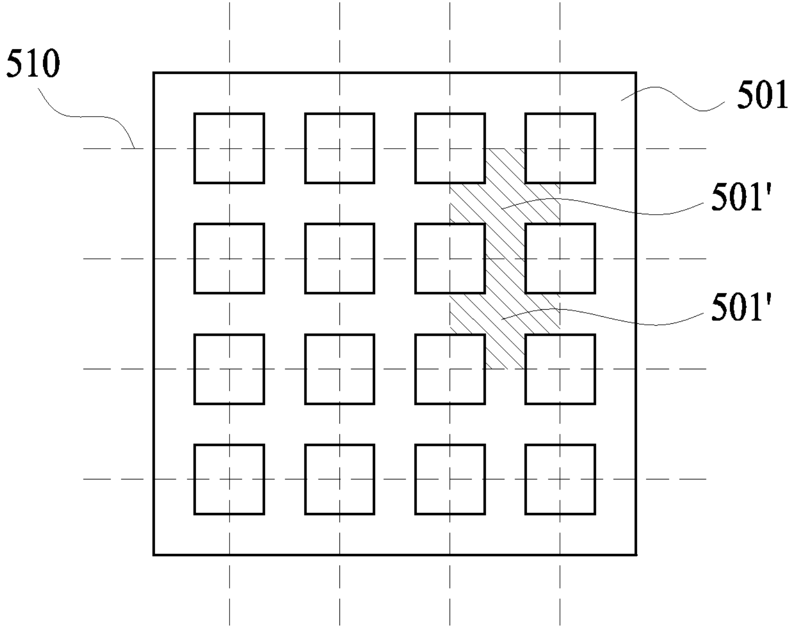


FIG. 13

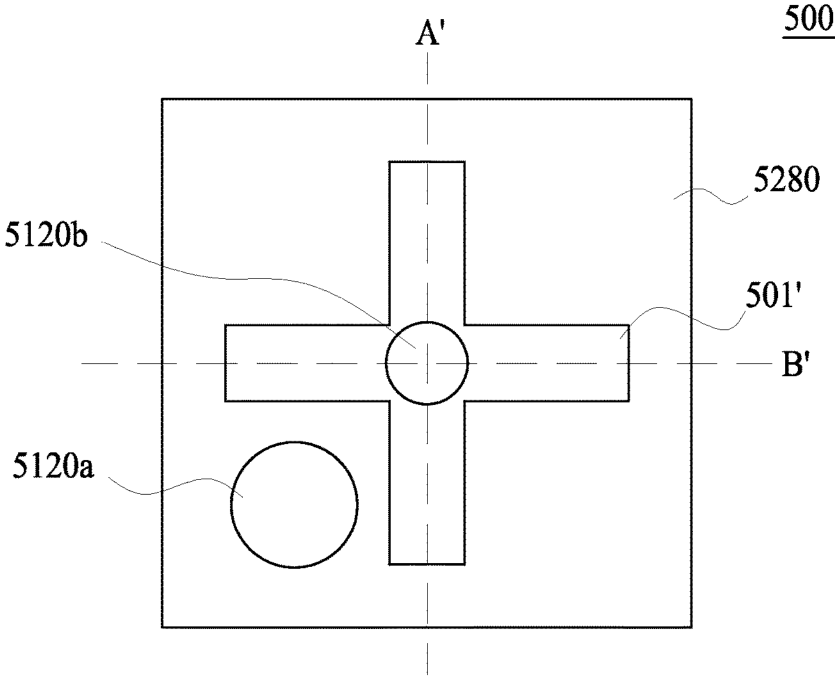


FIG. 14A

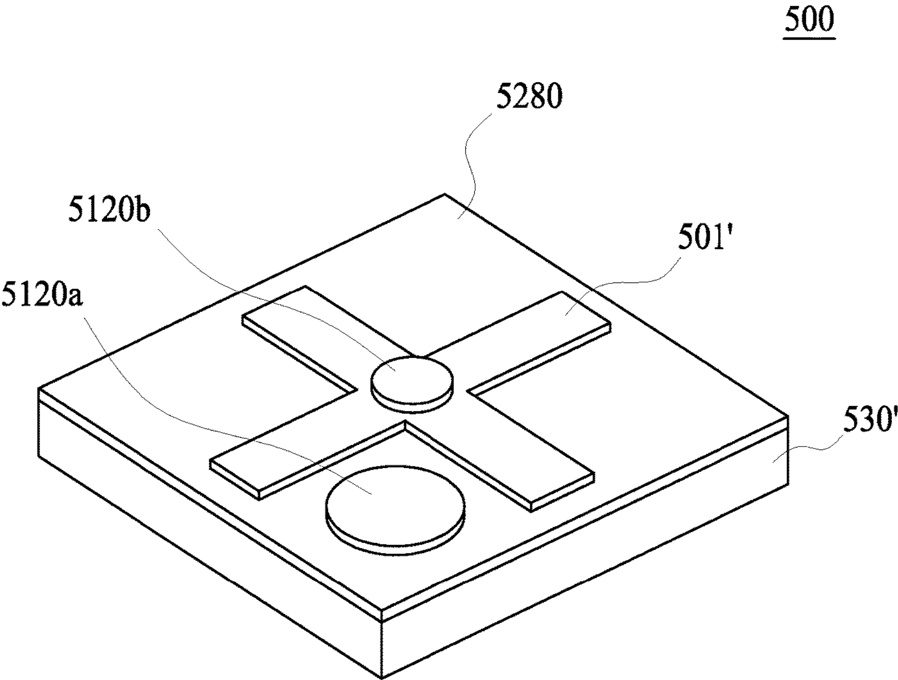


FIG. 14B

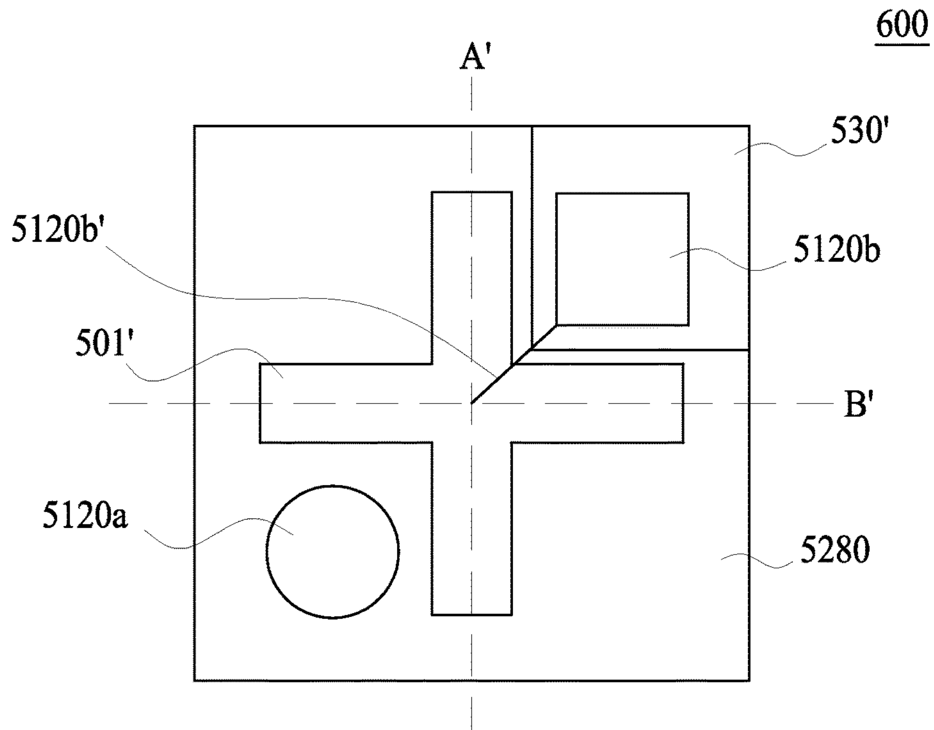


FIG. 14C

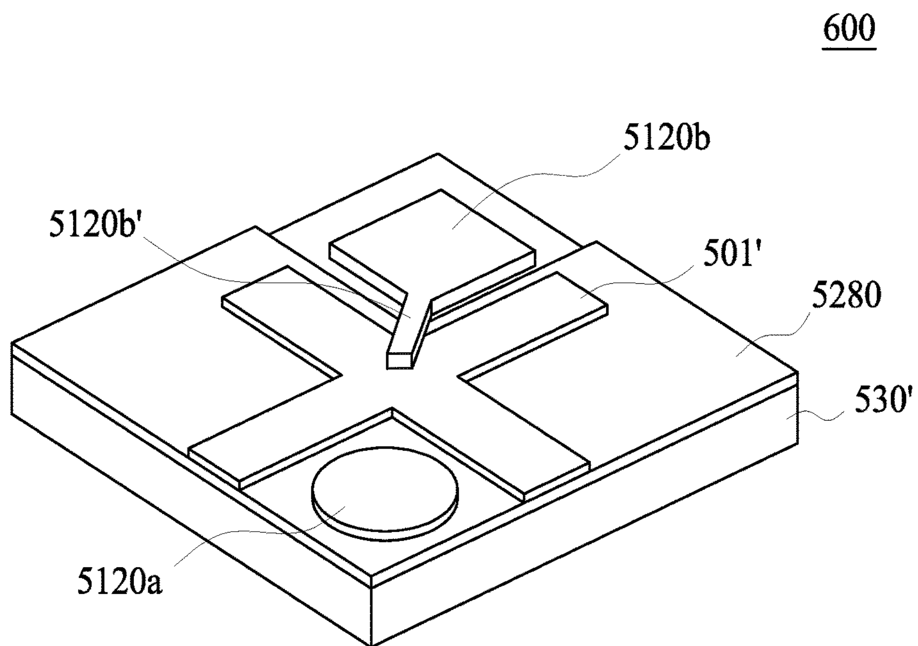


FIG. 14D

SEMICONDUCTOR LIGHT EMITTING DEVICE AND METHOD OF FABRICATING THE SAME

TECHNICAL FIELD

The application is related to a method of fabricating a semiconductor light-emitting device, and especially is related to a fabricating method of forming two different semiconductor epitaxial stacks on a single substrate.

DESCRIPTION OF BACKGROUND ART

As the technology developing, the semiconductor light-emitting device has significantly contributed to information, communications, and energy conversion applications. For example, the semiconductor light-emitting device can be applied to fiber-optic communications, optical storage and military systems. For energy conversion applications, the semiconductor light-emitting device generally has three types: a device for converting electrical energy into light, such as light-emitting diode; a device for converting light signal into electrical signal, such as optical detector; and a device for converting light radiation energy into electrical energy, such as solar cell.

Growth substrate is very important for the semiconductor light-emitting device. Semiconductor epitaxial structure, which is necessary for forming the semiconductor light-emitting device, is formed on the growth substrate and is also supported by the growth substrate. Therefore, it is important to choose a suitable growth substrate for growing a high quality semiconductor epitaxial structure of the semiconductor light-emitting device.

However, a substrate suitable for growth is sometimes not suitable for support. In conventional process of fabricating the red light diode, GaAs substrate, which is opaque to red light, is used as the growth substrate, because the difference of the lattice constant between GaAs substrate and the semiconductor epitaxial structure of the red light device is the smallest. But, the opaque growth substrate reduces the light-emitting efficiency of the light device, as the light device is operated for emitting a light.

Since the growth substrate and the support substrate for the light device should meet different conditions, the technology of transferring substrate is developed. Namely, the semiconductor epitaxial structure grows on the growth substrate firstly, and then the semiconductor epitaxial structure is transferred to the support substrate for the following fabricating process. The steps of transferring the semiconductor epitaxial structure from the growth substrate to the support substrate include removing the growth substrate and bonding the semiconductor epitaxial structure and the support substrate, wherein removing the growth substrate is one of the key steps.

The method of removing the growth substrate from the semiconductor epitaxial structure includes dissolving the growth substrate by etchant, grinding the growth substrate, or forming a sacrificial layer between the growth substrate and the semiconductor epitaxial structure in advance and removing the sacrificial layer by etching process to separate the growth substrate and the semiconductor epitaxial structure. However, the growth substrate is going to be discarded no matter in the process of dissolving the growth substrate by etchant or the process of grinding the growth substrate. The growth substrate that cannot be reused means a waste in the environmentally-oriented era. So, for fabricating the semiconductor light-emitting device, if the growth substrate and the semiconductor epitaxial structure are separated by using the sacrificial layer, how to effectively implement the process of selectively transferring the semiconductor epitaxial structure is one of the research topics.

SUMMARY OF THE DISCLOSURE

A method of manufacturing a semiconductor light-emitting device, comprises the steps of providing a first substrate; providing multiple epitaxial units on the first substrate, wherein the plurality of epitaxial units comprises: multiple first epitaxial units, wherein each of the first epitaxial units has a first geometric shape and a first area; and multiple second epitaxial units, wherein each of the second epitaxial units has a second geometric shape and a second area; providing a second substrate with a surface; transferring the multiple second epitaxial units to the surface of the second substrate; and dividing the first substrate to form multiple first semiconductor light-emitting devices, wherein each of the first semiconductor light-emitting devices has the first epitaxial unit; wherein the first geometric shape is different from the second geometric shape, or the first area is different from the second area.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**A shows a side view of a semiconductor light-emitting device during the process in accordance with the first step of a manufacturing method of the first embodiment of the present application;

FIG. **1**B shows a side view of a semiconductor light-emitting device during the process in accordance with the second step of a manufacturing method of the first embodiment of the present application;

