US 20130130417A1

(19) United States

(12) Patent Application Publication

WU et al.

(10) Pub. No.: US 2013/0130417 A1

(43) Pub. Date: May 23, 2013

(54) MANUFACTURING METHOD OF A LIGHT-EMITTING DEVICE

(76) Inventors: **Jar-Yu WU**, Kaohsiung City (TW); **Biau-Dar Chen**, Tainan City (TW); **Chun-Lung Tseng**, Kaohsiung City (TW); **Chih-Hung Wang**, Tainan City (TW); **Hung-Yao Lin**, Tainan City (TW)

(21) Appl. No.: **13/302,462**

(22) Filed: **Nov. 22, 2011**

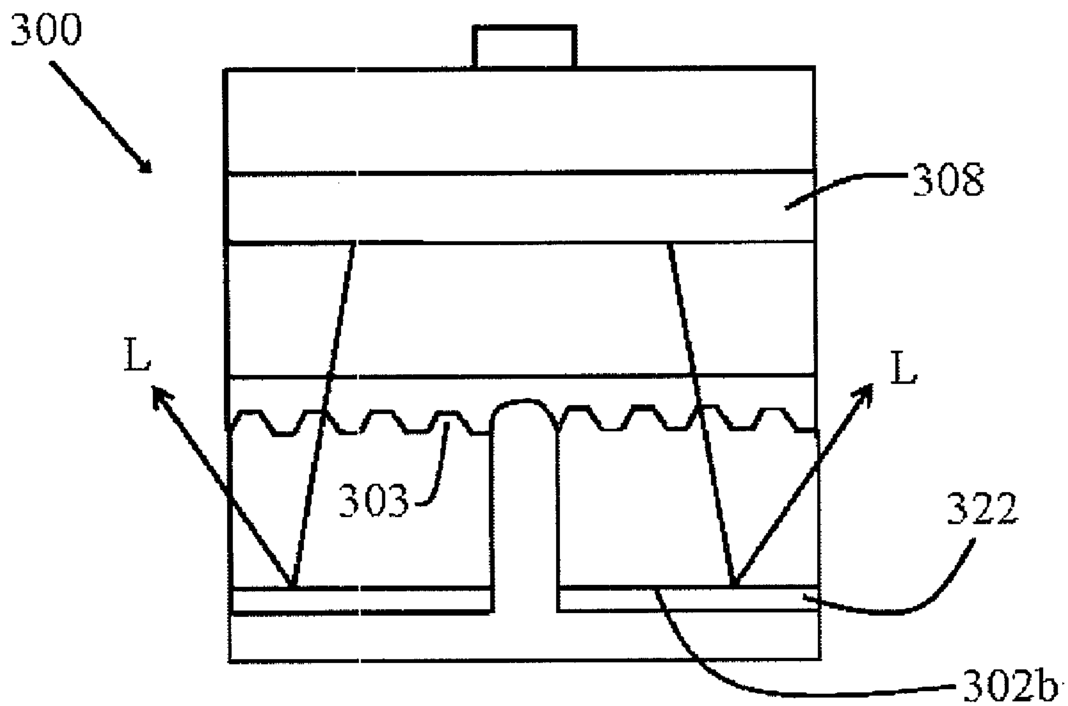
Publication Classification

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

(52) **U.S. Cl.**
USPC **438/22**; 257/E33.066

(57) **ABSTRACT**

A method for manufacturing a light-emitting device includes steps of: providing a substrate comprising an upper surface and a lower surface opposite to the upper surface; processing the upper surface to be an uneven surface; forming a light-emitting structure on the upper surface of the substrate; and forming a hole through the substrate by radiating a coherent laser beam to the lower surface of the substrate for a predetermined time; wherein the band gap energy of the coherent laser beam is higher than the band gap energy of the substrate thereby the substrate is etched away by the laser beam.



