(19) **United States**
(12) **Patent Application Publication**
YEN et al.

(10) **Pub. No.: US 2014/0073075 A1**
(43) **Pub. Date: Mar. 13, 2014**

(54) **METHOD FOR SEPARATING LIGHT-EMITTING DIODE FROM A SUBSTRATE**

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(21) Appl. No.: **13/611,951**

(22) Filed: **Sep. 12, 2012**

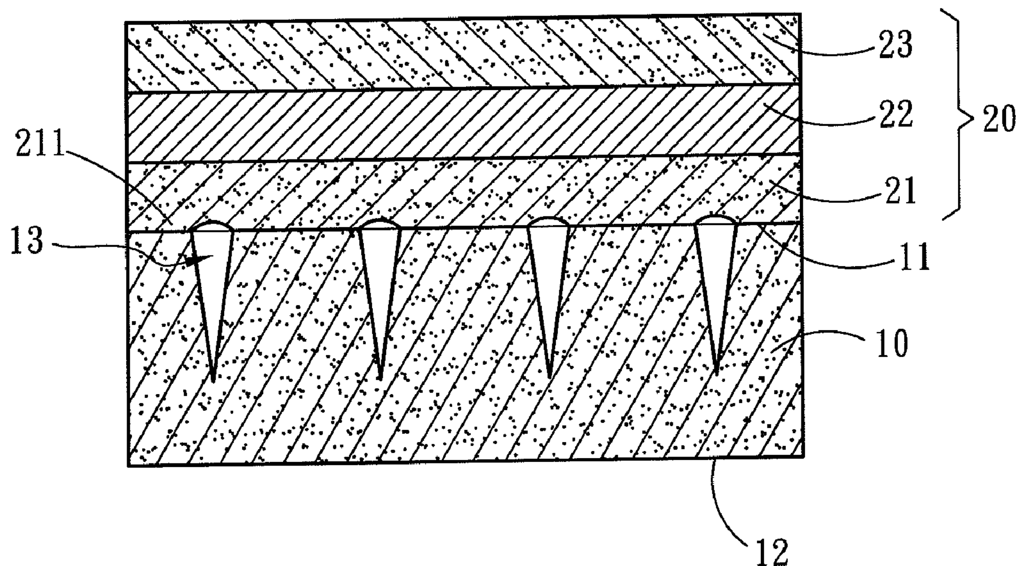
Publication Classification

(51) **Int. Cl.**
H01L 33/48 (2010.01)

(52) **U.S. Cl.**
USPC **438/42**; 257/E33.055

(57) **ABSTRACT**

A method for separating a light-emitting diode (LED) from a substrate comprises the following steps. First, a substrate is provided which includes a junction surface and a bottom surface far away from the junction surface. Then a plurality holes are formed on the junction surface. An LED structure is further grown on the junction surface, and includes a junction portion bonded to the junction surface. The bottom surface is then polished to be shrunk to communicate with the holes. Finally, the junction portion is etched by an etching liquid via the holes to separate the LED structure from the substrate. Accordingly, by forming the holes, the LED structure and the substrate can be separated through polishing and etching processes, thereby providing a high yield rate as well as reduced production costs.



