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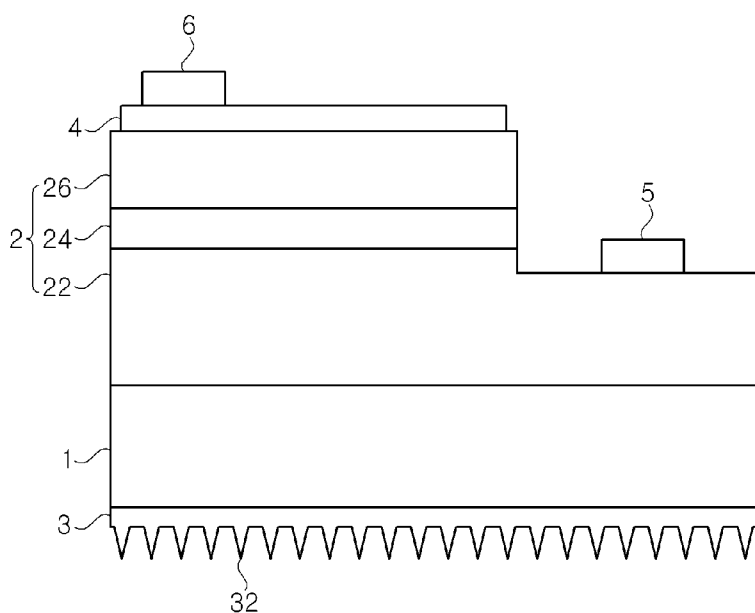
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(54) Title: LIGHT EMITTING DIODE AND METHOD FOR MANUFACTURING THE SAME



(57) Abstract: Disclosed is a light emitting diode (LED). The LED includes a transparent substrate having a first surface and a second surface; a GaN-based semiconductor-laminated structure including a first conductive semiconductor layer, an active layer and a second conductive semiconductor layer and formed on the first surface of the transparent substrate; and a refractive index control layer formed on the second surface of the transparent substrate and having a pattern on a lower surface thereof. With the refractive index control layer, loss of light generated in a lower surface of the transparent substrate can be reduced to improve light extraction efficiency.



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Description

Title of Invention: LIGHT EMITTING DIODE AND METHOD FOR MANUFACTURING THE SAME

Technical Field

- [1] The present invention relates to a light emitting diode and a method for manufacturing the same.

Background Art

- [2] In general, a light emitting diode (LED) is a semiconductor light emitting device that directly converts a current into light, using a principle that when a voltage is applied to a p-n junction of a semiconductor, electrons in an n-region meet and are recombined with holes in a p-region to emit light. This LED has superior energy conversion efficiency, long lifespan and superior directivity of light, can be driven at a low voltage, does not require a preheating time and a complicated driving circuit, and well resists impact and vibration. Hence, much attention is paid to the LED as a next-generation light source that would be substituted for existing light sources such as an incandescent electric lamp, a fluorescent lamp and a mercury lamp.
- [3] The improvement of the efficiency of the LED is made generally in two directions. The first is to improve internal quantum efficiency determined by crystalline and epitaxial layer structures. The second is to improve light extraction efficiency so that generated light can be maximally emitted to the outside of the LED. At this time, the light extraction efficiency is improved by developing a structure for facilitating heat emission or by minimizing internal light loss due to total internal reflection at an interlayer interface and the like. In order to minimize such internal light loss due to the total internal reflection at the interlayer interface, there has been known a method for decreasing the probability of total internal reflection at an interlayer interface by patterning the interlayer interface.
- [4] Usually, an LED includes a semiconductor-laminated structure formed on a sapphire substrate, and the semiconductor-laminated structure includes a first conductive semiconductor layer, an active layer and a second conductive semiconductor layer in order in a direction away from the sapphire substrate. In this LED, when light generated in the active layer passes through the first conductive semiconductor layer and the sapphire substrate to travel toward the front of the LED, a portion of the light is subjected to total internal reflection at an interface between the first conductive semiconductor layer and the sapphire substrate. Therefore, the portion of the light does not travel to the outside of the LED and thus is lost inside the LED.
- [5] In order to reduce the generation of the total internal reflection, there has been con-

ventionally proposed an LED in which a convexo-concave pattern is formed on an upper surface of a transparent substrate, i.e., at an interface between a first conductive semiconductor layer and the transparent substrate, thereby reducing total internal reflection at the interface.

- [6] The conventional LED prevents light loss by decreasing the property of total internal reflection at an upper portion of the transparent substrate, but the improvement of the light extraction efficiency of the conventional LED is limited by light traveling to a lower portion of the transparent substrate.

Disclosure of Invention

Technical Problem

- [7] An object of the present invention is to provide a light emitting diode capable of preventing light loss due to emission of light through a second surface opposite to a first surface of a transparent substrate on which a semiconductor-laminated structure is formed.

Solution to Problem

- [8] A light emitting diode (LED) according to an embodiment of the present invention includes a transparent substrate having a first surface and a second surface opposite to the first surface; a GaN-based semiconductor-laminated structure comprising a first conductive semiconductor layer, an active layer and a second conductive semiconductor layer and formed on the first surface of the transparent substrate; and a refractive index control layer formed on the second surface of the transparent substrate and having a pattern on a lower surface thereof.
- [9] The refractive index control layer is employed to reduce total internal reflection at a lower portion of the transparent substrate and to scatter light by the pattern, thereby improving the light extraction efficiency of the LED.
- [10] In an embodiment, the pattern may include a plurality of pyramid structures.
- [11] In an embodiment, the refractive index control layer comprises a metal oxide layer with a rock salt structure, and the metal oxide layer is formed on the second surface of the transparent substrate by depositing to form the pyramid structures.
- [12] In an embodiment, the metal oxide layer may comprise MgO-, NiO-, CaO- or ZnO-based metal oxides.
- [13] In an embodiment, the metal oxide layer may comprise a MgO-based metal oxide represented by the formula: $\text{Mg}_x\text{M}_{1-x}\text{O}$ ($x \leq 1$, and M is metal). In an embodiment, the M may comprise at least one of Be, Ca, Sr and Ba.
- [14] In an embodiment, the MgO-based metal oxide comprises an impurity doped into the surface thereof, and the impurity is selected from the group consisting of B, In, Zn, Tl, Al, Sn, Ga, Te, Si, C, Ge, N, P, As, Sb, Bi, S, Se, Br, I, Ti and oxides thereof.