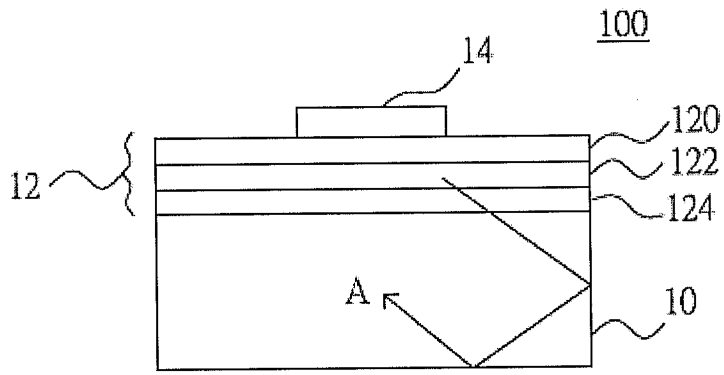


FIG.1
(Related Art)

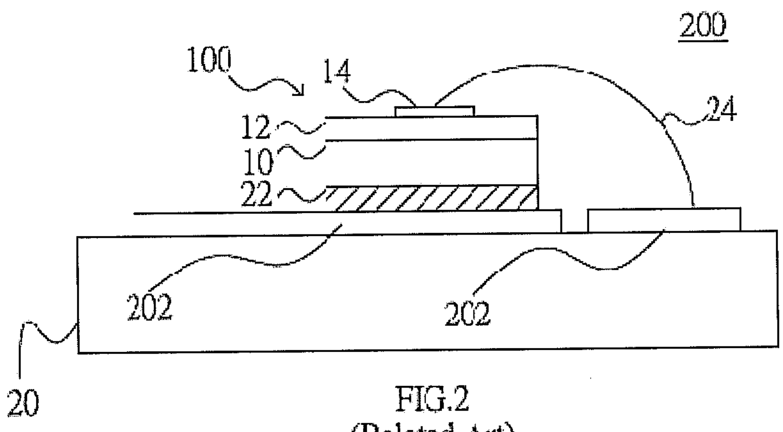


FIG.2
(Related Art)