FIG. **1**C shows a side view of a semiconductor light-emitting device during the process in accordance with the third step of a manufacturing method of the first embodiment of the present application;

FIG. **1**D shows a side view of a semiconductor light-emitting device during the process in accordance with the fourth step of a manufacturing method of the first embodiment of the present application;

FIG. **1**E shows a side view of a semiconductor light-emitting device during the process in accordance with the fifth step of a manufacturing method of the first embodiment of the present application;

FIG. **1**F shows a side view of a semiconductor light-emitting device during the process in accordance with the sixth step of a manufacturing method of the first embodiment of the present application;

FIG. **1**G shows a first side view of a semiconductor light-emitting device during the process in accordance with the seventh step of a manufacturing method of the first embodiment of the present application;

FIG. **1**H shows a second side view of a semiconductor light-emitting device during the process in accordance with the seventh step of a manufacturing method of the first embodiment of the present application;

FIG. **2**A shows a side view of a semiconductor light-emitting device during the process in accordance with the first step of a manufacturing method of the second embodiment of the present application;

FIG. **2**B shows a side view of a semiconductor light-emitting device during the process in accordance with the second step of a manufacturing method of the second embodiment of the present application;

FIG. 2C shows a side view of a semiconductor light-emitting device during the process in accordance with the third step of a manufacturing method of the second embodiment of the present application;

FIG. 2D shows a side view of a semiconductor light-emitting device during the process in accordance with the fourth step of a manufacturing method of the second embodiment of the present application;

FIG. 2E shows a side view of a semiconductor light-emitting device during the process in accordance with the fifth step of a manufacturing method of the second embodiment of the present application;

FIG. 2F shows a side view of a semiconductor light-emitting device during the process in accordance with the sixth step of a manufacturing method of the second embodiment of the present application;

FIG. 2G shows a first side view of a semiconductor light-emitting device during the process in accordance with the seventh step of a manufacturing method of the second embodiment of the present application;

FIG. 2H shows a second side view of a semiconductor light-emitting device during the process in accordance with the fifth step of a manufacturing method of the second embodiment of the present application;

FIG. 3A shows a first top view of the semiconductor light-emitting device during the process in accordance with the seventh step of the first embodiment of the present application;

FIG. 3B shows a side view of the semiconductor light-emitting device during the process in accordance with the eighth step of the first embodiment of the present application;

FIG. 3C shows a top view of the semiconductor light-emitting device during the process in accordance with the eighth step of the first embodiment of the present application;

FIG. 4A shows a second top view of the semiconductor light-emitting device during the process in accordance with the seventh step of the first embodiment of the present application;

FIG. 4B shows a side view of the second semiconductor light-emitting device during the process in accordance with the eighth step of the first embodiment of the present application;

FIG. 4C shows a top view of the second semiconductor light-emitting device during the process in accordance with the eighth step of the first embodiment of the present application;

FIG. 5A shows a top view of the high-voltage semiconductor light-emitting device during the process in accordance with the first step of the first embodiment of the present application;

FIG. 5B shows a side view of the high-voltage semiconductor light-emitting device during the process in accordance with the first step of the first embodiment of the present application;

FIG. 6A shows a side view of the encapsulated semiconductor light-emitting device during the process in accordance with the first step of the third embodiment of the present application;

FIG. 6B shows a side view of the encapsulated semiconductor light-emitting device during the process in accordance with the second step of the third embodiment of the present application;

FIG. 6C shows a side view of the encapsulated semiconductor light-emitting device during the process in accordance with the third step of the third embodiment of the present application;

FIG. 6D shows a side view of the encapsulated semiconductor light-emitting device during the process in accordance with the fourth step of the third embodiment of the present application;

FIG. 6E shows a side view of the encapsulated semiconductor light-emitting device during the process in accordance with the fifth step of the third embodiment of the present application;

FIG. 7 shows a top view of the semiconductor light-emitting device during the process in accordance with the sixth step of the first embodiment of the present application;