- [15] In an embodiment, the metal oxide layer may have a thickness of 5000 Å to 4 μm. More preferably, the metal oxide layer has a thickness of less than 2 μm. At this time, the thickness of the metal oxide layer may be nearly identical to that of the pattern.
- [16] In an embodiment of the present invention, the LED further includes a reflective layer formed on the refractive index control layer so as to cover the pattern, wherein the reflective layer is formed of a reflective material having a reflectivity of 90% or more for a wavelength of 420 to 450 nm.
- [17] In an embodiment, the refractive index control layer may have a refractive index of a middle value between the refractive index of a GaN-based semiconductor and the refractive index of air. The transparent substrate may be a sapphire substrate, and the refractive index control layer may have a refractive index smaller than that of the sapphire substrate.
- [18] A method for manufacturing an LED according to an embodiment of the present invention is characterized by including: preparing a transparent substrate having opposite first and second surfaces opposite to the first surface; forming a GaN-based semiconductor-laminated structure on the first surface of the transparent substrate; and forming a refractive index control layer on the second surface of the transparent substrate, wherein the refractive index control layer comprises a pattern on a lower surface thereof.
- [19] At this time, the refractive index control layer may be formed by e-beam depositing a metal oxide with a rock salt structure on the second surface of the transparent substrate, and the pattern is formed by the deposition. The metal oxide may comprise MgO-, NiO-, CaO- or ZnO-based metal oxides. Further, the metal oxide may be a MgO-based metal oxide represented by the formula: $Mg_xM_{1-x}O$ ($x \leq 1$, and M is metal), and the M may comprise at least one of Be, Ca, Sr and Ba. The metal oxide may be doped with an impurity selected from the group consisting of B, In, Zn, Tl, Al, Sn, Ga, Te, Si, C, Ge, N, P, As, Sb, Bi, S, Se, Br, I, Ti and oxides thereof. The second surface of the transparent substrate may be surface-treated by using oxygen plasma, nitrogen plasma or ultraviolet ozone (UVO) before the e-beam deposition.
- [20] The transparent substrate may be a sapphire substrate.

Advantageous Effects of Invention

- [21] According to embodiments of the present invention, it is possible to reduce total internal reflection even in a lower surface of a sapphire substrate that in contact with air. A pyramid structure is formed such that a flat surface does not exist at the lower surface of the sapphire substrate, thereby maximizing the effect of reducing total internal reflection.
- [22] As compared with a conventional LED including a sapphire substrate with a flat

lower surface, a horizontal LED to which a MgO layer with a plurality of pyramid structures as a refractive index control layer is applied according to the present invention has light output increased by about 13 % at the substantially same thickness.

Brief Description of Drawings

- [23] Fig. 1 is a sectional view illustrating a light emitting diode (LED) according to one embodiment of the present invention.
- [24] Figs. 2 to 6 are sectional views illustrating a method for manufacturing the LED according to one embodiment of the present invention.
- [25] Fig. 7 is scanning electron microscope (SEM) photographs showing pyramid pattern structures depending on thicknesses of a MgO layer formed as a refractive index control layer in the LED according to the embodiment of the present invention.
- [26] Fig. 8 illustrates a high-resolution transmission electron microscope (TEM) photograph showing the pyramid pattern structure of the MgO layer along with a diagrammatic view showing a pyramid crystalline structure of MgO.
- [27] Fig. 9 is a graph showing a normalized light output of a GaN-based horizontal LED to which the MgO layer with the pyramid pattern structure is applied, according to the embodiment of the present invention.

Mode for the Invention

- [28] Hereinafter, preferred embodiments of the present invention will be described in detail with reference to the accompanying drawings. The following embodiments are provided only for illustrative purposes so that those skilled in the art can fully understand the spirit of the present invention. Therefore, the present invention is not limited to the following embodiments but may be implemented in other forms. In the drawings, the widths, lengths, thicknesses and the like of elements are exaggerated for convenience of illustration. Further, an expression that one element is placed "on" or "above" another element indicates not only a case where the element is placed "directly on" or "just above" the other element but also a case where a further element is interposed between the element and the other element. Like reference numerals indicate like elements throughout the specification and drawings.
- [29] Fig. 1 is a sectional view illustrating a light emitting diode (LED) according to one embodiment of the present invention.
- [30] Referring to Fig. 1, the LED according to the embodiment of the present invention comprises a transparent substrate 1, a semiconductor-laminated structure 2 and a refractive index control layer 3. Further, the LED may further comprise a transparent electrode layer 4, a first electrode pad 5 and a second electrode pad 6.
- [31] The transparent substrate 1 comprises an upper surface (or first surface) and a lower surface (or second surface) opposite to the upper surface. The transparent substrate 1 is

not particularly limited as long as it is a substrate through which light generated in an active layer 24 is transmitted. For example, the transparent substrate 1 may be a sapphire substrate. Hereinafter, the transparent substrate 1 will be described as a sapphire substrate.