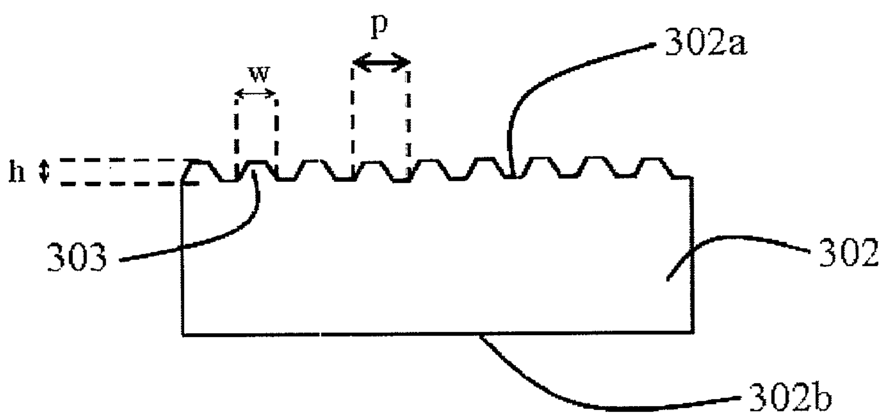


FIG. 3A

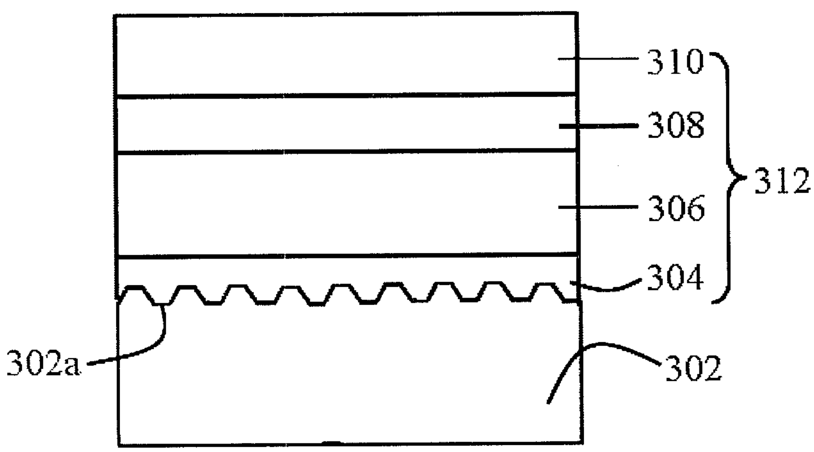


FIG. 3B

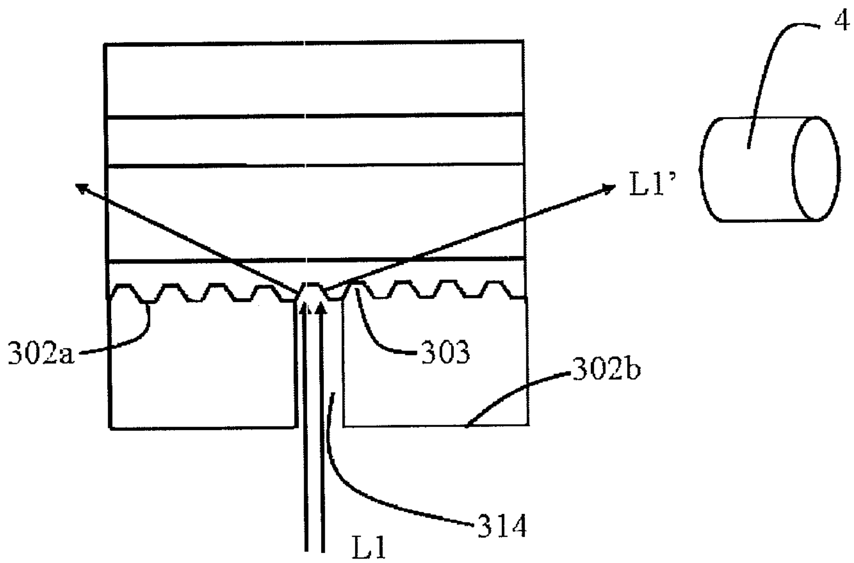


FIG. 3C

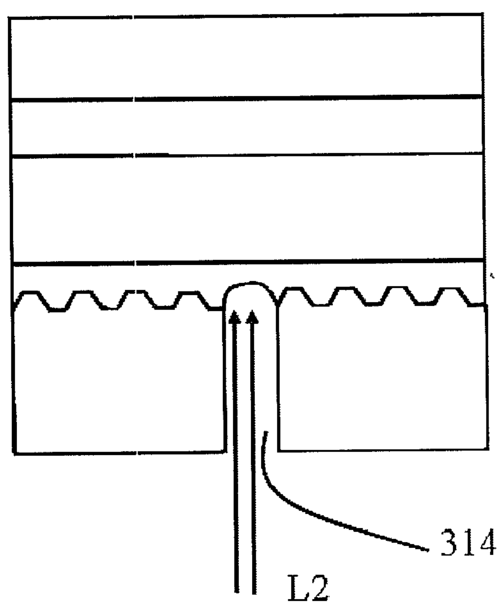


FIG. 3D

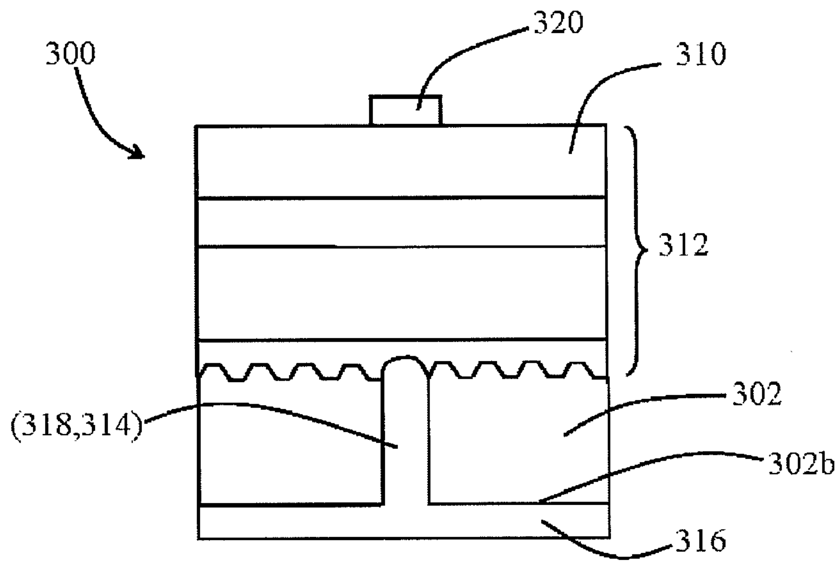


FIG. 3E

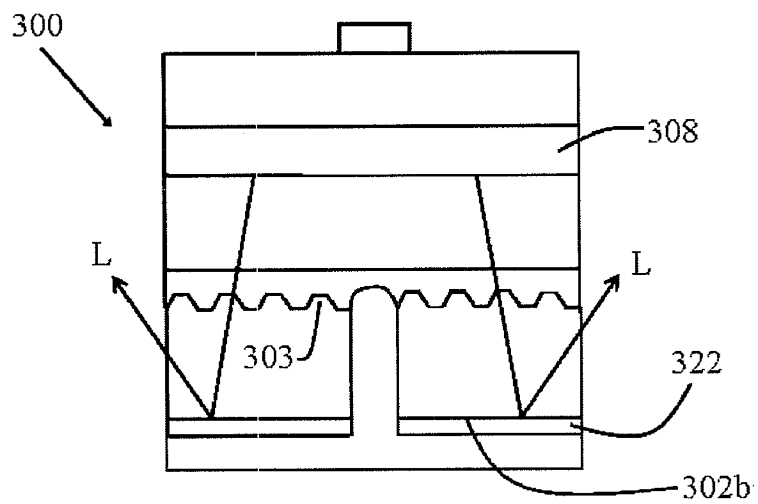


FIG. 4

MANUFACTURING METHOD OF A LIGHT-EMITTING DEVICE

TECHNICAL FIELD

[0001] The application relates to a manufacturing method of a light-emitting device.

DESCRIPTION OF BACKGROUND ART

[0002] The light radiation theory of light emitting diode (LED) is to generate light from the energy released by the electron moving between an n-type semiconductor and a p-type semiconductor. Because the light radiation theory of LED is different from the incandescent light which heats the filament, the LED is called a "cold" light source. Moreover, the LED is more sustainable, longevous, light and handy, and less power-consumption, therefore it is considered as another option of the light source for the illumination markets. The LED applies to various applications like the traffic signal, backlight module, street light, and medical instruments, and is gradually replacing the traditional lighting sources.

[0003] FIG. **1** illustrates the structure of a conventional light emitting device **100** which includes a transparent substrate **10**, a semiconductor stack **12** formed above the transparent substrate **10**, and an electrode **14** formed above the semiconductor stack **12**, wherein the semiconductor stack **12** comprises, from the top, a first conductive-type semiconductor layer **120**, an active layer **122**, and a second conductive-type semiconductor layer **124**.

[0004] In addition, the light emitting device **100** can be further connected to other components in order to form a light emitting apparatus. FIG. **2** illustrates a conventional light emitting apparatus including a sub-mount **20** carrying an electrical circuit **202**, a solder **22** formed above the sub-mount **20**; wherein the light emitting device **100** is bonded to the sub-mount **20** and is electrically connected with the electrical circuit **202** on the sub-mount **20** by the solder **22**, and an electric connection structure **24** that electrically connects the electrode **14** of the light emitting device **100** to the electrical circuit **202** on the sub-mount **20**. The sub-mount **20** may be a lead frame or a large size mounting substrate in order to facilitate circuit design and enhance heat dissipation.

