US 20130146837A1

(19) **United States**

(12) **Patent Application Publication**

SHEN et al.

(10) **Pub. No.: US 2013/0146837 A1**

(43) **Pub. Date: Jun. 13, 2013**

(54) **LIGHT EMITTING DIODE WITH MULTIPLE TRANSPARENT CONDUCTIVE LAYERS AND METHOD FOR MANUFACTURING THE SAME**

(75) Inventors: **CHIA-HUI SHEN**, Hukou (TW); **TZU-CHIEN HUNG**, Hukou (TW)

(73) Assignee: **ADVANCED OPTOELECTRONIC TECHNOLOGY, INC.**, Hsinchu Hsien (TW)

(21) Appl. No.: **13/563,756**

(22) Filed: **Aug. 1, 2012**

(30) **Foreign Application Priority Data**

Dec. 12, 2011 (CN) 201110411758.0

Publication Classification

(51) **Int. Cl.**

H01L 33/42 (2010.01)

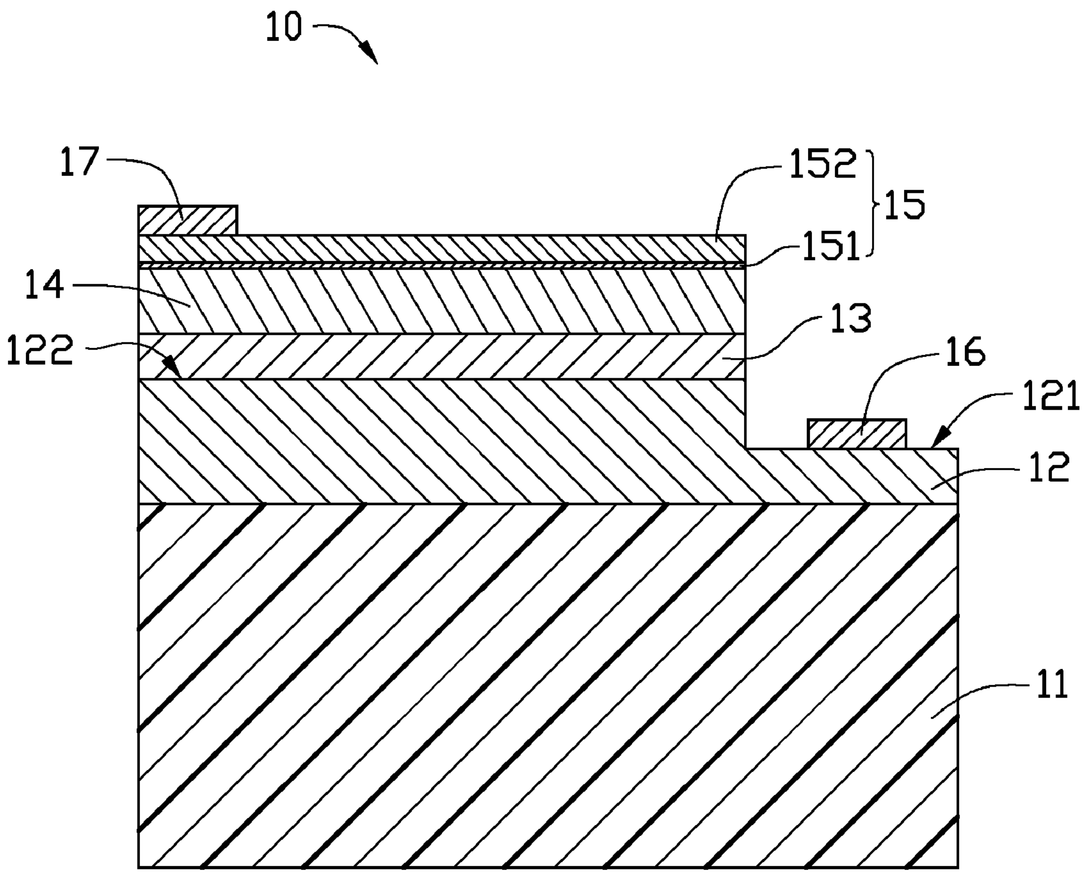
H01L 33/06 (2010.01)