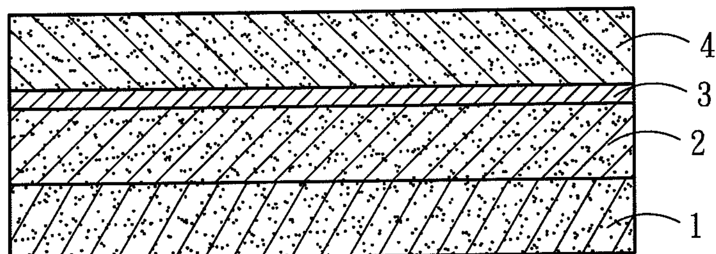


Fig. 1A

PRIOR ART

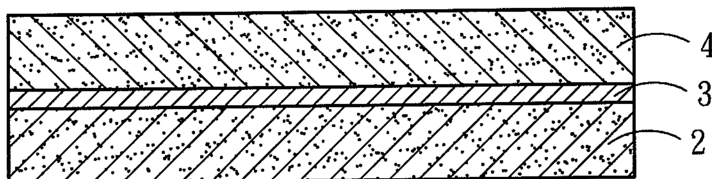


Fig. 1B

PRIOR ART

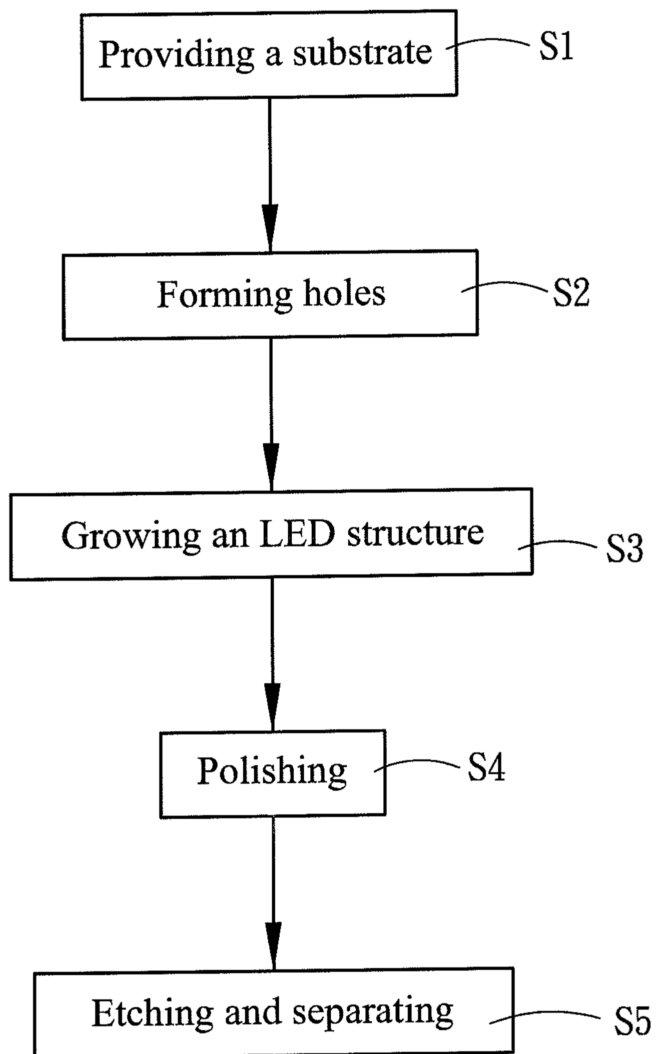


Fig. 2

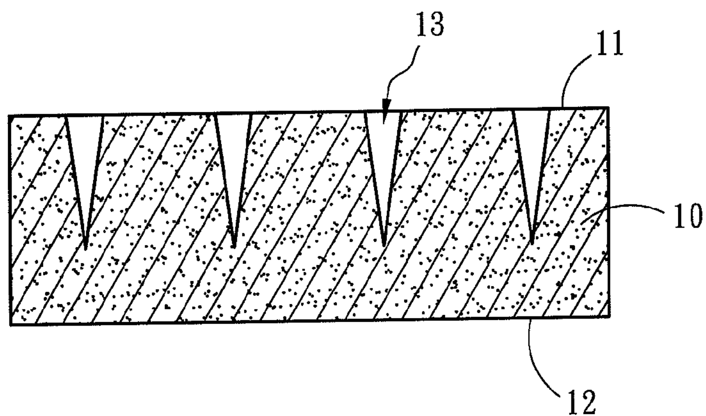


Fig. 3A

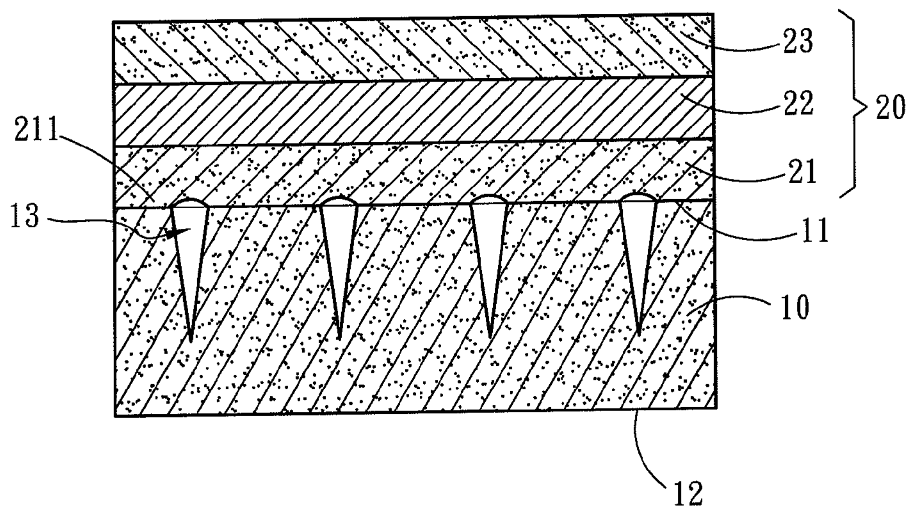


Fig. 3B

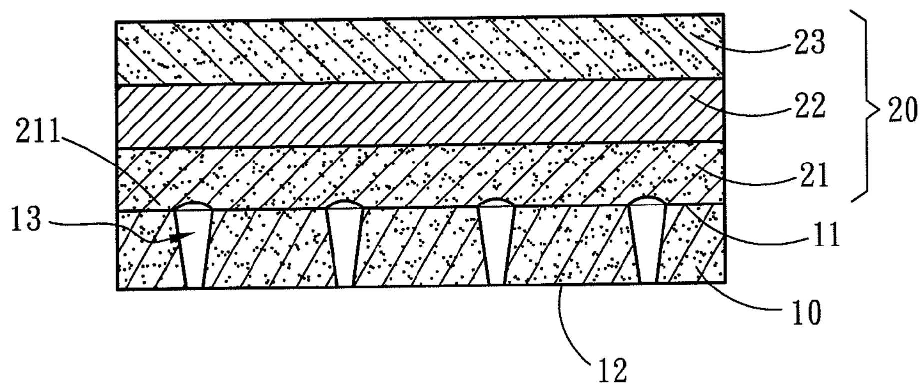


Fig. 3C

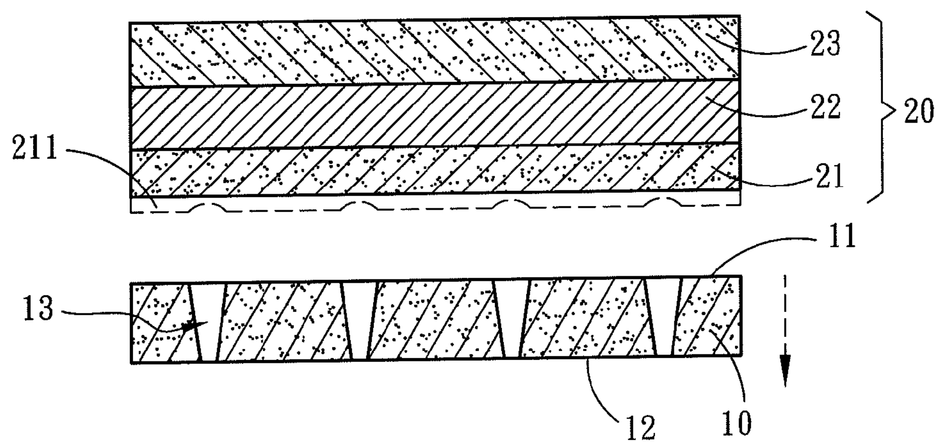


Fig. 3D

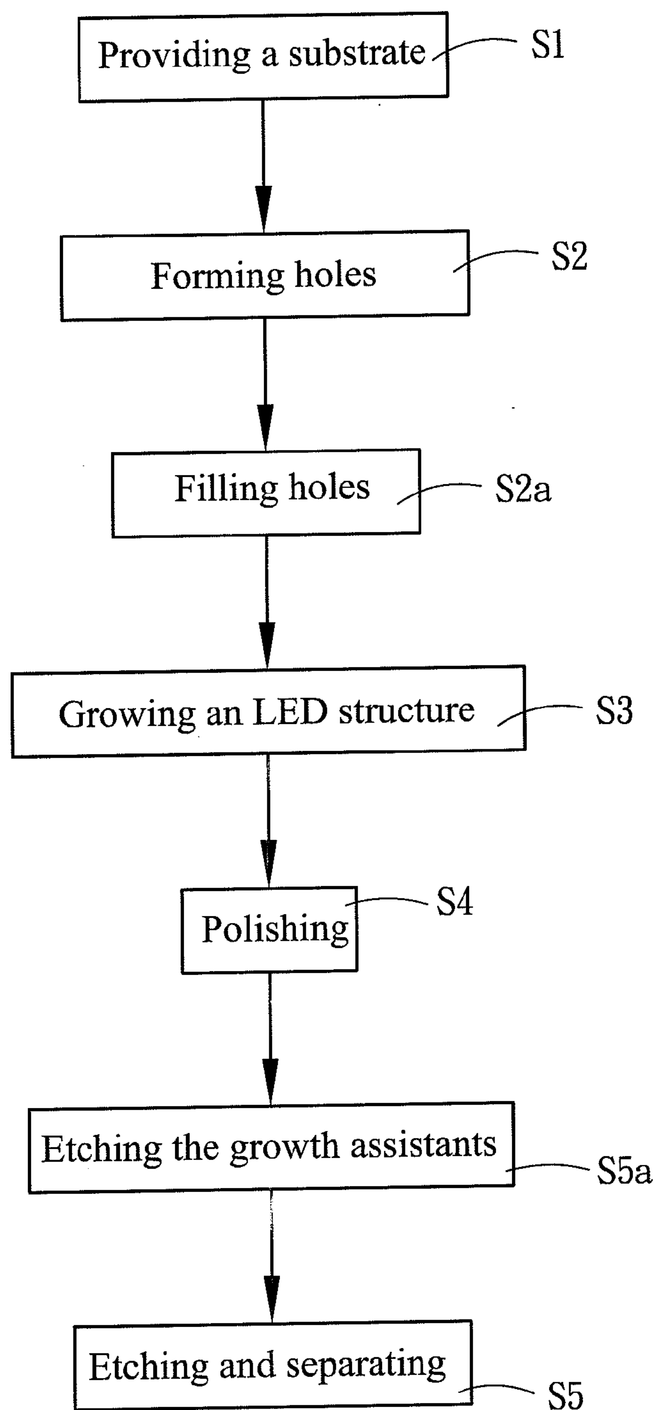


Fig. 4

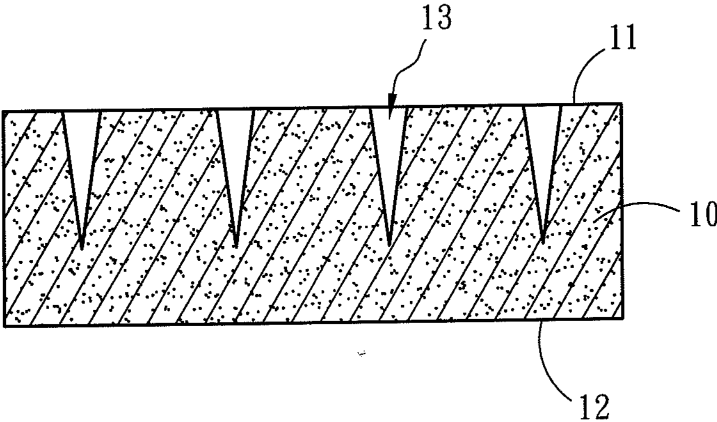


Fig. 5A

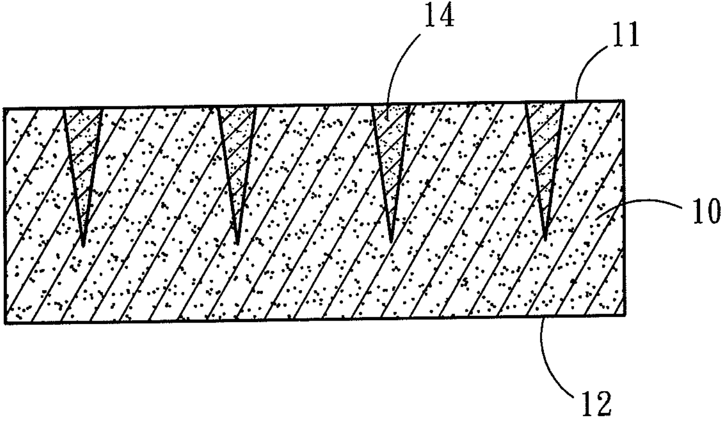


Fig. 5B

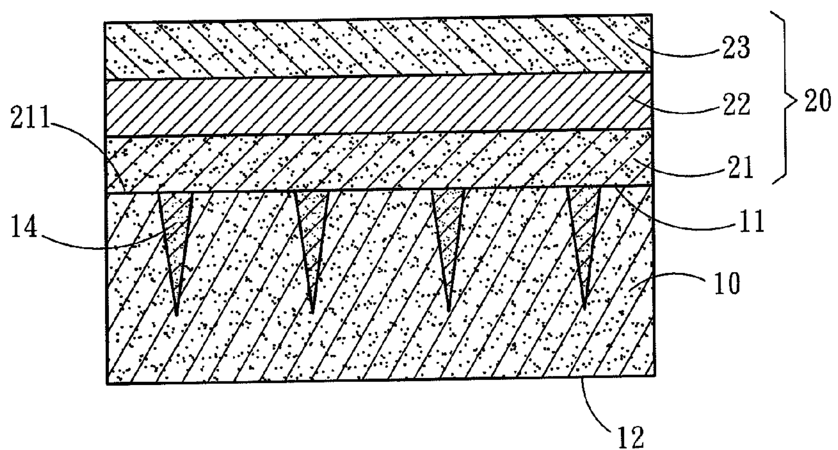


Fig. 5C

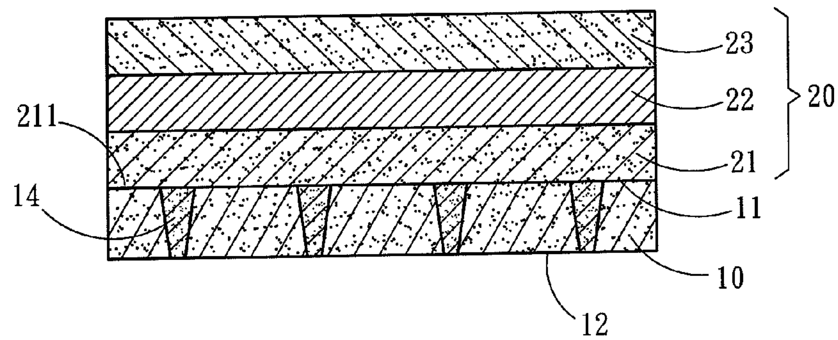