[0005] Nevertheless, because the surface of the transparent substrate **10** of the conventional light emitting device **100** as shown in FIG. **1** is substantially flat and the refractive index of the transparent substrate **10** is different from the refractive index of the external environment, the total internal reflection (TIR) occurs when a light A emitted from the active layer **122**. Therefore the light extraction efficiency from the light emitting device **100** is reduced drastically.

SUMMARY OF THE DISCLOSURE

[0006] A method for manufacturing a light-emitting device includes steps of: providing a substrate comprising an upper surface and a lower surface opposite to the upper surface; processing the upper surface to be an uneven surface; forming a light-emitting structure on the upper surface of the substrate; and forming a hole through the substrate by radiating a coherent laser beam to the lower surface of the substrate for a predetermined time; wherein the band gap energy of the coherent laser beam is higher than the band gap energy of the substrate thereby the substrate is etched away by the laser beam.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. **1** illustrates the structure of a conventional light emitting device.

[0008] FIG. **2** illustrates the structure of a conventional light emitting apparatus.

[0009] FIGS. **3**A to **3**E show a method for manufacturing a light-emitting device of a first embodiment of the present application.

[0010] FIG. **4** is a cross-sectional view of a light-emitting device of a second embodiment of the present application.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0011] As shown in FIGS. **3**A to **3**E, a method for manufacturing a light-emitting device of a first embodiment of the present application is disclosed. Referring to FIG. **3**A, a substrate **302** having an upper surface **302*a*** and a lower surface **302*b*** opposite to the upper surface **302*a*** is provided, and then the upper surface **302*a*** is patterned by such as ICP process to be an uneven surface. The uneven surface can include a periodic pattern having a plurality of pattern units **303** having a pitch p and a raised portion **303*a***. The width w of the raised portions **303*a*** is about 2 μm, and the height h of the raised portion **303*a*** is about 1.5 μm. The material of the substrate **302** includes conductive material such as Si, SiC, GaAs, or GaP, or insulating material such as sapphire, glass, or diamond. In the embodiment, the substrate **302** is preferably insulative and has a monocrystalline structure, such as sapphire.

[0012] Referring to FIG. **3**B, a light-emitting structure **312** is formed by sequentially forming a buffer layer **304**, a first semiconductor layer **306**, an active layer **308**, and a second semiconductor layer **310** on the upper surface **302*a*** of the substrate **302**. Each of the first semiconductor layer **306**, active layer **308**, and second semiconductor layer **310** can be formed in an MOCVD chamber and composed of materials such as the series of aluminum gallium indium phosphide (AlGaInP), the series of aluminum gallium indium nitride (AlGaInN), and/or the series of zinc oxide (ZnO). The active layer **308** can be configured to be a single heterostructure (SH), a double heterostructure (DH), a double-side double heterostructure (DDH), or a multi-quantum well (MQW) structure.

[0013] Referring to FIG. **3**C, radiating a first coherent laser beam L_1 to the lower surface **302*b*** of the substrate **302** for a predetermined time to form a hole **314** through the substrate **302**. The band gap energy of the first coherent laser beam L_1 is higher than the band gap energy of the substrate **302** thereby a portion of the substrate **302** is removed away by the coherent laser beam L_1. A portion of the substrate **302** is etched by the first coherent laser beam L_1 until the first coherent laser beam L_1 reaches the upper surface **302*a***. A part of the first coherent laser beam L_1 becomes a non-coherent laser light L_1' by being deflected from the direction of the first coherent laser beam L_1 during a predetermined time, and a photo-detector **4** can detect the intensity of the non-coherent laser light L_1' to communicate to a controller (not shown) to stop radiating the coherent laser beam L_1 when the intensity of the non-coherent laser light L_1' is detected. Mostly, the intensity of the non-coherent laser light can be detected when the first coherent laser beam reaches the uneven surface. The pitch p of each of the pattern units **303** can be equal to the wavelength of the coherent laser beam L_1, or the pitch p is smaller than the wavelength of the coherent laser beam L_1. The distance d between two adjacent pattern units **303** is smaller than the wavelength of the laser beam L_1.