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

USPC **257/13**; 438/22; 257/E33.064

(57) **ABSTRACT**

An LED includes a first semiconductor layer, a second semiconductor layer, an active layer, a first transparent conductive layer, and a second transparent conductive layer. The first transparent conductive layer is formed on the second semiconductor layer. The second transparent conductive layer is formed on the first transparent conductive layer. The thickness of the first transparent conductive layer is less than that of the second transparent conductive layer. The density of the first transparent conductive layer is larger than that of the second transparent conductive layer. The disclosure further includes a method for manufacturing the LED.



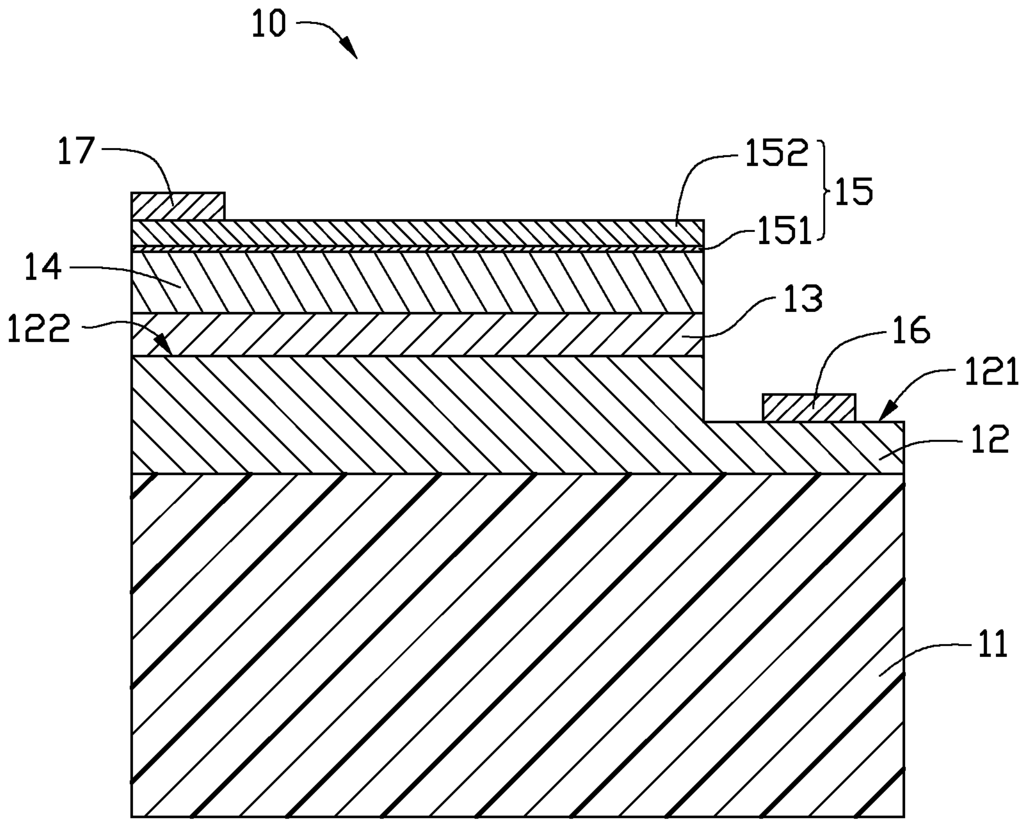


FIG. 1

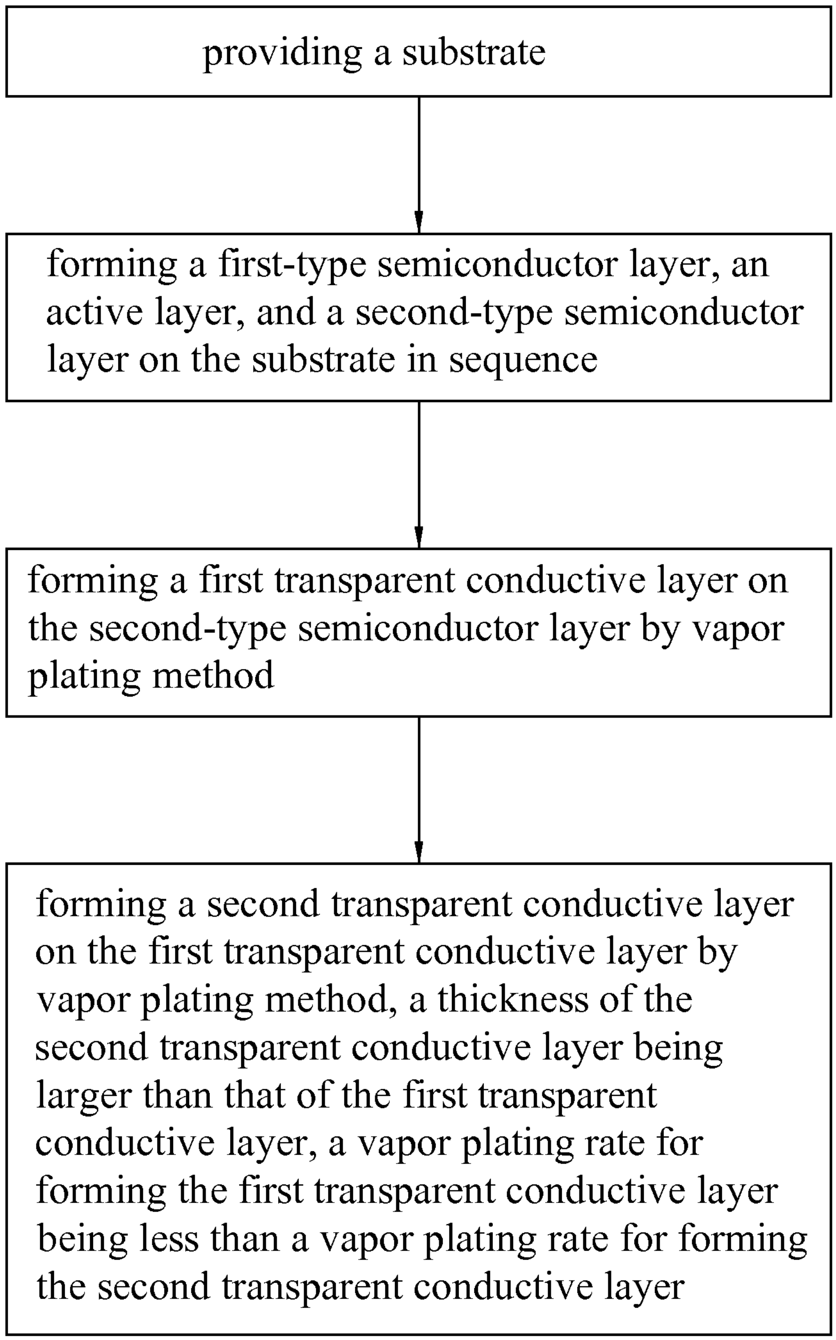

providing a substrate
forming a first-type semiconductor layer, an active layer, and a second-type semiconductor layer on the substrate in sequence
forming a first transparent conductive layer on the second-type semiconductor layer by vapor plating method
forming a second transparent conductive layer on the first transparent conductive layer by vapor plating method, a thickness of the second transparent conductive layer being larger than that of the first transparent conductive layer, a vapor plating rate for forming the first transparent conductive layer being less than a vapor plating rate for forming the second transparent conductive layer

FIG. 2

LIGHT EMITTING DIODE WITH MULTIPLE TRANSPARENT CONDUCTIVE LAYERS AND METHOD FOR MANUFACTURING THE SAME

BACKGROUND

[0001] 1. Technical Field

[0002] The disclosure relates to light emitting diodes, and particularly to a light emitting diode with multiple transparent conductive layers and a method for manufacturing the light emitting diode.