Fig. 5D

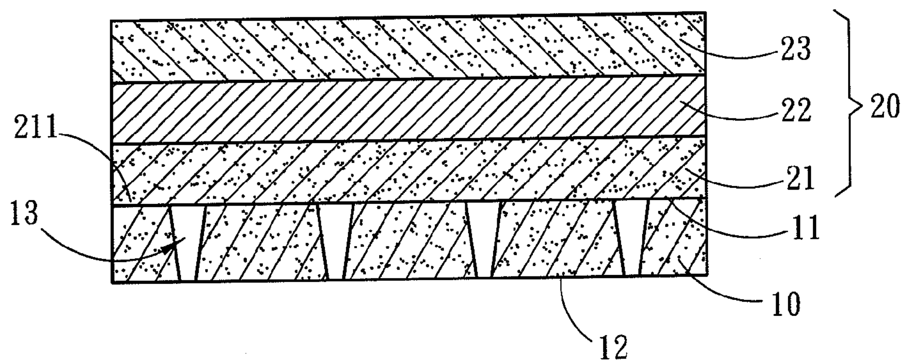


Fig. 5E

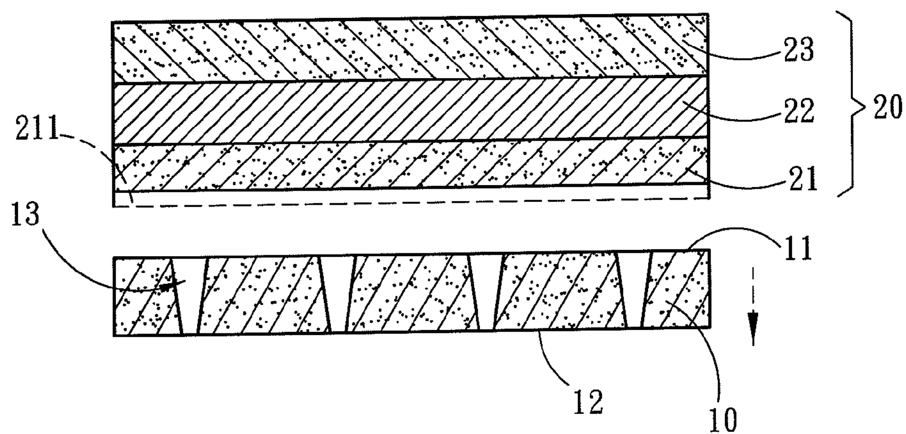


Fig. 5F

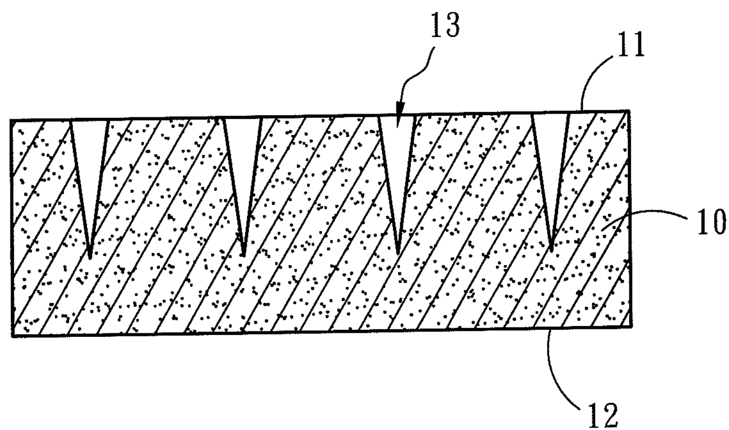


Fig. 6A

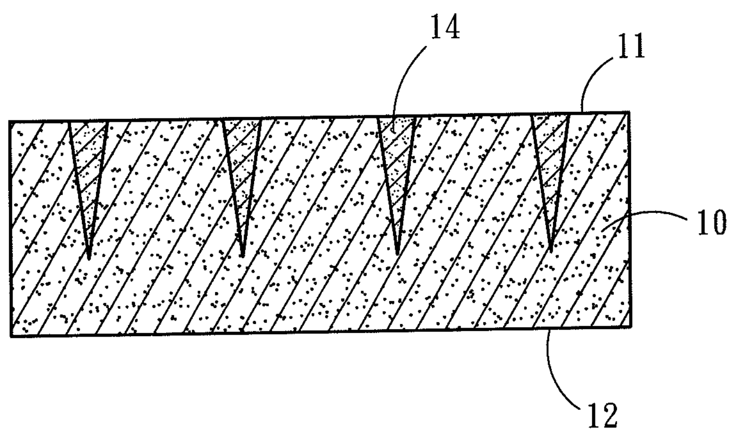


Fig. 6B

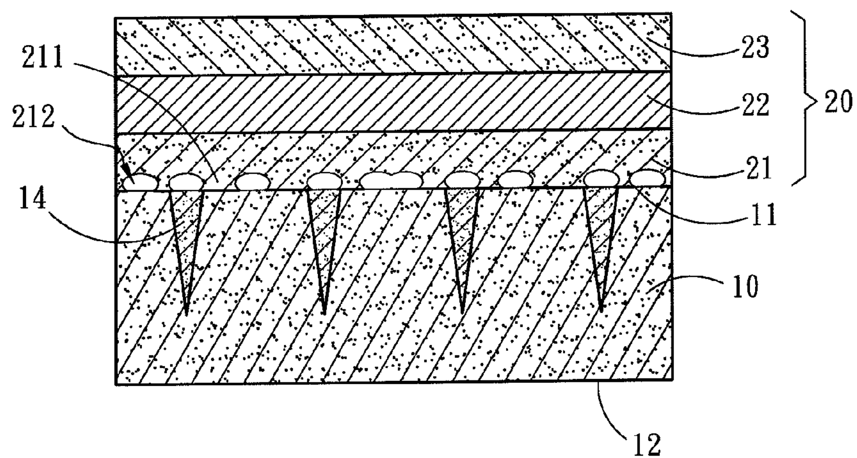


Fig. 6C

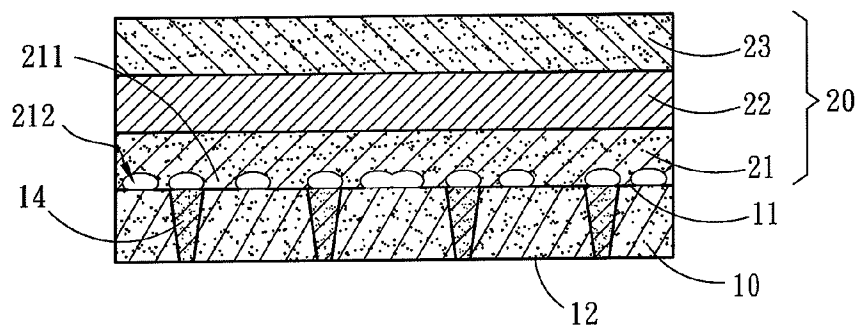


Fig. 6D

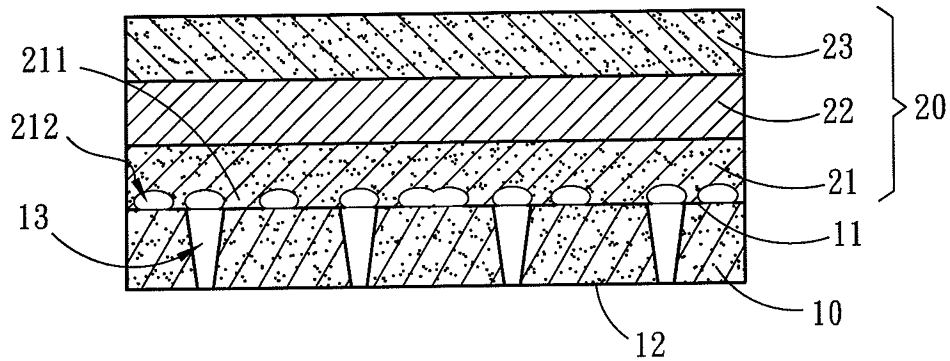


Fig. 6E

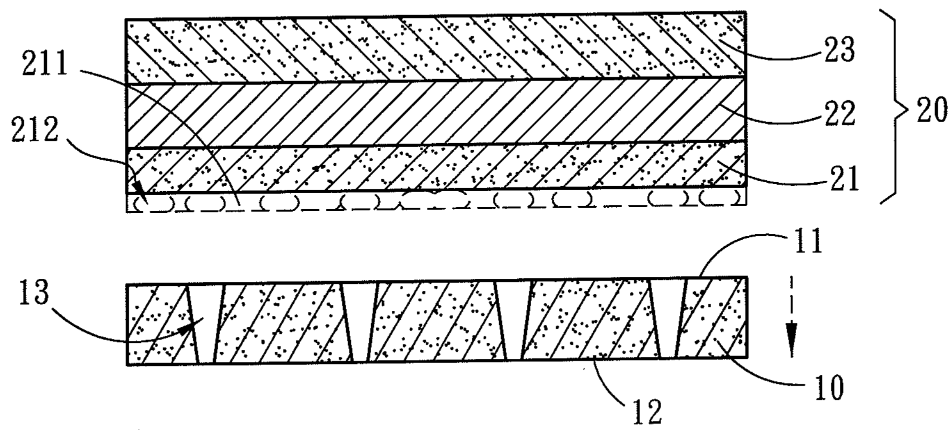


Fig. 6F

METHOD FOR SEPARATING LIGHT-EMITTING DIODE FROM A SUBSTRATE

FIELD OF THE INVENTION