- [32] The semiconductor-laminated structure 2 is formed on the upper surface of the sapphire substrate 1, and the refractive index control layer 3 described in detail below is formed on the lower surface of the sapphire substrate 1. Although not shown, the sapphire substrate 1 may be a patterned sapphire substrate (PSS) having a predetermined convexo-concave pattern formed on the upper surface, i.e., at an interface between the sapphire substrate and the semiconductor-laminated structure 2.
- [33] The semiconductor-laminated structure 2 may be formed using the sapphire substrate 1 as a growth substrate, and comprises a first conductive semiconductor layer 22, the active layer 24 and a second conductive semiconductor layer 26. The active layer 24 is interposed between the first conductive semiconductor layer 22 and the second conductive semiconductor layer 26. The first conductive semiconductor layer 22 is a layer formed adjacent to the sapphire substrate 1, and may be an n-type semiconductor layer. Furthermore, the second conductive semiconductor layer 26 is a layer positioned relatively away from the sapphire substrate 1, and may be a p-type semiconductor layer. On the contrary, the first conductive semiconductor layer 22 may be a p-type semiconductor layer, and the second conductive semiconductor layer 26 may be an n-type semiconductor layer.
- [34] The first conductive semiconductor layer 22, the active layer 24 and the second conductive semiconductor layer 26 may comprise a GaN-based compound semiconductor material, i.e., an (Al, In, Ga)N. The active layer 24 has components and a composition ratio determined to emit light of a desired wavelength, e.g., ultraviolet light or blue light. The first conductive semiconductor layer 22 and/or the second conductive semiconductor layer 26 may be formed into a single-layered structure as shown in this figure, but may be formed into a multi-layered structure. The active layer 24 may also be formed into a single or multiple quantum well structure. Although not shown, a buffer layer for decreasing lattice mismatch may be interposed between the sapphire substrate 1 and the first conductive semiconductor layer 22.
- [35] The LED according to this embodiment is a horizontal LED that has both the first and second electrode pads 5, 6 formed at the upper portion thereof, and has a structure in which partial regions of the second conductive semiconductor layer 26 and the active layer 24 are removed in the semiconductor-laminated structure 2 so that an upper portion of the first conductive semiconductor layer 22 is exposed and the first electrode pad 5 is formed in the exposed region. The first electrode pad 5 is formed in the exposed region of the upper portion of the first conductive semiconductor layer 22,

and the second electrode pad 6 is formed at an upper portion of the second conductive semiconductor layer 26.

[36] As shown, the transparent electrode layer 4 may be formed on the second conductive semiconductor layer 26, and the second electrode pad 6 may be formed on the transparent electrode layer 4. The transparent electrode layer 4 is formed of, for example, indium tin oxide (ITO) or Ni/Au. Since the specific resistivity of the transparent electrode layer is lower than that of the second conductive semiconductor layer 26, the transparent electrode layer serves to spread current.

[37] In this embodiment, the refractive index control layer 3 may be a MgO layer formed on the lower surface of the sapphire substrate 1 by depositing. The MgO layer in combination with the sapphire substrate of which refractive index is $n=1.77$ has a refractive index of a middle value ($n=1.74$) between the refractive index ($n=2.5$) of the GaN-based semiconductor and the refractive index ($n=1$) of air, thereby serving as a refractive index control layer capable of decreasing total internal reflection by controlling refractive index. In this case, the refractive index control layer 3 (hereinafter, referred to as a "MgO refractive index control layer") has a refractive index smaller than that of the sapphire substrate, i.e., a refractive index having a relatively small difference from the refractive index of the air, thereby further decreasing the total internal reflection. Moreover, the MgO refractive index control layer 3 may comprise a pattern that is in contact with the air and can reduce the total internal reflection on the lower surface thereof through which light is emitted. The pattern may comprise a plurality of pyramid structures 32.

[38] As described above, the MgO refractive index control layer 3 performs a refractive index control function together with the sapphire substrate 1, thereby increasing a critical angle of light at which the light generated in the active layer 24 and then passing through the first conductive semiconductor layer 22 is emitted to the outside of the LED via the sapphire substrate 1 and the MgO refractive index control layer 3. Further, a pyramid pattern structure is formed on a surface of the MgO refractive index control layer 3 without performing a separate additional process in the MgO deposition process, so that light incident on the MgO refractive index control layer 3 is further scattered. Thus, a larger amount of light can be reflected back to the inside of the device and then emitted to the outside of the device.

[39] At this time, the thickness of the MgO refractive index control layer 3 and pyramid pattern thereof may be determined in a range of $5000 \text{ \AA}$ to $4 \text{ }\mu\text{m}$.

[40] A method for manufacturing the LED according to one embodiment of the present invention will be described with reference to Figs. 2 to 6.

[41] First, referring to Fig. 2, a GaN-based first conductive semiconductor layer 22, a GaN-based active layer 24 and a GaN-based second conductive semiconductor layer

26 are sequentially formed on an upper surface of a sapphire substrate 1, for example, using a metal oxide chemical vapor deposition (MOCVD) or molecular beam epitaxy (MBE) technique. The thickness of the sapphire substrate 1 may be preferably 100 to 400 μm , and most preferably 150 μm or less. It is possible to use a process of decreasing the thickness of the sapphire substrate 1 to 150 μm or less through a lapping process. The lapping process may be performed after formation of the semiconductor-laminated structure, particularly, just before the deposition process of the MgO layer described below.

[42] Next, referring to Fig. 3, partial regions of the second conductive semiconductor layer 26 and the active layer 24 are patterned and removed by using a photolithography technique to expose a partial region 222 of the first conductive semiconductor layer 22.