FIG. 8 shows a top view of the encapsulated semiconductor light-emitting device during the process in accordance with the fifth step of the third embodiment of the present application;

FIG. 9 shows a top view of the semiconductor light-emitting device during the process in accordance with the first step of the fourth embodiment of the present application;

FIG. 10A shows an oblique side view of the semiconductor light-emitting device during the process in accordance with the second step of the fourth embodiment of the present application;

FIG. 10B shows an oblique side view of the semiconductor light-emitting device during the process in accordance with the second step of the fourth embodiment of the present application;

FIG. 11A shows a side view of the semiconductor light-emitting devices during the process in accordance with the first step of the fifth embodiment of the present application;

FIG. 11B shows a side view of the semiconductor light-emitting devices during the process in accordance with the second step of the fifth embodiment of the present application;

FIG. 11C shows a side view of the semiconductor light-emitting devices during the process in accordance with the third step of the fifth embodiment of the present application;

FIG. 11D shows a side view of the semiconductor light-emitting devices during the process in accordance with the fourth step of the fifth embodiment of the present application;

FIG. 11E shows a side view of the semiconductor light-emitting devices during the process in accordance with the fifth step of the fifth embodiment of the present application;

FIG. 12A shows a side view of the conventional flip-chip type semiconductor light-emitting device;

FIG. 12B shows a side view of the flip-chip type semiconductor light-emitting device in accordance with the first embodiment of the present application;

FIG. 13 shows an oblique side view of the semiconductor light-emitting device in accordance with the first step of the fourth embodiment of the present application;

FIG. 14A shows a top view of the semiconductor light-emitting device in accordance with the fourth embodiment of the present application;

FIG. 14B shows an oblique side view of the semiconductor light-emitting device in accordance with the fourth embodiment of the present application;

FIG. 14C shows a top view of the other type semiconductor light-emitting device in accordance with the fourth embodiment of the present application;

FIG. **14**D shows an oblique side view of the other type semiconductor light-emitting device in accordance with the fourth embodiment of the present application.

REFERENCE SIGNS

Growth substrate **10**, **210**, **510**;
n-type semiconductor layer **112**, **2112**, **5112**;
Active layer **114**, **2114**, **5114**;
p-type semiconductor layer **116**, **2116**, **5116**;
Semiconductor epitaxial stack **110**, **2110**, **5110**;
p-side electrode **120***a*, **120***b*, **2120***a*, **2120***b*, **5120***b;*
First support substrate **20**, **220**, **520**, **60**;
First adhesive layer **135**, **2135**, **5130**;
n-side electrode **130***a*, **130***b*, **2130***a*, **2130***b*, **130***b*', **5120***a;*
Metal oxide transparent conductive layer **140**, **2140**;
Reflective layer **150**, **2150**;
First epitaxial unit **201**, **2201**, **501**;
Second epitaxial unit **202**, **2202**, **502**, **501**';
Second adhesive layer **230**, **2230**, **5230**;
Transparent metal oxide conductive layer **5280**;
Second support substrate **30**, **530**;
Semiconductor light-emitting device **200**, **300**, **400**, **500**, **600**;
Patterned sacrificial layer **2123**;
p-type extension **130***a*', **5120***b';*
n-type extension **130***a";*
Conductive through hole **134**;
Insulative layer **132**, **232**;
Third epitaxial unit **202**';
Metal conductive connection structure **125**;
p-type bonding pad **120***b*', **1310**;
n-type bonding pad **120***b*", **1320**;
Transparent structure **40**;
Insulative scattering layer **410**;
Opening **411**, **412**;
Second support substrate unit **530**';
Cross epitaxial unit **501**';
Tin solder **260**, **560**;
submount **50**', **20**';
light-emitting device **5000**, **2000**;
Symmetrical surface A', B';
direction D°

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

First Embodiment

FIGS. **1**A to **1**H show a method of manufacturing a semiconductor light-emitting device in accordance with an embodiment of the application.

FIG. **1**A shows a semiconductor epitaxial stack **110** including an n-type semiconductor layer **112**, an active layer **114**, and a p-type semiconductor layer **116** on a growth substrate **10**. The n-type semiconductor layer **112**, the active layer **114**, and the p-type semiconductor layer **116** can be sequentially formed on the growth substrate **10** by conventional epitaxial growth process. In the embodiment, the material of the growth substrate **10** comprises GaAs, germanium (Ge), indium phosphide (InP), sapphire (Al_2O_3), silicon carbide (SiC), silicon (Si), lithium aluminum oxide ($LiAlO_2$), zinc oxide (ZnO), gallium nitride (GaN), or aluminum nitride (AlN). In the embodiment, the n-type semiconductor layer **112** can be aluminum gallium indium phosphide (AlGaInP) series material or other materials; the material of the p-type semiconductor layer **116** can be GaP or other materials; the material of the active layer **114** comprises aluminum gallium indium phosphide (AlGaInP) series material, aluminum gallium indium nitride (AlGaInN) series material or zinc oxide (ZnO) series material, and the structure of the active layer **114** comprises single heterostructure (SH), double heterostructure (DH), double-side double heterostructure (DDH), or multi-quantum well (MWQ) structure. Specifically, the active layer **114** can be made of intrinsic, p-type or, n-type semiconductor material. While an electrical current flows through the semiconductor epitaxial stack **110**, the active layer **114** is able to emit a light. When the active layer **114** is made of aluminum gallium indium phosphide (AlGaInP) series material, the active layer **114** is able to emit an amber series of light, such as a red light, an orange light and a yellow light. When the active layer **114** is made of aluminum gallium indium nitride (AlGaInN) series material, the active layer **114** is able to emit a blue or a green light. Besides, the semiconductor epitaxial stack **110** can include more semiconductor layers with different functions.

FIG. **1**B shows that the p-side electrodes **120***a*, **120***b* are patterned on the p-type semiconductor layer **116** by lithography process with sputtering, thermal deposition, or electroplating method. The material of the p-side electrodes **120***a*, **120***b* can be metal, such as Au, Ag, Cu, Al, Pt, Ni, Ti, Sn, and the alloy thereof or the stacking layers thereof.

As FIG. **1**C shows, after forming the p-type semiconductor layer **116**, a first support substrate **20** is prepared, and a first adhesive layer **135** is formed on the first support substrate **20** by spin coating or deposition. And, the semiconductor epitaxial stack **110** is adhered to the first support substrate **20** with the first adhesive layer **135**. Then, the growth substrate **10** can be removed by wet etching or laser lift-off. The first support substrate **20** can be made from single material and can be composite substrate which is made from combination of different materials. For example, the first support substrate **20** can include a first substrate and a second substrate which is bonded with the first substrate (not shown). In the embodiment, the material of the support substrate **20** comprises inorganic material, such as sapphire (Al_2O_3), lithium aluminum oxide ($LiAlO_2$), zinc oxide (ZnO), gallium nitride (GaP), glass and aluminum nitride (AlN), or organic polymer material. As FIG. **1**C shows, a transferring structure is formed by the semiconductor epitaxial stack **110** transferred to the first support substrate **20** and the first support substrate **20**. In order to increase the light-emitting efficiency of the semiconductor light-emitting device made from the semiconductor epitaxial stack **110**, a portion of the surface of the p-type semiconductor layer **116** can be roughened by wet etching or dry etching.

After the semiconductor epitaxial stack **110** is transferred to the support substrate **20**, the patterned n-side electrodes **130***a*, **130***b* are formed on the exposed surface of the n-type semiconductor layer **112** by lithography process with sputtering, thermal deposition, or electroplating as shown in FIG. **1**D. The material of the n-side electrodes **130***a*, **130***b* can be metal, such as Au, Ag, Cu, Al, Pt, Ni, Ti, Sn, and the alloy thereof or the stacking layers thereof.

FIG. **1**E shows that, in order to fit different processes of fabricating different semiconductor light-emitting devices, the following processes on the n-side electrodes **130***a*, **130***b* can be the same or different. In the embodiment, a metal oxide transparent conductive layer **140** is formed on the surface of the semiconductor epitaxial stack **110** by CVD or PVD. Then, a reflective layer **150** is formed on a portion of the metal oxide transparent conductive layer **140**. The material of the metal oxide transparent conductive layer **140**

comprises ITO, IZO, InO, SnO, FTO, ATO, CTO, AZO, GZO or the combination thereof; the material of the reflective layer **150** comprises metal, such as Au, Ag, Cu, Cr, Al, Pt, Ni, Ti, Sn, Be or the alloy or the stacking layers thereof or Distributed Bragg Reflector (DBR), wherein DBR is made from the stacking layers comprising Al_2O_3, SiO_2, TiO_2 or AlN. Then, a portion of the metal oxide transparent conductive layer **140**, which is uncovered by the reflective layer **150**, is removed, and the metal oxide transparent conductive layer **140** only clads the n-side electrode **130***a*.