[0001] The present invention relates to a method for manufacturing a light-emitting diode (LED), and particularly to a method for separating an LED from a substrate.

BACKGROUND OF THE INVENTION

[0002] A light-emitting diode (LED) is principally formed by a multiple epitaxy structure of a light-emitting semiconductor material. For example, a blue LED is chiefly formed by a gallium nitride based (GaN-based) epitaxy film, which is internally a PN structure with one-directional electrical conductivity.

[0003] The above-mentioned blue LED usually adopts a sapphire substrate to grow a high-quality GaN-based epitaxy film thereon; however, a sapphire substrate has poor thermal and electrical conductivities. Therefore, conventional blue LED can only adopt a lateral structure having positive and negative electrodes located at a same side of the substrate. Thus, a light-emitting area of the LED element is decreased, and the resistance and forward voltage drop are increased due to a current crowding effect.

[0004] Please refer to FIGS. **1**A and **1**B for the schematic diagrams of a conventional LED element before and removing a sapphire substrate respectively. To improve the foregoing defects, a method used nowadays for manufacturing a high-performance LED element is to first grow a GaN-based epitaxy film **2** on a sapphire substrate **1**. A binding layer **3** is then grown on the epitaxy film **2**, and a new substrate **4** is formed on the binding layer **3**. By laser lift-off or chemical mechanical polishing, the sapphire substrate **1** is further removed to allow the GaN-based epitaxy film **2** to remain on the new substrate **4**. The new substrate **4** has a high heat dissipation coefficient and good electricity conductivity and is therefore more adaptable to high driving current applications, thereby solving issues such as heat dissipation under a high lumen flux of an LED element.