[0003] 2. Description of the Related Art

[0004] A conventional light emitting diode (LED) includes a substrate, a light emitting structure having an N-type semiconductor layer, an active layer and a P-type semiconductor layer formed on the substrate in sequence, and two electrodes (i.e., N-type and P-type electrodes) respectively connected to the N-type and P-type semiconductor layers. To obtain an even current distribution in the semiconductor layers while do not lower the light extraction efficiency, a transparent conductive layer which is made of indium tin oxide (ITO) is formed on the light emitting structure.

[0005] The transparent conductive layer is required to have a relatively high electrical property and a relatively short manufacturing time. The electrical property of the transparent conductive layer varies along with different parameters for forming the transparent conductive layer. The higher the density of the transparent conductive layer is, the better the electrical property but the longer the manufacturing time of the transparent conductive layer is required. In contrast, the lower the density of the transparent conductive layer is, the shorter the manufacturing time required, but the poorer the electrical property of the transparent conductive layer is.

[0006] Therefore, it is desirable to provide a light emitting diode and a method for manufacturing a light emitting diode with both good electrical property and relatively short manufacturing time.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] Many aspects of the disclosure can be better understood with reference to the drawings. The components in the drawings are not necessarily drawn to scale, the emphasis instead being placed upon clearly illustrating the principles of the present light emitting diode and a method for manufacturing the light emitting diode. Moreover, in the drawings, like reference numerals designate corresponding parts throughout the views.

[0008] FIG. **1** is a cross-sectional view of a light emitting diode in accordance with one embodiment of the present disclosure.

[0009] FIG. **2** is a flow chart showing steps of a method for manufacturing the light emitting diode of FIG. **1**.

DETAILED DESCRIPTION

[0010] Referring to FIG. **1**, a light emitting diode **10** in accordance with one embodiment is provided. The light emitting diode **10** includes a substrate **11**, a light emitting structure, a transparent conductive layer **15** formed on the light emitting structure, a first electrode **16**, and a second electrode **17** having an opposite polarity with respect to the first electrode **16**. In this embodiment, the light emitting structure includes a first-type semiconductor layer **12**, an active layer **13** and a second-type semiconductor layer **14**. The transparent conductive layer **15** is transparent to light and conductive to electricity. When a bias is applied to the first and second electrodes **16**, **17**, electron holes and electrons flow from the first-type semiconductor layer **12** and the second-type semiconductor layer **14** to recombine at the active layer **13**, whereby light is emitted from the active layer **13**.

[0011] The substrate **11** is dielectric. The substrate **11** can be sapphire (α-Al_2O_3) substrate, silicon carbide (SiC) substrate, etc.

[0012] The first-type semiconductor layer **12**, the active layer **13**, the second-type semiconductor layer **14**, and the transparent conductive layer **15** are formed on the substrate **11** in sequence from bottom to top. In other words, the first-type semiconductor layer **12** is formed on the substrate **11** directly. The active layer **13** is sandwiched between the first-type semiconductor layer **12** and the second-type semiconductor layer **14**. The first-type semiconductor layer **12**, the active layer **13** and the second-type semiconductor layer **14** can be made of III-V or II-VI compound semiconductors. The first-type semiconductor layer **12** and the second-type semiconductor layer **14** are doped with different materials. In this embodiment, the first-type semiconductor layer **12** is N-type doped, and the second-type semiconductor layer **14** is P-type doped. In alternative embodiment, the first-type semiconductor layer **12** can be P-type doped, and the second-type semiconductor layer **14** can be N-type doped.

[0013] The first-type semiconductor layer **12** includes an exposed first area **121** and a covered second area **122** both far away from the substrate **11**. The exposed first area **121** of the first-type semiconductor layer **12** is formed by inductively coupled plasma dry etching. The first area **121** is positioned at a lateral end of the first-type semiconductor **12** and is uncovered by the active layer **13** and the second-type semiconductor layer **14**. The second area **122** is covered by the active layer **13** and the second-type semiconductor layer **14**.