[43] Next, referring to Fig. 4, a transparent electrode layer 4 is formed by depositing, for example, ITO or Ni/Au on an upper surface of the second conductive semiconductor layer 26, and a second electrode pad 6 and a first electrode pad 5 are formed on an upper surface of the transparent electrode layer 4 and the exposed region 222 of the first conductive semiconductor layer 22, respectively.

[44] Alternatively, the transparent electrode layer 4 may be formed just after the process of forming the first conductive semiconductor layer 22, the active layer 24 and the second conductive semiconductor layer 26, described in Fig. 2, and then partially removed together with the second conductive semiconductor layer 26 and the active layer 24 by means of the photolithography process of exposing the upper portion of the first conductive semiconductor layer 22.

[45] Next, referring to Fig. 5, a MgO refractive index control layer 3 having a refractive index control function in combination with the sapphire substrate 1 is formed by depositing MgO to a predetermined thickness on a lower surface of the sapphire substrate 1. Before the deposition of the MgO, a surface treatment for increasing affinity with a MgO layer may be first performed on a target surface of the sapphire substrate 1, i.e., the lower surface. As for the surface treatment, an oxygen plasma treatment, a nitrogen plasma treatment, an ultraviolet ozone (UVO) treatment or the like may be used.

[46] With the crystal structure of MgO, a pyramid pattern having a plurality of pyramid structures 32 may be formed on the MgO refractive index control layer 3 only by means of a deposition process, particularly an e-beam deposition process, without a separate additional process. In this case, the structure and shape of the pyramid pattern are changed depending on the deposition thickness of MgO. Thus, it is possible to obtain a pyramid pattern with a desired structure by controlling the deposition thickness.

[47] The MgO refractive index control layer 3 may be formed of a MgO-based oxide. The MgO-based oxide may be a ternary or higher multinary oxide obtained by adding one

or more elements to MgO.

- [48] The MgO-based ternary oxide may comprise, for example, $\text{Mg}_x\text{Be}_{1-x}\text{O}$ ($x \leq 1$), $\text{Mg}_x\text{Ca}_{1-x}\text{O}$ ($x \leq 1$), $\text{Mg}_x\text{Sr}_{1-x}\text{O}$ ($x \leq 1$) and $\text{Mg}_x\text{Ba}_{1-x}\text{O}$ ($x \leq 1$).
- [49] Further, the MgO-based multinary oxide may comprise a compound of two or more elements of Be, Ca, Sr and Ba with Mg.
- [50] Moreover, the MgO-based oxide may comprise a doped impurity in a surface thereof. In this case, the impurity used may comprise B, In, Zn, Tl, Al, Sn, Ga, Te, Si, C, Ge, N, P, As, Sb, Bi, S, Se, Br, I, Ti or a metal oxide thereof.
- [51] The MgO-based metal oxide may be a metal oxide with a rock salt structure in which the pattern with the pyramid structures 32 described above is voluntarily formed by e-beam deposition. In addition to the MgO-based metal oxide, another oxide material with the rock salt structure in which the pattern with the pyramid structures is formed by the e-beam deposition may be NiO, CaO, ZnO or a metal oxide containing the foregoing. The metal oxides described above may be deposited on the sapphire substrate or another substrate to form a pattern with a plurality of pyramid structures. Thus, they can be utilized as the refractive index control layer in the LED according to the present invention.
- [52] It is preferable that the process of forming the refractive index control layer 3 is performed after the process shown in Fig. 3, although it may also be performed at any time before or after the various processes described above.
- [53] Next, referring to Fig. 6, Ag may be deposited through an additional process on a rear surface of the LED 1, i.e., a lower surface of the MgO refractive index control layer 3, so as to form an Ag reflective layer 7 covering the pattern of the MgO refractive index control layer 3. Instead of Ag, another reflective material such as Al may be applied to the lower surface of the MgO refractive index control layer 3. In addition to Ag, Al or a metal material containing the foregoing, another reflective material may be applied as the reflective layer 7. The reflective material may be preferably a material having a reflectivity of 90% or more for a wavelength of 420 to 450 nm.
- [54] Fig. 7 is scanning electron microscope (SEM) photographs showing the pyramid pattern structures depending on the thicknesses of a MgO layer formed as the refractive index control layer in the LED according to the embodiment of the present invention. Referring to Fig. 7, surfaces of MgO layers deposited to a thickness of 0.7 μm , 2 μm and 4 μm can be seen. Thus, it can be appreciated that the pyramid structures on the surfaces of the MgO layers are differently and successfully formed depending on the respective thicknesses.
- [55] Fig. 8 illustrates a high-resolution transmission electron microscope (TEM) photograph showing the pyramid pattern structure of the MgO layer along with a diagrammatic view showing a pyramid crystalline structure of MgO. Referring to Fig. 8, it

can be seen that the MgO pyramid structure is terminated with a (200) plane and has a growth direction of (111). This can be described as the voluntary formation of the pyramid pattern in order to lower the energy of a thin film in a deposition process because the (200) plane has a surface energy much lower than that of the (111) plane in the MgO layer having the rock salt structure.

[56] Fig. 9 is a graph showing a normalized light output of a GaN-based horizontal LED to which the MgO layer with the pyramid pattern structure is applied, according to the embodiment of the present invention.

[57] Referring to Fig. 9, the normalized light output of the GaN-based horizontal LED to which the MgO layer with the pyramid pattern structure is applied is compared with that of an LED having a conventional sapphire substrate. For the LED to which the MgO layer is applied, light outputs thereof were measured after the MgO layer was deposited to different thicknesses of 0 μm , 0.2 μm , 0.7 μm , 2 μm and 4 μm on the lower surface of the sapphire substrate. When assuming that a thickness in the absence of MgO layer is considered zero as a point of reference, it could be seen that the light outputs at thicknesses of 0.2 μm and 0.7 μm were increased by 12.9 % and 10.1 %, respectively. In addition, it could be seen that the light outputs at thicknesses of 2 μm and 4 μm were rather decreased by 1% and 0.2%, respectively.