[0005] However, in the above-mentioned method of removing the sapphire substrate, the laser lift-off process is costly and produces stress which is difficult to control and may cause fragmentation. Moreover, the chemical mechanical polishing process may cause problems such as low polishing accuracy, difficulty in controlling a polishing range, and over-polishing or under-polishing.

SUMMARY OF THE INVENTION

[0006] Therefore the primary object of the present invention is to solve the issues of high costs and difficulty in control of a conventional method for separating an LED element from a substrate.

[0007] To achieve the above object, the invention provides a method for separating an LED from a substrate. The method includes:

[0008] Step S**1**: providing a substrate, the substrate including a junction surface and a bottom surface far away from the junction surface.

[0009] Step S**2**: forming a plurality of holes on the junction surface.

[0010] Step S**3**: growing an LED structure on the junction surface the LED structure including a junction portion bonded to the junction surface.

[0011] Step S**4**: polishing the bottom surface to make the bottom surface to be shrunk to communicate with the holes.

[0012] Step S**5**: etching the junction portion by an etching liquid through the holes to separate the LED structure from the substrate.

[0013] Accordingly, by forming the holes and polishing the bottom surface to communicate with the holes, the junction portion can be etched by the etching liquid through the holes to separate the LED structure from the substrate. Thus it is easy to control the polishing process to provide a high yield rate as well as reduced production costs.

[0014] The foregoing, as well as additional objects, features and advantages of the invention will be more readily apparent from the following detailed description, which proceeds with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] FIG. **1**A is a schematic diagram of a conventional LED element before removing a sapphire substrate.

[0016] FIG. **1**B is a schematic diagram of a conventional LED element after removing a sapphire substrate.

[0017] FIG. **2** is a flowchart showing the steps of a method for separating an LED structure from a substrate according to a first embodiment of the present invention.

[0018] FIG. **3**A to **3**D are schematic diagrams of the manufacturing processes of a method for separating an LED structure from a growth substrate according to the first embodiment of the present invention.

[0019] FIG. **4** is a flowchart showing the steps of a method for separating an LED structure from a substrate according to a second embodiment of the present invention.

[0020] FIGS. **5**A to **5**F are schematic diagrams of the manufacturing processes of a method for separating an LED structure from a growth substrate according to the second embodiment of the present invention.

[0021] FIGS. **6**A to **6**F are schematic diagrams of the manufacturing processes according to a third embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0022] Please refer to FIG. **2** for a flowchart showing the steps of a method for separating an LED from a growth substrate according to first embodiment of the present invention and to FIGS. **3**A to **3**D for schematic diagrams of the manufacturing processes of a method for separating an LED from a growth substrate according to the first embodiment. The method for separating an LED from a substrate **10** includes the following steps.

[0023] Referring to FIG. **3**A, in Step S**1** and Step S**2**, a substrate **10** is first provided. The substrate **10** includes a junction surface **11** and a bottom surface **12** far away from the junction surface. A plurality of holes **13** are then formed on the junction surface by etching. In this embodiment, the substrate **10** is a sapphire substrate. The holes **13** are formed at a height between 10 and 50 μm and a width between 2 and 6 μm. The width of the holes **13** gradually decreases from the junction surface **11** towards the bottom surface **12** because of etching while the holes **13** do not penetrating the substrate **10**.

[0024] Referring to FIG. **3**B, in Step S**3**, an LED structure **20** is grown on the junction surface **11**, and a junction portion **211** on the LED structure **20** bonds to the junction surface **11**. In this embodiment, the LED structure **20** includes a light-emitting epitaxy layer **21**, an intermediate layer **22** bonded to the light-emitting epitaxy layer **21**, and a support substrate **23** bonded to the intermediate layer **22**. In this embodiment, the light-emitting epitaxy layer **21** is made of gallium nitride as example while it can also be made of a gallium nitride based material such as indium gallium nitride and aluminum gallium nitride. The junction portion **211** is a part of the light-emitting epitaxy layer **21**, and is bonded to the junction surface **11**. The intermediate layer **22** may be a binding layer or a combination of a binding layer with a reflecting layer and a stress releasing layer.

[0025] Referring to FIG. **3**C, in Step S**4**, the bottom surface **12** is polished by chemical mechanical polishing such that the bottom surface **12** gradually moves towards the junction surface **11** to communicate with the holes **13**. It should be noted that, since the purpose of polishing the bottom surface **12** is to make the bottom surface communicate **12** with the holes **13** thus, the height of the holes **13** can be controlled to accord with the polishing accuracy of the chemical mechanical polishing process in order to maintain simple operations without over demanding polishing accuracy.

[0026] Referring to FIG. **3**D, in Step S**5**, an etching liquid is guided to the junction portion **211** through the holes **13** to perform an etching process to separate the LED structure **20** from the substrate **10**. In this embodiment, the etching liquid is a gallium nitride etching liquid such as potassium hydroxide or sodium hydroxide. The etching liquid seeps into the LED structure **20** via the holes **13** to etch the junction portion **211**. After the junction portion **211** is etched, the LED structure **20** is separated from the substrate **10**.