FIG. **1**F shows a side view of multiple first epitaxial units **201** and multiple second epitaxial units **202** above the first substrate **20** disclosed in the embodiment, which are totally divided by using dry etching in order to break off the electrical connection through the semiconductor epitaxial stack **110**.

Specifically, the semiconductor epitaxial stack **110** is divided into the first epitaxial units **201** and the second epitaxial units **202** by forming a patterned photoresist layer (not shown) on the surface of the n-type semiconductor layer **112** and then using the dry etching, such as Inductively Coupled Plasma (ICP) and Plasma Etching (PE), to etch from the n-type semiconductor layer **112**. In the embodiment, on the support substrate **20**, the first epitaxial units **201** and the second epitaxial units **202** have different geometric shapes and areas, wherein each of the first epitaxial units **201** has the p-side electrode **120***a* and the n-side electrode **130***a* as shown in FIG. **1**G, and each of the second epitaxial units **202** has the p-side electrode **120***b* and the n-side electrode **130***b* as shown in FIG. **1**H.

Besides, as FIG. **7** shows, the second epitaxial unit **202** is about around the first epitaxial unit **201** from the top view. As FIG. **1**F shows, in order to increase the light-emitting efficiency of the semiconductor light-emitting device, a portion of the surface of the n-type semiconductor layer **112** of the first epitaxial unit **201** or/and the second epitaxial unit **202** can be roughened by wet etching or dry etching. Then, a patterned second adhesive layer **230** is formed on a portion of the surface of the semiconductor epitaxial stack **110**, which is corresponding to the position of the second epitaxial units **202**, by spin coating or deposition through a patterned mask, such as patterned photoresist. The portion of the semiconductor epitaxial stack **110** corresponding to the second epitaxial units **202** is prepared for being transferred again.

The next step is to prepare a second support substrate **30**. The second support substrate **30** is adhered to the second epitaxial units **202** with the patterned second adhesive layer **230** by heating or pressing. Next, a laser is irradiated through the first support substrate **20** to dissolve the first adhesive layer **135** between the first support substrate **20** and the p-type semiconductor layer **116**, and then the second epitaxial units **202** are transferred to the second support substrate **30**. After the second epitaxial units **202** are adhered to the second support substrate **30**, the remaining first adhesive layer **135** on the surface of the second epitaxial units **202** on the second support substrate **30** is removed by dry or wet etching. FIGS. **1**G and **1**H show the first support substrate **20** with the first epitaxial units **201** and the second support substrate **30** with the second epitaxial units **202**, wherein the top views thereof are respectively shown in FIGS. **3**A and **4**A. In the embodiment, FIG. **4**A show a top view of the second epitaxial units **202**, wherein the second epitaxial units **202** are arranged in a U-shape. In the following process, the first support substrate **20** and one of the first epitaxial units **201** are formed as a semiconductor light-emitting device **200**, and the second support substrate **30** and the second epitaxial units **202** are formed as a semiconductor light-emitting device **300**, wherein the top views thereof are respectively shown in FIGS. **3**C and **4**C.

In the embodiment, as the above mentioned, the second epitaxial units **202** and the first support substrate **20** are separated by the laser to dissolve the first adhesive layer **135**. Besides, a material which has low adhesion with the first support substrate **20**, such as SiO_2, can be used as the first adhesive layer **135**. The second epitaxial units **202** can be separated from the first support substrate **20** by physical mechanical force after the second epitaxial units **202** are selectively adhered to the second substrate **30** through the patterned second adhesive layer **230**.

Second Embodiment

FIGS. **2**A to **2**H show a method of manufacturing a semiconductor light-emitting device in accordance with another embodiment of present application.

FIG. **2**A shows a semiconductor epitaxial stack **2110** including an n-type semiconductor layer **2112**, an active layer **2114**, and a p-type semiconductor layer **2116** on a growth substrate **210**. The n-type semiconductor layer **2112**, the active layer **2114**, and the p-type semiconductor layer **2116** can be sequentially formed on the growth substrate **210** by conventional epitaxial growth process. In the embodiment, the material of the growth substrate **210** comprises GaAs, germanium (Ge), indium phosphide (InP), sapphire, (Al_2O_3), silicon carbide (SiC), silicon (Si), lithium aluminum oxide ($LiAlO_2$), zinc oxide (ZnO), gallium nitride (GaN) or aluminum nitride (AlN). In the embodiment, the n-type semiconductor layer **2112** can be aluminum gallium indium phosphide (AlGaInP) series material or other materials; the material of the p-type semiconductor layer **2116** can be GaP or other materials; the material of the active layer **2114** comprises aluminum gallium indium phosphide (AlGaInP) series material, aluminum gallium indium nitride (AlGaInN) series material or zinc oxide (ZnO) series material, and the structure of the active layer **2114** comprises single heterostructure (SH), double heterostructure (DH), double-side double heterostructure (DDH), or multi-quantum well (MWQ) structure. Specifically, the active layer **2114** can be made of intrinsic, p-type, or n-type semiconductor material. While an electrical current flows through the semiconductor epitaxial stack **2110**, the active layer **2114** is able to emit a light. When the active layer **2114** is made of aluminum gallium indium phosphide (AlGaInP) series material, the active layer **2114** is able to emit an amber series of light, such as a red light, an orange light, and a yellow light. When the active layer **2114** is made of aluminum gallium indium nitride (AlGaInN) series material, the active layer **2114** is able to emit a blue or a green light. Besides, the semiconductor epitaxial stack **2110** can include more semiconductor layers with different functions.

FIG. **2**B shows that the p-side electrodes **2120***a*, **2120***b* are patterned on the p-type semiconductor layer **2116** by lithography process with sputtering, thermal deposition, or electroplating. The material of the p-side electrodes **2120***a*, **2120***b* can be metal, such as Au, Ag, Cu, Al, Pt, Ni, Ti, Sn, and the alloy thereof or the stacking layers thereof.

As FIG. **2**C shows, after the p-side electrodes **2120***a*, **2120***b* are formed, a support substrate **220** is provided, and a patterned sacrificial layer **2123** is formed on a surface of the support substrate **220** by lithography process. The position of the patterned sacrificial layer **2123** is corresponding to multiple second epitaxial units which are prepared to be transferred in the later step. Next, a first adhesive layer **2135**

is formed by spin coating or deposition. The semiconductor epitaxial stack **2110** is adhered to the first support substrate **220** by the first adhesive layer **2135**. The first adhesive layer **2135** can be coated on the surface of the first support substrate **220** for covering the patterned sacrificial layer **2123**. In other way, the first adhesive layer **2135** can also be coated on the surface of the p-type semiconductor layer **2116** and cover the p-side electrodes **2120***a*, **2120***b*. Then, the semiconductor epitaxial stack **2110** and the first support substrate **220** are bonded by heating and/or pressing. Finally, the growth substrate **210** is removed by wet etching or laser lift-off to form the structure shown in FIG. **2**C.

The first support substrate **220** is not limited to a single material and can be composite substrate which is made from combination of different materials. For example, the first support substrate **220** can include a first substrate and a second substrate which is bonded with the first substrate (not shown). In the embodiment, the material of the support substrate **220** comprises inorganic material, such as sapphire (Al_2O_3), lithium aluminum oxide ($LiAlO_2$), zinc oxide (ZnO), gallium nitride (GaP), glass and aluminum nitride (AlN), or organic polymer material. As FIG. **2**C shows, in order to increase the light-emitting efficiency of the semiconductor light-emitting device made from the semiconductor epitaxial stack **2110**, a portion of the surface of the p-type semiconductor layer **2116** can be roughened by wet etching or dry etching.

After the semiconductor epitaxial stack **2110** is transferred to the support substrate **220**, the patterned n-side electrodes **2130***a*, **2130***b* are formed on the exposed surface of the n-type semiconductor layer **2112** by lithography process with sputtering, thermal deposition, or electroplating as shown in FIG. **2**D. The material of the n-side electrodes **2130***a*, **2130***b* can be metal, such as Au, Ag, Cu, Al, Pt, Ni, Ti, Sn, and the alloy thereof or the stacking layers thereof.

FIG. **2**E shows that, in order to fit different processes of fabricating different semiconductor light-emitting devices, the following processes on the n-side electrodes **2130***a*, **2130***b* can be the same or different. In the embodiment, on the surface of the semiconductor epitaxial stack **2110**, a metal oxide transparent conductive layer **2140** and/or a reflective layer **2150** can be formed on the surface of the n-type semiconductor layer **2112** by CVD or PVD. The material of the metal oxide transparent conductive layer **2140** comprises ITO, IZO, InO, SnO, FTO, ATO, CTO, AZO, GZO, or the combination thereof; the material of the reflective layer **2150** comprises metal, such as Au, Ag, Cu, Cr, Al, Pt, Ni, Ti, Sn, Be, or the alloy or the stacking layers thereof.