[58] That is, it has been found that the light efficiency of the LED is changed depending on the thickness of the MgO layer, and the light efficiency is increased only within a predetermined thickness range of the MgO layer.

[59] The pyramid structure formed in the MgO layer can be fabricated by using general photolithography patterning, without using e-beam lithography patterning that is high in cost and difficult to be applied to a large-area wafer process. Further, in forming the pyramid structure, it is characterized by requiring no separate additional patterning process in addition to a deposition process and thus is very effective in terms of application to a large area and fabrication cost.

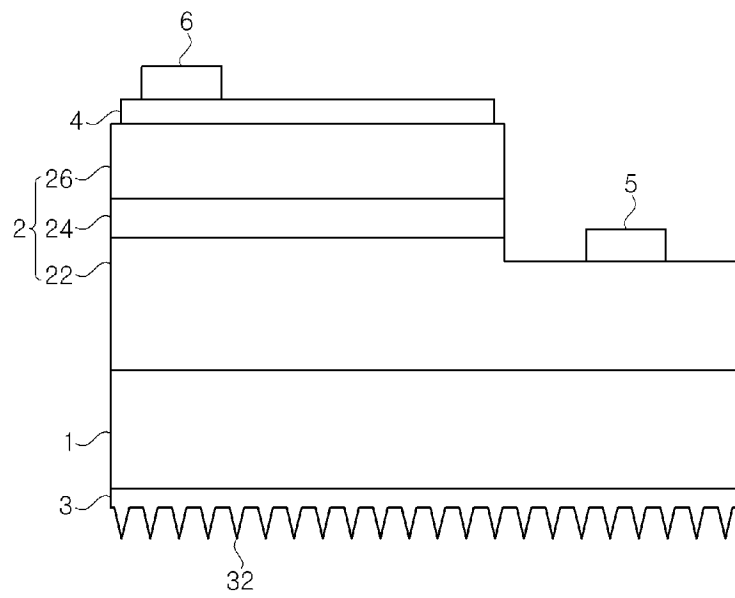
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Claims

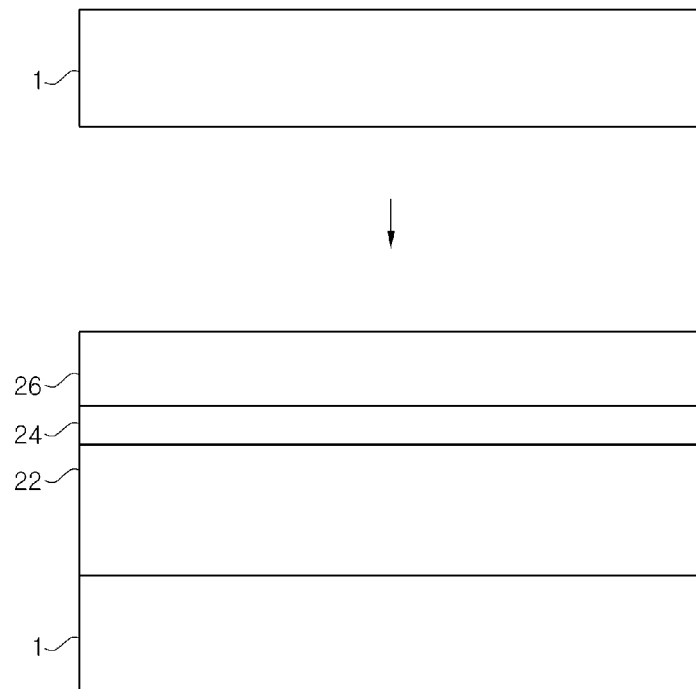
- [Claim 1] A light emitting diode (LED), comprising:
a transparent substrate having a first surface and a second surface opposite to the first surface;
a GaN-based semiconductor-laminated structure comprising a first conductive semiconductor layer, an active layer and a second conductive semiconductor layer and formed on the first surface of the transparent substrate; and
a refractive index control layer formed on the second surface of the transparent substrate and having a pattern on a lower surface thereof.
- [Claim 2] The LED of Claim 1, wherein the pattern comprises a plurality of pyramid structures.
- [Claim 3] The LED of Claim 2, wherein the refractive index control layer comprises a metal oxide layer with a rock salt structure, and the metal oxide layer is formed on the second surface of the transparent substrate by depositing to form the pyramid structures.
- [Claim 4] The LED of Claim 3, wherein the metal oxide layer comprises MgO-, NiO-, CaO- or ZnO-based metal oxides.
- [Claim 5] The LED of Claim 3, wherein the metal oxide layer comprises a MgO-based metal oxide represented by the formula: $Mg_xM_{1-x}O$ ($x \leq 1$, and M is metal).
- [Claim 6] The LED of Claim 5, wherein the M comprises at least one of Be, Ca, Sr and Ba.
- [Claim 7] The LED of Claim 5, wherein the MgO-based metal oxide comprises an impurity doped into the surface thereof, and the impurity is selected from the group consisting of B, In, Zn, Tl, Al, Sn, Ga, Te, Si, C, Ge, N, P, As, Sb, Bi, S, Se, Br, I, Ti and oxides thereof.
- [Claim 8] The LED of Claim 5, wherein the metal oxide layer has a thickness of $5000 \text{ \AA}$ to $4 \text{ }\mu\text{m}$.
- [Claim 9] The LED of Claim 8, wherein the metal oxide layer has a thickness of less than $2 \text{ }\mu\text{m}$.
- [Claim 10] The LED of Claim 1, further comprising a reflective layer formed on the refractive index control layer so as to cover the pattern, wherein the reflective layer is formed of a reflective material having a reflectivity of 90% or more for a wavelength of 420 to 450 nm.
- [Claim 11] The LED of Claim 1, wherein the refractive index control layer has a refractive index of a middle value between the refractive index of a