[0014] The active layer **13** can be a single quantum well (SQW) structure or a multiple quantum well (MQW) structure.

[0015] The transparent conductive layer **15** is formed on the second-semiconductor layer **14** by vapor plating method. The transparent conductive layer **15** includes a first transparent conductive layer **151** and a second transparent conductive layer **152**. The first and second transparent conductive layers **151**, **152** are both made of ITO and accordingly are both ITO layers. The first transparent conductive layer **151** is directly grown on the second-type semiconductor layer **14**, and the second transparent conductive layer **152** is grown on the first transparent conductive layer **151**. A thickness of the first transparent conductive layer **151** is less than that of the second transparent conductive layer **152**. The thickness of the first transparent conductive layer **151** is less than 600 angstroms. The thickness of the second transparent conductive layer **152** ranges from 1000 angstroms to 5000 angstroms. Vapor plating parameters for forming the first transparent conductive layer **151** and the second transparent conductive layer **152** are different. The density of the first transparent conductive layer **151** is larger than that of the second transparent conductive layer **152**.

[0016] The first electrode **16** is formed on the first area **121** of the first-type semiconductor layer **12**. The second electrode **17** is formed on the second transparent conductive layer **152**. The first electrode **16** has a same polarity as the first-type semiconductor layer **12**, and the second electrode **17** has a same polarity as the second-type semiconductor layer **14**.

[0017] FIG. 2 shows a flow chart of a method for manufacturing the light emitting diode **10**. The method for manufacturing the light emitting diode **10** includes the following steps.

[0018] Firstly, the substrate **11** is provided.

[0019] Secondly, the first-type semiconductor layer **12**, the active layer **13**, and the second-type semiconductor layer **14** are successively formed on the substrate **11**. In this embodiment, the first-type semiconductor layer **12**, the active layer **13**, and the second-type semiconductor layer **14** can be successively formed on a sapphire substrate or a GaN substrate through a Metal Organic Chemical Vapor Deposition (MOCVD) equipment.

[0020] Thirdly, the first transparent conductive layer **151** is formed on the second-type semiconductor layer **14** by vapor plating method. The first transparent conductive layer **151** is formed by using a vapor plating rate less than 0.5 angstrom per second. The thickness of the first transparent conductive layer **151** is controlled in a range less than 600 angstroms. The lower the vapor plating rate for forming the first transparent conductive layer **151** is, the larger the density of the first transparent conductive layer **151**.

[0021] Fourthly, the second transparent conductive layer **152** is formed on the first transparent conductive layer **151** by vapor plating method. The second transparent conductive layer **152** is formed by using a vapor plating rate more than 0.5 angstrom per second. The thickness of the second transparent conductive layer **152** is more than 1000 angstroms and less than 5000 angstroms.

[0022] A step of forming the first electrode **16** on the first area **121** of the first-type semiconductor **12** and a step of forming the second electrode **17** on the second transparent conductive layer **152** can be further provided after the step of forming the transparent conductive layer **15**.

[0023] According to the disclosure, since the first transparent conductive layer **151** is formed with a relatively low vapor plating rate, the first transparent conductive layer **151** has an excellent electrical property. As such, the first transparent conductive layer **151** can be formed in ohmic contact with the second-type semiconductor layer **14** to drop a working voltage of the light emitting diode **10**. In addition, a relatively small thickness of the first transparent conductive layer **151** can reduce its manufacturing time as much as possible. Although the second transparent conductive layer **152** is formed with a relatively high vapor plating rate, the working voltage of the light emitting diode **10** will not be increased significantly, because the second transparent conductive layer **152** is formed in ohmic contact with the first transparent conductive layer **151**. Furthermore, although the second transparent conductive layer **152** has a relatively large thickness, the manufacturing time for forming the second transparent conductive layer **152** is still relatively short, because the second transparent conductive layer **152** is formed with a relatively high vapor plating rate. Therefore, the light emitting diode **10** can have good electrical property and relatively short manufacturing time.