FIG. **2**F shows a side view of multiple first epitaxial units **2201** and multiple second epitaxial units **2202** above the first substrate **220** disclosed in the embodiment, which are divided by dry etching. And, the first adhesive layer **2135** and the patterned sacrificial layer **2123** are also divided.

Specifically, the semiconductor epitaxial stack **2110** is divided into the first epitaxial units **2201** and the second epitaxial units **2202** by forming a patterned photoresist layer (not shown) on the surface of the n-type semiconductor layer **2112** and then the dry etching, such as Inductively Coupled Plasma (ICP) and Plasma Etching (PE), to etch from the n-type semiconductor layer **2112**. In the embodiment, on the support substrate **220**, the first epitaxial units **2201** and the second epitaxial units **2202** have different geometric shapes and areas, wherein each of the first epitaxial units **2201** has the p-side electrode **2120***a* and the n-side electrode **2130***a*, and each of the second epitaxial units **2202** has the p-side electrode **2120***b* and the n-side electrode **2130***b*.

As FIG. **2**F shows, in order to increase the light-emitting efficiency of the semiconductor light-emitting device, a portion of the surface of the n-type semiconductor layer **2112** of the first epitaxial unit **2201** or/and the second epitaxial unit **2202** can be roughened by wet etching or dry etching. Then, a patterned second adhesive layer **2230** is formed on a portion of the surface of the semiconductor epitaxial stack **2110** prepared for being transferred again, which is corresponding to the portion of the surface of the n-type semiconductor layer **2112** of the second epitaxial units **2202**, by spin coating or deposition through a patterned mask, such as patterned photoresist.

In the embodiment, the material of the patterned second adhesive layer **2230** comprises organic material, such as Acrylic acid, Unsaturated polyester, Epoxy, Oxetane, Vinyl ether, Nylon, PP, PBT, PPO, PC, ABS, and PVC; metal, such as Ti, Au, Be, W, Al, Ge, Cu, and the alloy thereof; oxide, such as ITO, CTO, ATO, IZO, AZO, ZTO, ZnO, and SiO_x; or nitride, such as SiN_x.

The next step is to prepare a second support substrate **230**. The second epitaxial units **2202** are adhered on the second support substrate **230** with the patterned second adhesive layer **2230** by heating or pressing. After the patterned sacrificial layer **2123** is removed or the adhesion of the patterned sacrificing layer **2123** is decreased by wet etching, dry etching, mechanical force separating, illuminating UV, or heating, the second epitaxial units **2202** are transferred to the second support substrate **230**.

Finally, the remaining first adhesive layer **2135** and/or the remaining patterned sacrificial layer **2123** on the surface of the second epitaxial units **2202** on the second support substrate **230** is removed by dry etching or wet etching. FIGS. **2**G and **2**H show the first support substrate **220** with the first epitaxial units **2201** and the second support substrate **230** with the second epitaxial units **2202**, wherein the top views thereof are respectively shown in FIGS. **3**A and **4**A. In the following process, the first support substrate **220** and one of the first epitaxial units **2201** are formed as a semiconductor light-emitting device **200**, and the second support substrate **230** and the second epitaxial units **2202** are formed as a semiconductor light-emitting device **300**, wherein the top views thereof are respectively shown in FIGS. **3**C and **4**C.

In the embodiment, the material of the patterned sacrificial layer **2123** comprises metal, such as Ti, Au, Ag, W, Al, Cr, Cu, Pt, and the combination thereof; UV dissociating glue; or dielectric material, such as SiO_x and SiN_x. As mentioned above, the patterned sacrificial layer **2123** can be removed by wet etching, dry etching or illuminating UV, or the adhesion between the patterned sacrificial layer **2123** and the first support substrate **220** can be decreased by heating, and then the second epitaxial unit **2202** and the first support substrate **220** is separated by mechanical force separating.

In the above embodiment, the side view and the top view of the semiconductor light-emitting device **200**, which can be a flip-chip light-emitting device, are respectively shown in FIGS. **3**B and **3**C. As shown in FIG. **3**B, in order to form two extensions **130***a*' and **130***a*" by dry etching, such as Reactive Ion Etching (RIE), Inductively Coupled Plasma (ICP), and Plasma Etching (PE), and through a patterned mask, such as patterned photoresist (not shown), a conductive through hole **134** is formed by etching the semiconductor epitaxial stack **110**(**2110**) along a direction perpendicular to the surface of the first support substrate **20** from the n-type semiconductor layer **112**(**2112**) to the p-side electrode **120***a*

(**2120***a*). An insulative layer **132** is formed on the side wall of the conductive through hole **134** by CVD or PVD to electrically insulate from the semiconductor epitaxial stack **110**(**2110**), and then a metal conductive structure is formed in the conductive through hole **134** to form a p-type extension **130***a*' which extends to the surface of the n-type semiconductor layer **112**(**2112**). The p-type extension **130***a*' and the n-type extension **130***a*" on the n-side electrodes **130***a*(**2130***a*) are formed at the same step and are able to constitute the two extensional electrodes of the flip-chip type semiconductor light-emitting device **200**. In another embodiment, when the flip-chip type semiconductor light-emitting device **200** electrically connects to the external electrical component, such as printed circuit board, the surface a of the n-type extension **130***a*" and the surface b of the p-type extension **130***a*' on the same side of the first epitaxial unit **201** can be designed to be in the same high level for forming a more reliable and more stable connecting structure.

In the aforementioned embodiment, FIGS. **4**B and **4**C respectively show the side view and the top view of the semiconductor light-emitting device **300**, which is a high-voltage single chip LED device, being transferred to the second support substrate **30**. In order to clearly present the process of producing the semiconductor light-emitting device **300**, the process steps and the structure are shown in FIGS. **4**A, **5**A, **5**B, **4**B and **4**C.

As shown in FIG. **4**A, the second epitaxial unit **202**(**2202**) is transferred to the second substrate **30**(**230**), wherein the p-side electrodes **120***b*(**2120***b*) are directly formed on the p-type semiconductor layer **116**(**2116**) after the semiconductor epitaxial stack **110** is formed on the growth substrate **10**(**210**), and the n-side electrodes **130***b*(**2130***b*) are directly formed on the n-type semiconductor layer **112**(**2112**) after the first substrate transferring process. Therefore, the n-side electrodes **130***b*(**2130***b*) are buried under the n-type semiconductor layer **112**(**2112**) (indicated by dotted line) after the second epitaxial unit **202**(**2202**) is transferred to the second support substrate **30**(**230**). In the meantime, the second epitaxial unit **202**(**2202**) has the p-side electrodes **120***b*(**2120***b*) on the surface thereof, and the patterned second adhesive layer **230**(**2230**) covers the second epitaxial unit **202**(**2202**) and the surface of the p-side electrodes **120***b*(**2120***b*).

As shown in FIG. **5**A, after the patterned second adhesive layer **230**(**2230**) on the second epitaxial units **202**(**2202**) and the surface of the p-side electrodes **120***b*(**2120***b*) is removed, the second epitaxial unit **202**(**2202**) is divided into multiple third epitaxial units **202**' by dry etching, such as Reactive Ion Etching (RIE), Inductively Coupled Plasma (ICP), and Plasma Etching (PE). In the meantime, a portion of each of the n-side electrodes **130***b*' (shown by oblique lines) under the third epitaxial units **202**' is exposed. Then, an insulative layer **232** is patterned and formed on a portion of the surface of each of the third epitaxial units **202**' and the side wall between the neighboring third epitaxial units **202**' by PVD or CVD and patterning process. FIG. **5**B shows a side view of the two neighboring third epitaxial units **202**' during the process. In the embodiment, the material of the insulative layer **232** is SiO_2. Besides SiO_2, the material of the insulative layer **232** comprises SiN_x, Al_2O_3, AlN or the combination thereof.

Next, a metal conductive connection structure **125** is formed between the neighboring third epitaxial units **202**' by lithography process to electrically connect the n-side electrode **130***b*' of one of the third epitaxial units **202**' and the p-side electrode **120***b* of the other one in an electrical series connection to form a high-voltage single chip semiconductor light-emitting device **300** shown in FIGS. **4**B and **4**C. In the semiconductor light-emitting device **300**, the p-side electrode **120***b*(**2120***b*) and the n-side electrode **130***b*' are respectively on the opposite sides of the third epitaxial units **202**'. The p-side electrode **120***b*(**2120***b*) and the n-side electrode **130***b*' of the two of the third epitaxial units **202**' at the ends of the semiconductor light-emitting device **300** are respectively connected to a p-type electrode pad **102***b*' and an n-type electrode pad **120***b*", wherein the p-side electrodes **120***b*(**2120***b*), the n-side electrodes **130***b*', the p-type electrode pad **102***b*' and the n-type electrode pad **120***b*" can be formed with the metal conductive connection structure **125** in the same step. As shown in FIG. **4**C, in the embodiment, the p-type electrode pad **102***b*' and the n-type electrode pad **120***b*" are formed on the surface of the second support substrate **30**(**230**) beyond the third epitaxial units **202**' and do not overlap with the surface of the third epitaxial units **202**' for increasing the light extracting efficiency of the semiconductor light-emitting device **300**.