- GaN-based semiconductor and the refractive index of air.
- [Claim 12] The LED of any one of Claims 1 to 11, wherein the transparent substrate is a sapphire substrate, and the refractive index control layer has a refractive index smaller than that of the sapphire substrate.
- [Claim 13] A method for manufacturing an LED, comprising:
preparing a transparent substrate having a first surface and a second surface opposite to the first surface;
forming a GaN-based semiconductor-laminated structure on the first surface of the transparent substrate; and
forming a refractive index control layer on the second surface of the transparent substrate,
wherein the refractive index control layer comprises a pattern on a lower surface thereof.
- [Claim 14] The method of Claim 13, wherein the refractive index control layer comprising the pattern is formed by e-beam depositing a metal oxide with a rock salt structure on the second surface of the transparent substrate.
- [Claim 15] The method of Claim 14, wherein the metal oxide comprises MgO-, NiO-, CaO- or ZnO-based metal oxides.
- [Claim 16] The method of Claim 14, wherein the metal oxide is a MgO-based metal oxide represented by the formula: $\text{Mg}_x\text{M}_{1-x}\text{O}$ ($x \leq 1$, and M is metal), and the M comprises at least one of Be, Ca, Sr and Ba.
- [Claim 17] The method of Claim 16, wherein the metal oxide is doped with an impurity selected from the group consisting of B, In, Zn, Tl, Al, Sn, Ga, Te, Si, C, Ge, N, P, As, Sb, Bi, S, Se, Br, I, Ti and oxides thereof.
- [Claim 18] The method of Claim 14, further comprising surface-treating the second surface of the transparent substrate by using oxygen plasma, nitrogen plasma or ultraviolet ozone (UVO) before the e-beam deposition.
- [Claim 19] The method of any one of Claims 13 to 18, wherein the transparent substrate is a sapphire substrate.

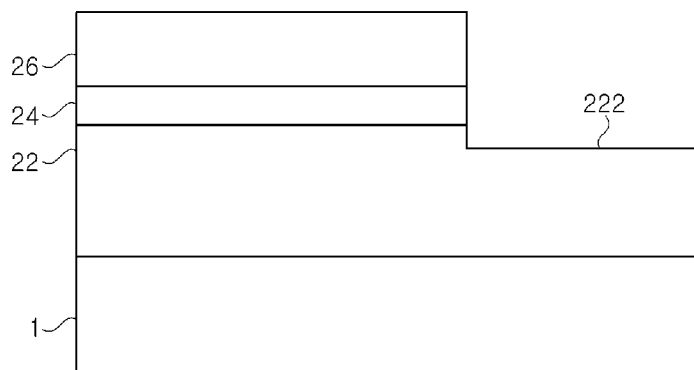
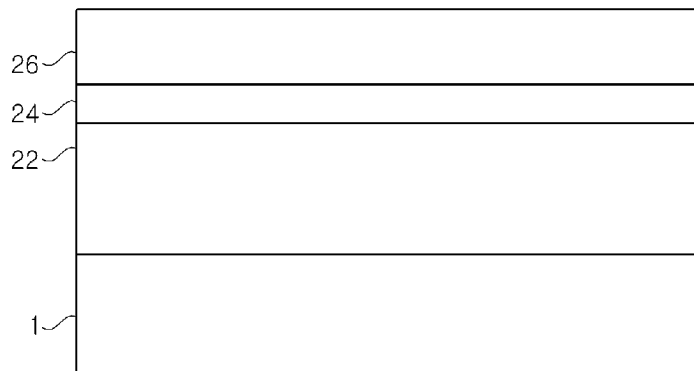
[Fig. 1]



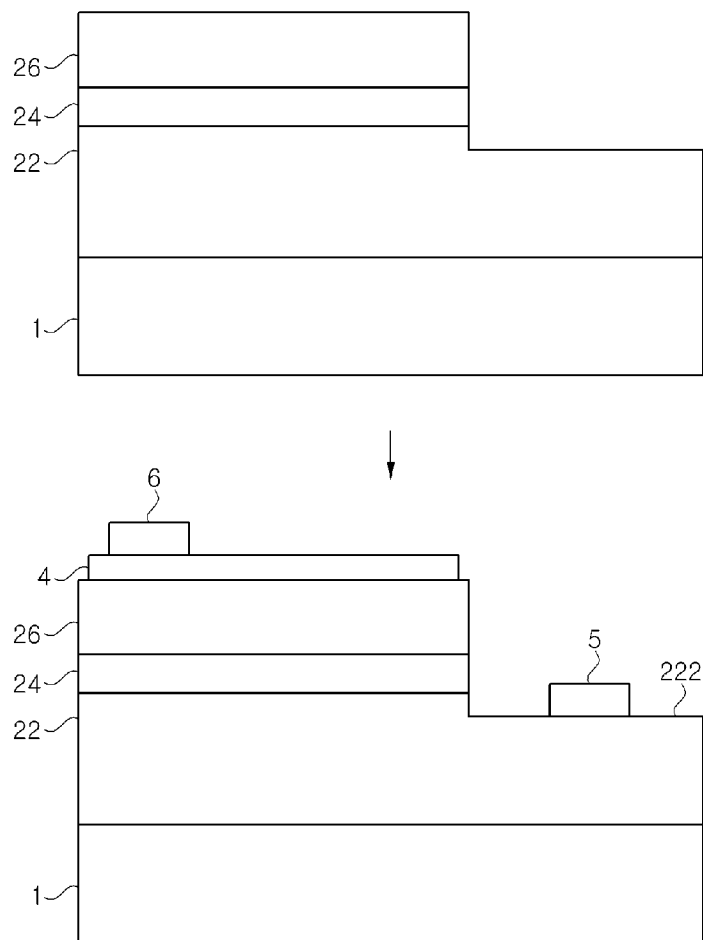
[Fig. 2]