[0027] Please refer to FIG. **4** for a flowchart showing the steps of a method for separating an LED structure from a growth substrate according to a second embodiment of the present invention and to FIGS. **5**A to **5**F for schematic diagrams of the manufacturing processes of a method for separating an LED structure from a growth substrate according to the second embodiment. Compared with the first embodiment, the second embodiment further includes a Step S**2***a* after Step S**2**. In Step S**2***a*, the holes **13** are filled with growth assistants **14**. In this embodiment the growth assistants **14** are silicon dioxide for example; however, this is not the limitation as the growth assistants **14** can also be selected from amorphous aluminum oxide, silicon nitride and aluminum nitride. A main purpose of Step S**2***a* is to provide the junction surface **11** with preferred evenness when growing the LED structure **20** thereon since the holes **13** at the junction surface **11** are filled by the growth assistants **14**. Hence, the quality of the light-emitting epitaxy layer **21** of the LED structure **20** is increased to give higher light-emitting efficiency. Furthermore, since the holes **13** are filled by the growth assistants **14** in Step S**2***a*, a Step S**5***a* is needed before Step S**5**. In Step S**5***a*, the growth assistants **14** in the holes **13** are etched by an auxiliary etching liquid. The auxiliary etching liquid is applied to etch the growth assistants **14** in the holes **13** such that the holes **13** can communicate with the LED structure **20**. Taking silicon dioxide as the growth assistants **14** for example, the auxiliary etching liquid may be a hydrofluoric acid solution. Accordingly, in Step S**5**, the junction portion **211** can be etched by the etching liquid.

[0028] Please refer to FIGS. **6**A to **6**F for schematic diagrams of the manufacturing processes according to a third embodiment of the present invention. Compared with the second embodiment, in Step S**3** of the third embodiment, a plurality of pores **212** are formed in the junction portion **211** at the time the junction portion **211** is formed. More specifically, when growing the LED structure **20**, the light-emitting epitaxy layer **21** is grown by metal organic chemical vapor deposition (MOCVD). By modulating manufacturing parameters such as changing the temperature, pressure and doping concentration, the junction portion **211** with the pores **212** is first formed on the junction surface **11**, and then a light-emitting body of the light-emitting epitaxy layer **21** is formed on the junction portion **211**. It should be noted that, a main purpose of forming the pores **212** is to increase a contact area between the etching liquid and the junction portion **211** when the junction portion **211** is etched in Step S**5** thus to also increase the etching speed of the etching liquid so that the LED structure **20** can be more easily separated from the substrate **10**.

[0029] In the method of the present invention, by forming the holes and polishing the bottom surface to communicate with the holes, the junction portion can be etched by the etching liquid through the holes to separate the LED structure from the substrate. Therefore it is easy to control the polishing process to provide a high yield rate as well as reduced production costs. Moreover, the growth assistants are filled into the holes in advance to further enhance the epitaxy quality of the LED structure. Furthermore, the pores are formed in the junction portion by modulating the manufacturing parameters to assist the LED structure to separate from the substrate.

[0030] While the preferred embodiments of the invention have been set forth for the purpose of disclosure, modifications of the disclosed embodiments of the invention as well as other embodiments thereof may occur to those skilled in the art. Accordingly, the appended claims are intended to cover all embodiments which do not depart from the spirit and scope of the invention.

What is claimed is:

1. A method for separating a light-emitting diode (LED) from a substrate, comprising the steps of:

S**1**) providing a substrate, the substrate comprising a junction surface and a bottom surface far away from the junction surface;

S**2**) forming a plurality of holes on the junction surface;

S**3**) growing an LED structure on the junction surface, the LED structure including a junction portion bonded to the junction surface;

S**4**) polishing the bottom surface to make the bottom surface be shrunk to communicate with the plurality of holes; and

S**5**) etching the junction portion by an etching liquid through the plurality of holes to separate the LED structure from the substrate.

2. The method of claim **1**, after step S**2**, further comprising a step of:

S**2***a*) filling the plurality of holes with growth assistants; and before step S**5**, further comprising a step of:

S**5***a*) etching the growth assistants in the plurality of holes by an auxiliary etching liquid.

3. The method of claim **2**, wherein the growth assistants are made of a material selected from a group consisting of silicon dioxide, amorphous aluminum oxide, silicon nitride and aluminum nitride.

4. The method of claim **2**, wherein step S**3** further comprise a step of: forming a plurality of pores in the junction portion at the same time that the junction portion is formed.

5. The method of claim **4**, wherein the plurality of pores are formed by metal organic chemical vapor deposition.

6. The method of claim **1**, wherein the substrate is a sapphire substrate.

7. The method of claim **1**, wherein the LED structure comprises a light-emitting epitaxy layer which is made of a material selected from the group consisting of gallium nitride, indium gallium nitride and aluminum gallium nitride.

8. The method of claim **1**, wherein the plurality of holes are formed at a height between 10 and 50 μm and a width between 2 and 6 μm.

* * * * *