For a skilled person in the art, besides the series structure, the third epitaxial units **202**' can also be connected to an electrical parallel structure between the neighboring third epitaxial units **202**'. Besides forming the metal conductive connection structure **125** between the third epitaxial units **202**', the method of electrically connecting the third epitaxial units **202**' further comprises forming a patterned electrically conductive structure on the surface of the second support substrate **30**(**230**), and then bonding each of the third epitaxial units **202**' in flip-chip type on the second support substrate **30**(**230**) and electrically connecting to the patterned electrically conductive structure. Through the patterned electrically conductive structure, the third epitaxial units **202**' can also be connected in series or parallel to form the semiconductor light-emitting device.

In the other embodiment, the semiconductor light-emitting device **200** can be produced as an encapsulated semiconductor light-emitting device **400** by subsequent processes, and the side view and the top view are respectively shown in FIGS. **6**C and **6**D. FIGS. **6**A to **6**C show the process and the structure of manufacturing the semiconductor light-emitting device **400** for clearly presenting the encapsulated semiconductor light-emitting device **400**.

FIG. **6**A shows a transparent structure **40** covering and surrounding the semiconductor light-emitting device **200** and the side wall of each of the epitaxial units thereof by spin coating and deposition, wherein the transparent structure **40** is transparent to the light emitted from the semiconductor light-emitting device **200**, and the transparent structure **40** is used to encapsulate the semiconductor light-emitting device **200** for increasing the mechanical strength the semiconductor light-emitting device **200**, disclosed in the embodiment. The material of the transparent structure **40** comprises Epoxy, Polyimide, Benzocyclobutene, Perfluorocyclobutane, SU8 photoresist, Acrylic Resin, Polymethylmethacrylate, Poly ethylene terephthalate, Polycarbonate, Polyetherimide, Fluorocarbon Polymer, Glass, Al_2O_3, SINR, SOG, Teflon, or the combination thereof.

FIG. **6**B shows that a portion of the transparent structure **40** is removed to expose the p-type extension **130***a*' and the n-type extension **130***a*". As shown in FIG. **6**C, an insulative scattering layer **410** is formed to cover the surface of the transparent structure **40** and a portion of the surface and side surface of the p-type extensions **130***a*' and the n-type extension **130***a*" by spin coating, deposition, stencil printing, or screen printing. The insulative scattering layer **410** can be used to scatter and reflect light and insulate against electrical

current so the use of scattering material, reflective material, and insulative material can be reduced. In that case, it further prevents the materials from being damaged caused by different material characteristics, such as the difference of thermal expansion coefficients and the mechanical strengths so the yield rate can be increased, the cost can be reduced, and the moisture can be prevented from entering the semiconductor light-emitting device **200**. The material of the insulative scattering layer **410** comprises Epoxy, SiO_x, Al_2O_3, TiO_2, Silicone, Resin, or the combination thereof.

Next, a portion of the insulative scattering layer **410**, which is corresponding to the position of the p-type extensions **130***a*' and the n-type extension **130***a*", is removed by lithography process to form openings **411**, **412** corresponding to the position of the p-type extensions **130***a*' and the n-type extension **130***a*". As shown in FIG. **6**D, in the step, the insulative scattering layer **410** covers the side wall and a portion surface of the p-type extensions **130***a*' and the n-type extension **130***a*" in order to increase the light extracting efficiency.

Finally, a p-type bonding pad **1310** and an n-type bonding pad **1320** are respectively formed in the openings **411**, **412** above the transparent structure **40** and the insulative scattering layer **410** for wire bonding by chemical plating, electroplating, or sputtering with mask. After completing the above process, the encapsulated semiconductor light-emitting device **400** is completed as shown in FIG. **6**E. Because the semiconductor epitaxial stack **110** is surrounded by encapsulating structure, the semiconductor light-emitting device **400** has better heat resistance, moisture resistance and oxidative stability. The semiconductor light-emitting device **400** is able to electrically connect to the printed circuit board by wire bonding or flip-chip bonding to form a light-emitting device, such as light bulb, back light unit, and vehicle lamp.

FIG. **8** shows a top view of the semiconductor light-emitting device **400**. The view along the direction D (shown in FIG. **6**E) perpendicular to the first support substrate **20** shows that the first epitaxial unit **201** of the semiconductor light-emitting device **200** is surrounded by the transparent structure **40**, wherein and the transparent structure **40** is covered by an insulative scattering layer (not shown). A portion of the insulative scattering layer is removed to form the openings **411**, **412** on the first epitaxial unit **201**, wherein the openings **411**, **412** are overlapped by the p-type bonding pad **1310** and the n-type bonding pad **1320** which electrically connect the first epitaxial unit **201**. The p-type bonding pad **1310** and the n-type bonding pad **1320** are out of the range of the first epitaxial unit **201**. Namely, the view along the direction perpendicular to the first support substrate **20** shows that a portion of the p-type bonding pad **1310** and a portion of the n-type bonding pad **1320** do not overlap with the first epitaxial unit **201**.

The aforementioned structure is able to increase the area of the metal bonding pad. As the semiconductor light-emitting device **400** electrically connects the external substrate, such as printed circuit board, the connection between the devices is more reliable and more stable. In a preferable embodiment, the exposed surface of the p-type bonding pad **1310** and the exposed surface of the n-type bonding pad **1320** on the same side of the first epitaxial unit **201** are in the same high level.

The p-type bonding pad **1310** and the n-type bonding pad **1320** are used for inducing an external electrical current, and the material thereof comprises Cu, Sn, Au, Ni, Ti, Pb, Cu—Sn, Cu—Zn, Cu—Cd, Sn—Pb—Sb, Sn—Pb—Zn, Ni—Sn, Ni—Co, Au alloy, Au—Cu—Ni—Au, or the combination thereof.

The view along the direction perpendicular to the substrate shows that the epitaxial unit can be formed to different shapes for meeting different demands. FIG. **9** shows that the epitaxial unit can be cut into square or cross disclosed in the embodiment. The semiconductor epitaxial stack **5110** on the growth substrate **510** is divided into a first epitaxial unit **501** and a second epitaxial unit **502**, and then the first epitaxial unit **501** and the second epitaxial unit **502** are respectively transferred to the first support substrate **520** and the second support substrate **530** as shown in FIGS. **10**A and **10**B.

Because the material of the first support substrate **520** and the second support substrate **530** comprises insulative material, such as sapphire (Al_2O_3), an electrically conductive layer can fully contact the surface of the support substrate, or be patterned to partially contact the support substrate for electrically connecting the epitaxial units on the support substrate, wherein the electrically conductive layer is made of transparent metal oxide conductive layer which is pervious to the light emitted from the epitaxial units. The transparent metal oxide conductive layer can be made by CVD or PVD, and the material of the transparent metal oxide conductive layer comprises ITO, IZO, InO, SnO, FTO, ATO, CTO, AZO, GZO or the combination thereof. The transparent metal oxide conductive layer can also be used for the material of the adhesive layer and formed with the substrate transferring process as mentioned above.

FIGS. **11**A to **11**E show a method of manufacturing a semiconductor light-emitting device by using a transparent metal oxide conductive layer as an adhesive material in accordance with another embodiment. As shown in FIG. **11**A, a semiconductor epitaxial stack is transferred from the growth substrate **510** to a first support substrate **520** with a first adhesive layer **5130** on thereof by the above mentioned method or a conventional method. And then, the semiconductor epitaxial stack is patterned and divided into a first epitaxial unit **501** and a second epitaxial unit **502**. The first adhesive layer **5130** comprises organic material, such as Acrylic acid, Unsaturated polyester, Epoxy, Oxetane, Vinyl ether, Nylon, PP, PBT, PPO, PC, ABS, and PVC; metal, such as Ti, Au, Be, W, Al, Ge, Cu, and the alloy thereof; oxide, such as ITO, CTO, ATO, IZO, AZO, ZTO, ZnO, and SiO_x; or nitride, such as SiN_x.