[0024] It is to be understood that the above-described embodiments are intended to illustrate rather than limit the disclosure. Variations may be made to the embodiments without departing from the spirit of the disclosure as claimed. The above-described embodiments illustrate the scope of the disclosure but do not restrict the scope of the disclosure.

What is claimed is:

1. A light emitting diode, comprising:

a light emitting structure; and

a transparent conductive layer formed on the light emitting structure, the transparent conductive layer comprising a first transparent conductive layer on the light emitting structure and a second transparent conductive layer on the first transparent conductive layer;

wherein a thickness of the first transparent conductive layer is less than that of the second transparent conductive layer, and a density of the first transparent conductive layer is larger than that of the second transparent conductive layer.

2. The light emitting diode of claim **1**, wherein the thickness of the first transparent conductive layer is less than 600 angstroms.

3. The light emitting diode of claim **2**, wherein the thickness of the second transparent conductive layer ranges from 1000 angstroms to 5000 angstroms.

4. The light emitting diode of claim **1**, wherein the light emitting structure comprises a first-type semiconductor layer, an active layer formed on the first-type semiconductor layer, and a second-type semiconductor layer formed on the active layer.

5. The light emitting diode of claim **4**, further comprising a first electrode and a second electrode, wherein the first-type semiconductor layer comprises a first area and a second area, the first area being exposed outside, the second area being covered by the active layer, the first electrode is formed on the first area of the first-type semiconductor layer, and the second electrode is formed on the second transparent conductive layer.

6. The light emitting diode of claim **4**, further comprising a substrate, wherein the first-type semiconductor, the active layer, the second-type semiconductor, and the transparent conductive layer are formed on the substrate in sequence.

7. The light emitting diode of claim **4**, wherein the first-type semiconductor layer is an N-type semiconductor layer and the second-type semiconductor layer is a P-type semiconductor layer.

8. The light emitting diode of claim **4**, wherein the active layer is a single quantum well structure or a multiple quantum well structure.

9. The light emitting diode of claim **1**, wherein the transparent conductive layer is in ohmic contact with the second-type semiconductor layer.

10. A method for manufacturing a light emitting diode comprising steps:

providing a substrate;

forming a light emitting structure on the substrate;

forming a first transparent conductive layer on the light emitting structure by vapor plating method; and

forming a second transparent conductive layer on the first transparent conductive layer by vapor plating method, a thickness of the second transparent conductive layer being larger than that of the first transparent conductive layer, a vapor plating rate for forming the first transparent conductive layer being less than a vapor plating rate for forming the second transparent conductive layer.

11. The method for manufacturing a light emitting diode of claim **10**, wherein the first transparent conductive layer is formed by using a vapor plating rate less than 0.5 angstrom per second.

12. The method for manufacturing a light emitting diode of claim **11**, wherein a thickness of the first transparent conductive layer is less than 600 angstroms.

13. The method for manufacturing a light emitting diode of claim **10**, wherein the second transparent conductive layer is formed by using a vapor plating rate larger than 0.5 angstrom per second.

14. The method for manufacturing a light emitting diode of claim **13**, wherein a thickness of the second transparent conductive layer ranges from 1000 angstroms to 5000 angstroms.

15. The method for manufacturing a light emitting diode of claim **10**, wherein the light emitting structure comprises a first-type semiconductor layer, an active layer formed on the first-type semiconductor layer, and a second-type semiconductor layer formed on the active layer.

16. The method for manufacturing a light emitting diode of claim **15**, wherein the first-type semiconductor layer comprises a first area and a second area, the first area being exposed outside, and the second area being covered by the active layer.

17. The method for manufacturing a light emitting diode of claim **16**, further comprising a step of forming a first electrode on the first area of the first-type semiconductor and a step of forming a second electrode on the second transparent conductive layer after the step of forming the second transparent conductive layer.

18. The method for manufacturing a light emitting diode of claim **15**, wherein the first-type semiconductor layer is an N-type semiconductor layer and the second-type semiconductor layer is a P-type semiconductor layer.

* * * * *