[0014] Referring to FIG. **3**D, radiating a second coherent laser beam L_2 for cleaning the byproducts (not shown) inside the hole **314**.

[0015] Referring to FIG. **3**E, a conductive structure **318** is formed in the hole **314** and electrically connected to the light-emitting structure **312**, and a first contact **316** is formed on the lower surface **302***b* and electrically connected to the conductive structure **318**. In another embodiment, the conductive structure **318** and the first contact **316** can also form a monolithic structure by deposition, electrical plating, or chemical plating. The conductive structure **318** can fill the hole **314** for better electrical contact between the light-emitting structure **312** and the first contact **316**. Further, a second contact **320** can be formed on the second semiconductor layer **310** of the light-emitting structure **312**. The first contact **316** and the second contact **320** are for electrically connecting to an external device such as a submount or a package unit.

[0016] As shown in FIG. **4**, a light-emitting device **300** of a second embodiment of the present application is shown. The primary difference between the present embodiment and the first embodiment is that a reflective layer **322** is formed between the lower surface **302***b* and the contact **316** to reflect the emitted-light L from the active layer **308** to enhance the light extraction of the light-emitting device **300**. Most of the emitted-light L passes through the upper surface **302***a* of the substrate **302** to reach the reflective layer **322**.

[0017] 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 for manufacturing a light-emitting device comprising steps of:

providing a substrate comprising an upper surface and a lower surface opposite to the upper surface;

processing the upper surface to be an uneven surface;

forming a light-emitting structure on the upper surface of the substrate; and

forming a hole through the substrate by radiating a first coherent laser beam to the lower surface of the substrate for a predetermined time;

wherein the band gap energy of the coherent laser beam is higher than the band gap energy of the substrate thereby a portion of the substrate is etched away by the first coherent laser beam.

2. The method according to claim **1**, further comprising forming a conductive structure in the hole and electrically connected to the light-emitting structure, and forming a first contact on the lower surface of the substrate and electrically connected to the conductive structure after forming the hole.

3. The method according to claim **1**, wherein a part of the first coherent laser beam becomes a non-coherent laser light during the predetermined time by being deflected from the direction of the first coherent laser beam.

4. The method according to claim **1**, further comprising detecting the intensity of the non-coherent laser light by a photo-detector.

5. The method according to claim **4**, further comprising stopping radiating the first coherent laser beam when the intensity of the non-coherent laser light is detected.

6. The method according to claim **5**, wherein the intensity of the non-coherent laser light is detected when the first coherent laser beam reaches the uneven surface.

7. The method according to claim **1**, wherein the uneven surface comprises a periodic pattern having plurality of pattern units having a pitch.

8. The method according to claim **7**, wherein the pitch is the same as the wavelength of the coherent laser beam.

9. The method according to claim **7**, wherein the pitch is smaller than the wavelength of the coherent laser beam.

10. The method according to claim **7**, wherein the distance between two adjacent pattern units is smaller than the wavelength of the laser beam.

11. The method according to claim **5**, further comprising cleaning the hole by a second coherent laser beam after stopping radiating the coherent laser beam.

12. The method according to claim **1**, wherein the step of forming the light-emitting structure comprising steps of forming a buffer layer on the uneven surface of the substrate, forming a first semiconductor layer on the buffer layer, forming an active layer on the first semiconductor layer, and forming a second semiconductor layer on the active layer.

13. The method according to claim **1**, further comprising forming a reflective layer on the lower surface of the substrate.

14. The method according to claim **1**, wherein the method is performed in an MOCVD chamber.

* * * * *