As FIGS. **11**A and **11**B show, a semiconductor epitaxial stack includes an n-type semiconductor layer **5112**, an active layer **5114** and a p-type semiconductor layer **5116**. As the aforementioned process, the semiconductor epitaxial stack is patterned and divided into a first epitaxial unit **501** and multiple second epitaxial units **502**. Next, two second adhesive layers **5230** are respectively formed on the surface of each second epitaxial unit **502** and on the surface of a second support substrate **530**, wherein the two second adhesive layers **5230** are made of the transparent metal oxide conductive layer. And then, the two second adhesive layers **5230** are connected by heating or pressing. The second adhesive layers **5230** can be formed on the full surface of the second support substrate **530** or patterned on the partial surface of the second support substrate **530**. As shown in FIGS. **11**C and **11**D, the first adhesive layer **5130** between the first support substrate **520** and the second epitaxial units **502** can be melted by illuminating laser or UV, and then the second epitaxial units **502** are transferred to the second support substrate **530**. After the second epitaxial units **502** are adhered to the second support substrate **530**, the remaining first adhesive layer **5130** on the surface of the each second

epitaxial unit **502** on the second support substrate **530** can be removed by dry or wet etching. Finally, the first epitaxial unit **501** and the multiple second epitaxial units **502** are respectively on the first support substrate **520** and the second support substrate **530** as shown in FIGS. **10**A and **10**B.

In the embodiment, the method to separate the first support substrate **520** and the second epitaxial units **502** includes melting the first adhesive layer **5130** by illuminating laser as mentioned above. Alternatively, a material with low adhesion force with the first support substrate **520**, such as SiO_2, is used as the first adhesive layer **5130** so a mechanical force can be applied to separate the first support substrate **520** and the second epitaxial units **502** after the second epitaxial units **502** are adhered to the second support substrate **530** by forming a patterned second adhesive layer **5230** on the surfaces of the second epitaxial units **502** which are chosen to be transferred again.

After the second epitaxial units **502** and the first support substrate **520** are separated, the second support substrate **530** has the second epitaxial units **502** thereon which are transferred again. Next, the second support substrate **530** can be patterned and divided into multiple second support substrate units (not shown) for forming light-emitting devices, wherein each of the second support substrate units has one or multiple second epitaxial units **502** thereon.

FIG. **11**E shows that a single second support substrate unit **530'** supports one second epitaxial unit **502** thereon. Because the patterned second adhesive layer **5230** is made of transparent metal oxide conductive layer, the patterned second adhesive layer **5230** is able to electrically connect the n-type semiconductor layer **5112** and extend to the surface of the second support substrate unit **530'** beyond the second epitaxial unit **502**. Next, an n-side electrode **5120***a* and a p-side electrode **5120***b* are respectively patterned on the surface of the second support substrate unit **530'** beyond the second epitaxial unit **502** and on the surface of the p-type semiconductor layer **5116** by lithography process with sputtering, thermal deposition, or electroplating. The n-side electrode **5120***a* produced by the aforementioned process is not on the surface of the second epitaxial unit **502** for avoiding shading the light and increasing the light extracting efficiency.

After the patterned second epitaxial units **502** are transferred to form the different semiconductor devices, the first epitaxial unit **501**, which remains on the first support substrate **520**, can be divided from the first support substrate **520** to form different semiconductor devices by subsequent different processes.

FIG. **13** shows that the remaining first epitaxial unit **501** can further form multiple semiconductor light-emitting devices with cross-shaped epitaxial units **501'** represented by the dotted line **510** by the cutting method disclosed in the embodiments. As FIGS. **14**A to **14**D indicate, the process disclosed in the embodiment can efficiently utilize the entire semiconductor epitaxial stack on the substrate.

The top views and oblique side views of different appearances in accordance with the aforementioned embodiment are described in the following description. FIG. **14**A shows a top view of the semiconductor light-emitting device **500** comprising the cross epitaxial unit **501'**, and FIG. **14**B shows an oblique side view thereof. In the embodiment, as shown in FIG. **14**A, a transparent metal oxide conductive layer **5280** is formed on the whole top surface of the second support substrate unit **530'**, and the patterned n-side electrode **5120***a* and the p-side electrode **5120***b* are respectively formed on the surface of the transparent metal oxide conductive layer **5280** extending out from the second epitaxial unit **502** and on the surface of the p-type semiconductor layer **5116**, wherein the patterned n-side electrode **5120***a* and the p-side electrode **5120***b* respectively and electrically contact the n-type semiconductor layer **5112** and the p-type semiconductor layer **5116**.

FIGS. **14**C and **14**D respectively show a top view and an oblique side view of the semiconductor light-emitting device **600** comprising the cross epitaxial unit **501'** in accordance with another embodiment. In the embodiment, the partially patterned transparent metal oxide conductive layer **5280**, which is used as an adhesion layer, is disposed on the surface of the second support substrate unit **530'**, wherein the second support substrate unit **530'** is an insulative substrate, such as sapphire (Al_2O_3). Then, the p-side electrode **5120***b* is disposed on the region of the surface of the second support substrate unit **530'** not covered by the transparent metal oxide conductive layer **5280**, and a p-type extension **5120***b'*, which extends from the p-side electrode **5120***b*, electrically contacts the p-type semiconductor layer **5116**. The patterned n-side electrode **5120***a* is disposed on the surface of the patterned second adhesive layer **5230** beyond the second epitaxial unit **502** and electrically contacts the n-type semiconductor layer **5112** through the patterned second adhesive layer **5230**. By the design, both of the patterned n-side electrode **5120***a* and the p-side electrode **5120***b* are not on the surface of the second epitaxial unit **502** for reducing the light shaded by the opaque metal material and for increasing the light extraction.

As FIGS. **14**A and **14**C respectively show the top views of the semiconductor light-emitting devices **500**, **600**, the cross epitaxial unit **501'** is made from the first epitaxial unit **501**, which has symmetrical shape and has two different symmetrical surfaces A' and B' perpendicular to the substrate, and the end portions of the cross epitaxial unit **501'** are near the edges of the second support substrate unit **530'**. Therefore, the portion of the second support substrate unit **530'** uncovered by the cross epitaxial unit **501'** can be partitioned into four regions. In another embodiment, the first epitaxial unit **501** can be made to L-shape epitaxial units or irregular polygon epitaxial units, and the second support substrate unit **530'** can also be partitioned into multiple regions, not limited to 4 regions.

In the embodiment, the second support substrate **530** is an insulative substrate, such as sapphire (Al_2O_3) substrate, aluminum nitride (AlN) substrate, glass substrate, and organic polymer substrate. And, the second support substrate **530** can also be an electrically conductive substrate, such as lithium aluminum oxide ($LiAlO_2$) substrate, zinc oxide (ZnO) substrate and gallium nitride (GaP) substrate. And, the second support substrate **530** can be a transparent substrate or a reflective substrate. Besides, the material of the second support substrate **530** can also be made of a high thermal dissipation material with a thermal conductivity coefficient larger than 24 W/m*k, such as Cu, Wu, AlN, Metal Matrix Composite (MMC), Ceramic Matrix Composite (CMC), SiC, Al, Si, Diamond, or the combination thereof.

Besides, for the aforementioned semiconductor light-emitting devices **200**, **300**, the area of each of the transparent support substrates (**20**, **30**) is larger than the area of the surface of the active layer **114** of the semiconductor epitaxial stack **110**. While the light enters the transparent support substrates (**20**, **30**) of which the refractivity is lower than the refractivity of the semiconductor epitaxial stack **110**, since the transparent support substrates (**20**, **30**) have larger area, more light can depart from the transparent support substrates (**20**, **30**). As shown in FIGS. **12**A and **12**B, for the conventional flip-chip type light-emitting devices, the conventional

flip-chip type light-emitting device and the active layer **114** thereof have the same areas. For the flip-chip type semiconductor light-emitting device **200** disclosed in the aforementioned embodiment, the area of the first support substrate **20** of the flip-chip type semiconductor light-emitting device **200** (shown in FIG. **3**C) is larger than twice the area of the surface of the active layer **114** thereof, which is different from the conventional flip-chip type light-emitting devices. The light-emitting devices **5000**, **2000** are respectively formed by respectively connecting the light-emitting diodes to the corresponding circuits of the submounts **50'**, **20'** through the tin solders **560**, **260**. In the meantime, there is more light L emitted from the active layer **114** which can be extracted from large support substrate **20** and not be absorbed again by the active layer **114**. Thus, the light-emitting device **2000** has better light extracting efficiency than the light-emitting device **5000**. Namely, as the large support substrate **20** is applied to the high-voltage semiconductor light-emitting device **300**, the encapsulated semiconductor light-emitting device **400**, or the semiconductor light-emitting devices **500**, **600** made from the single second epitaxial units **502**, the light extracting efficiencies thereof can also be improved.