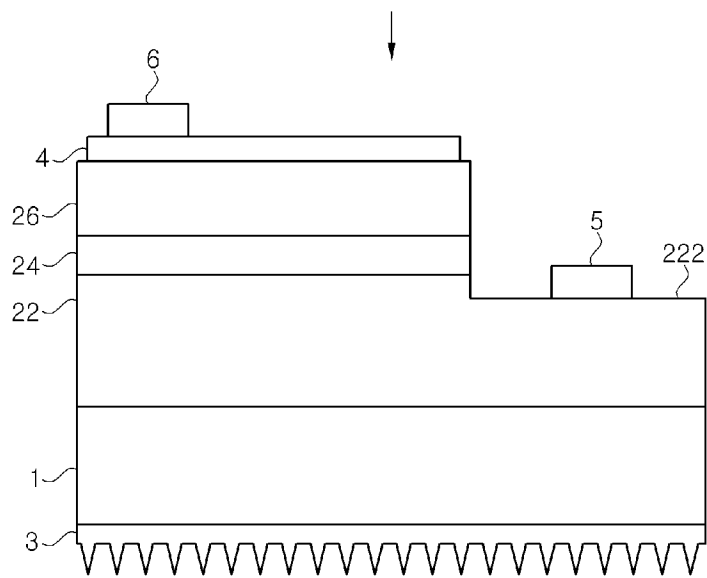
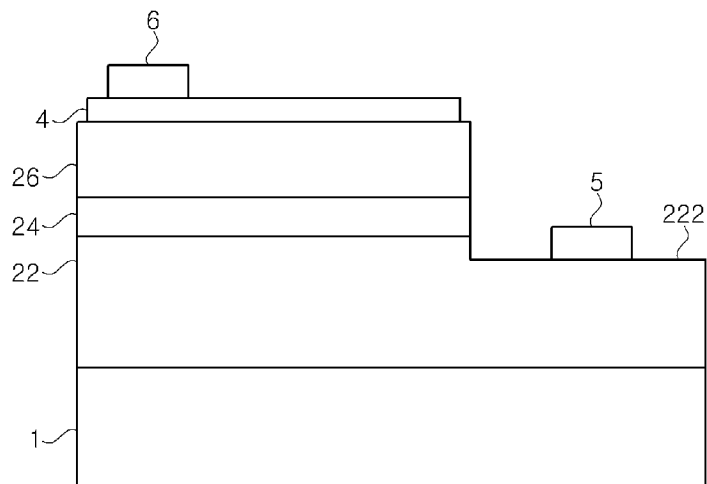
[Fig. 3]



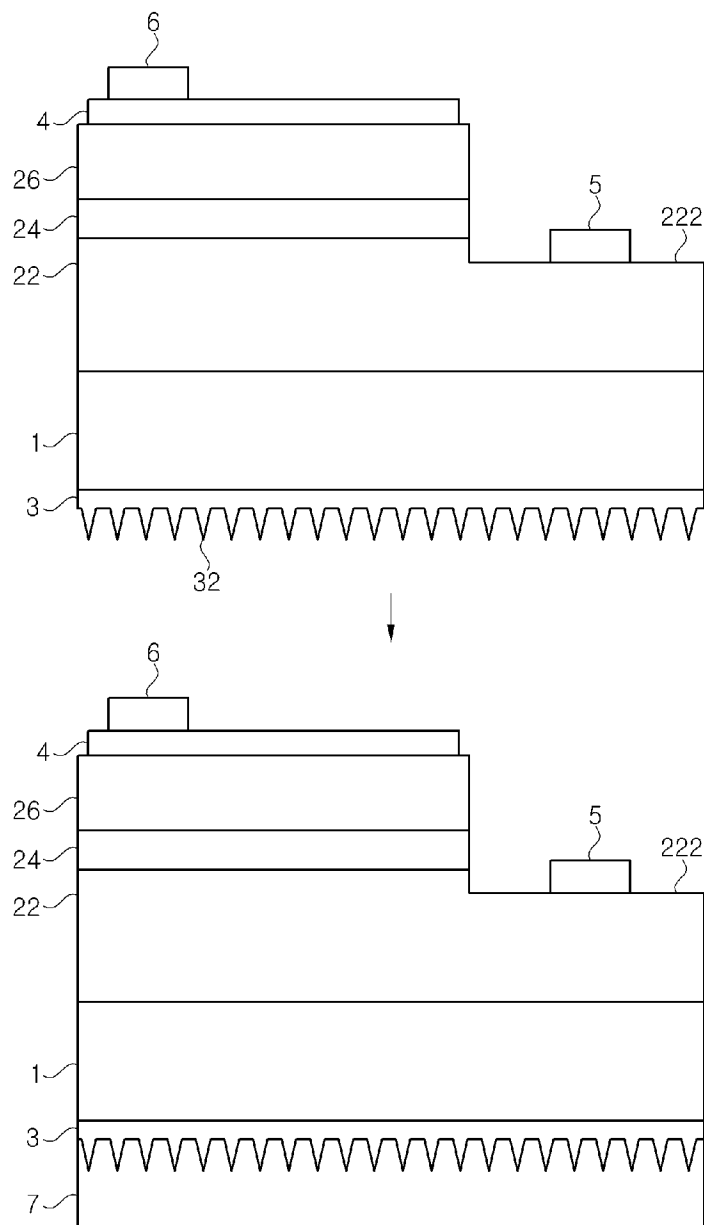
[Fig. 4]