In different embodiment, the number of the semiconductor epitaxial stack(s) on a single support substrate is not limited to one. In order to simplify the process, after a semiconductor epitaxial stack is formed on a larger first support substrate **20**, multiple the same first epitaxial units **201** and second epitaxial units **202** as shown in FIG. **7** can be formed by lithography process and transferring process. Next, the multiple second epitaxial units **202** formed on the first support substrate **20** are transferred to the larger second support substrate **30** (such as a wafer) at the same time, and the first epitaxial units **201** remain on the first support substrate **20**. Next, after the first support substrate **20** and the second support substrate **30** are processed by aforementioned process, the multiple semiconductor light-emitting devices **200** comprising the first epitaxial units **201**, of which the size is the same as the size of the substrate shown in FIG. **3**C, can be formed by cutting the first support substrate **20**; and similarly, the multiple semiconductor light-emitting devices **300** comprising the third epitaxial units **202'**, of which the size is the same as the size of the substrate shown in FIG. **4**C, can be formed by cutting the second support substrate **30**.

One of the semiconductor light-emitting devices **200** matches one of the semiconductor light-emitting devices **300**, and one unit of a single semiconductor epitaxial stack **110** on a single substrate can form one semiconductor light-emitting devices **200** and one semiconductor light-emitting devices **300**. Therefore, the semiconductor light-emitting devices **200**, **300** should have approximately the same sizes. In other words, the areas of the substrates thereof are approximately the same as shown in FIGS. **3**C and **4**C.

Although the present application has been explained above, it is not the limitation of the range, the sequence in practice, the material in practice, or the method in practice. Any modification or decoration for present application is not detached from the spirit and the range of such.

What is claimed is:

1. A method of manufacturing a semiconductor light-emitting device, comprising the steps of:

providing a first substrate;

providing a semiconductor epitaxial stack;

providing a first adhesion layer connecting the first substrate and the semiconductor epitaxial stack;

patterning the semiconductor epitaxial stack to multiple epitaxial units;

separating the multiple epitaxial units and the first substrate, wherein the multiple epitaxial units comprises:

multiple first epitaxial units, wherein each of the first epitaxial units has a first geometric shape and a first area; and

multiple second epitaxial units, wherein each of the second epitaxial units has a second geometric shape and a second area;

providing a second substrate with a surface;

transferring the multiple second epitaxial units to the surface of the second substrate;

dividing the first substrate to form multiple first semiconductor light-emitting devices, wherein each of the first semiconductor light-emitting devices has one of the first epitaxial units; and

dividing the second substrate to form multiple second semiconductor light-emitting devices, wherein each of the second semiconductor light-emitting devices has one of the second epitaxial units;

wherein the first geometric shape is different from the second geometric shape or the first area is different from the second area.

2. The method of manufacturing a semiconductor light-emitting device according to claim **1**, wherein the step of transferring the multiple second epitaxial units to the surface of the second substrate further comprises: providing a second adhesion layer connecting the second substrate and the semiconductor epitaxial stack.

3. The method of manufacturing a semiconductor light-emitting device according to claim **2**, wherein the step of transferring the multiple second epitaxial units to the surface of the second substrate further comprises: partially removing the first adhesion layer on the multiple second epitaxial units after connecting the second substrate and the semiconductor epitaxial stack.

4. The method of manufacturing a semiconductor light-emitting device according to claim **1**, wherein the step of forming semiconductor epitaxial stack further comprising:

forming a first type conductivity semiconductor layer on the first substrate;

forming a second type conductivity semiconductor layer on the first type conductivity semiconductor layer; and

forming an active layer between the first type conductivity semiconductor layer and the second type conductivity semiconductor layer.

5. The method of manufacturing a semiconductor light-emitting device according to claim **3**, further comprising forming a second adhesion layer on a portion of a surface of the second substrate, wherein the portion of the surface is corresponding to the multiple second epitaxial units.

6. The method of manufacturing a semiconductor light-emitting device according to claim **1**, wherein the second adhesion layer comprises organic material, metal or inorganic material.

7. The method of manufacturing a semiconductor light-emitting device according to claim **1**, wherein the first geometric shape and/or the second geometric shape comprises square, rectangle, or cross-shape.

8. The method of manufacturing a semiconductor light-emitting device according to claim **5**, further comprising a first electrode on the second epitaxial unit.

9. The method of manufacturing a semiconductor light-emitting device according to claim **4**, wherein the step of forming the first semiconductor light-emitting devices comprises respectively forming a first electrode electrically

connecting a surface of the first type conductivity semiconductor layer and a second electrode electrically connecting a surface of the second type conductivity semiconductor layer.

10. The method of manufacturing a semiconductor light-emitting device according to claim **1**, wherein each of the first semiconductor light-emitting devices comprises only one the first epitaxial unit and a first substrate for carrying the first epitaxial unit.

11. The method of manufacturing a semiconductor light-emitting device according to claim **1**, further comprising dividing each of the second epitaxial units to multiple third epitaxial units, wherein each of the multiple second semiconductor light-emitting devices comprises at least two the third epitaxial units and a second substrate unit which is divided from the second substrate for carry the third epitaxial units.

12. The method of manufacturing a semiconductor light-emitting device according to claim **1**, wherein each of the multiple second semiconductor light-emitting devices comprises at least two the second epitaxial units and a second substrate unit which is divided from the second substrate for carry the second epitaxial units.

13. The method of manufacturing a semiconductor light-emitting device according to claim **11**, further comprising forming at least one conductive connective structure for connecting the third epitaxial units in parallel or in series.

14. The method of manufacturing a semiconductor light-emitting device according to claim **13**, further comprising forming the conductive connective structure on a surface of the second substrate.

15. The method of manufacturing a semiconductor light-emitting device according to claim **13**, further comprising forming the conductive connective structure on the third epitaxial units.

16. The method of manufacturing a semiconductor light-emitting device according to claim **11**, wherein the second epitaxial units arrange in U-type.

17. The method of manufacturing a semiconductor light-emitting device according to claim **1**, wherein the step of forming the first adhesion layer comprises:

forming a patterned sacrificial layer on the first substrate; and

forming the first adhesion layer on the patterned sacrificial layer, wherein the patterned sacrificial layer is corresponding to the position of the second epitaxial units.

18. The method of manufacturing a semiconductor light-emitting device according to claim **17**, further comprising removing the patterned sacrificial layer.

19. The method of manufacturing a semiconductor light-emitting device according to claim **4**, wherein the step of forming the multiple first semiconductor light-emitting devices further comprises forming a first electrode and a second electrode respectively connecting the first epitaxial unit, wherein the first electrode in on a surface of the first type conductivity semiconductor layer of the first epitaxial unit, and the second electrode is through the first epitaxial unit and on the first type conductivity semiconductor layer and a surface of the second type conductivity semiconductor layer.

20. The method of manufacturing a semiconductor light-emitting device according to claim **9**, further comprising forming a transparent structure covering a side wall of the first epitaxial unit.

21. The method of manufacturing a semiconductor light-emitting device according to claim **20**, wherein the transparent structure comprises Epoxy, Polyimide, Benzocyclobutene, Perfluorocyclobutane, SU8 photoresist, Acrylic Resin, Polymethylmethacrylate, Poly ethylene terephthalate, Polycarbonate, Polyetherimide, Fluorocarbon Polymer, Glass, Al2O3, SINR, SOG, Teflon, or the combination thereof.

22. The method of manufacturing a semiconductor light-emitting device according to claim **20**, wherein the first epitaxial unit further comprises a first bonding pad and a second bonding pad on the transparent structure and electrically connecting the first electrode and the second electrode respectively.

23. The method of manufacturing a semiconductor light-emitting device according to claim **20**, further comprising forming an insulated scattering layer on the transparent structure, wherein the insulated scattering layer covers side walls and a portion surface of the first electrode and the second electrode of the first epitaxial unit.

24. The method of manufacturing a semiconductor light-emitting device according to claim **22**, wherein the first bonding pad and the second bonding pad of the first epitaxial unit are over the region of the first epitaxial unit.

25. The method of manufacturing a semiconductor light-emitting device according to claim **22**, wherein the first bonding pad and the second bonding pad are formed by sputtering, thermal deposition, or electroplating method.

26. The method of manufacturing a semiconductor light-emitting device according to claim **1**, further comprising forming a metallic oxide conductive layer on the surface of the second substrate.

27. The method of manufacturing a semiconductor light-emitting device according to claim **26**, further comprising forming a first electrode on the surface of the second substrate exposing from the metallic oxide conductive layer, wherein the first electrode connects the first semiconductor layer of the second epitaxial unit.

28. The method of manufacturing a semiconductor light-emitting device according to claim **11**, further comprising forming a first bonding pad and a second bonding pad on the second substrate, and the first bonding pad and the second bonding pad electrically connects the third epitaxial unit.

29. The method of manufacturing a semiconductor light-emitting device according to claim **28**, wherein the first bonding pad and the second bonding pad are formed on the second substrate beside of the third epitaxial unit.

* * * * *