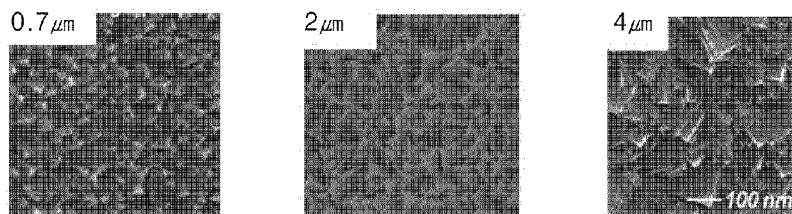
[Fig. 5]



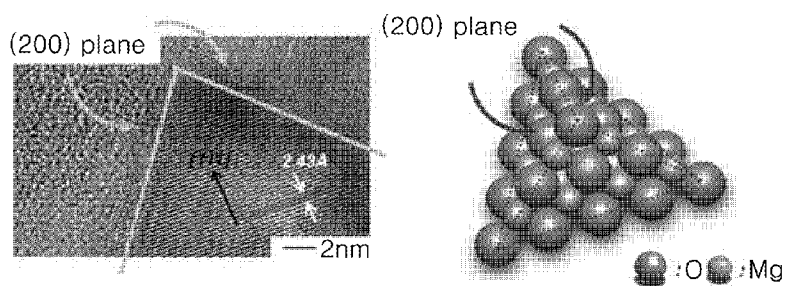
[Fig. 6]



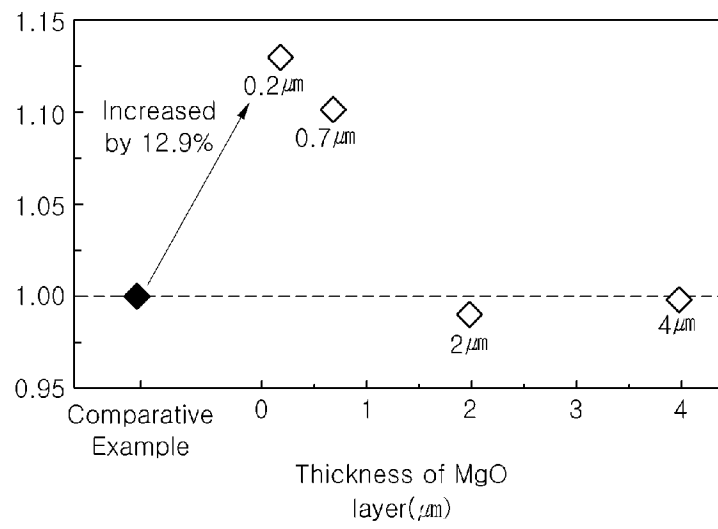
[Fig. 7]



[Fig. 8]



[Fig. 9]



A. CLASSIFICATION OF SUBJECT MATTER**H01L 33/20(2010.01)i, H01L 33/22(2010.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H01L 33/20; H01L 33/28; H01L 33/00; H01L 29/06; H01L 33/22

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & keywords: LED, light scattering, reflective layer, rock salt structure, metal oxide

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	KR 10-0638666 B1 (SAMSUNG ELECTRO-MECHANICS CO., LTD.) 30 October 2006 See abstract, page 3, line 44 - page 5, line 13, claims 1, 4, 6, 13-14 and figures 2(a), 4.	1, 10-13, 19
Y		2-9, 14-18
Y	KR 10-1165259 B1 (POSTECH ACADEMY-INDUSTRY FOUNDATION et al.) 10 August 2012 See paragraphs [0025]-[0032], [0039], [0046], claims 4-7 and figure 1.	2-9, 14-18
A		1, 10-13, 19
A	JP 2009-289947 A (KYOCERA CORP.) 10 December 2009 See paragraphs [0022]-[0049] and figures 1-2.	1-19
A	US 2006-0261323 A1 (HYO WON SUH et al.) 23 November 2006 See paragraphs [0030]-[0037] and figures 2a-2b.	1-19
A	US 2008-0105882 A1 (MICHAEL R. T. TAN et al.) 08 May 2008 See paragraphs [0014]-[0028], claim 1 and figure 2.	1-19



Further documents are listed in the continuation of Box C.



See patent family annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

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Date of the actual completion of the international search

16 December 2013 (16.12.2013)

Date of mailing of the international search report

17 December 2013 (17.12.2013)

Name and mailing address of the ISA/KR

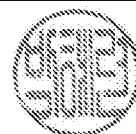
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/KR2013/007760

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
KR 10-0638666 B1	30/10/2006	JP 2006-191103 A JP 5037013 B2 KR 10-2006-0079737 A US 2006-0145170 A1	20/07/2006 26/09/2012 06/07/2006 06/07/2006
KR 10-1165259 B1	10/08/2012	CN 103098240 A KR 10-2012-0005326 A KR 10-2012-0005418 A US 2013-0207074 A1 WO 2012-005459 A2 WO 2012-005459 A3	08/05/2013 16/01/2012 16/01/2012 15/08/2013 12/01/2012 03/05/2012
JP 2009-289947 A	10/12/2009	None	
US 2006-0261323 A1	23/11/2006	JP 2006-324672 A JP 4777141 B2 KR 10-0638819 B1 US 8373184 B2	30/11/2006 21/09/2011 19/10/2006 12/02/2013
US 2008-0105882 A1	08/05/2008	TW 200834987 A TW I385821 B US 7977702 B2	16/08/2008 11/02/2013 12/07/2011