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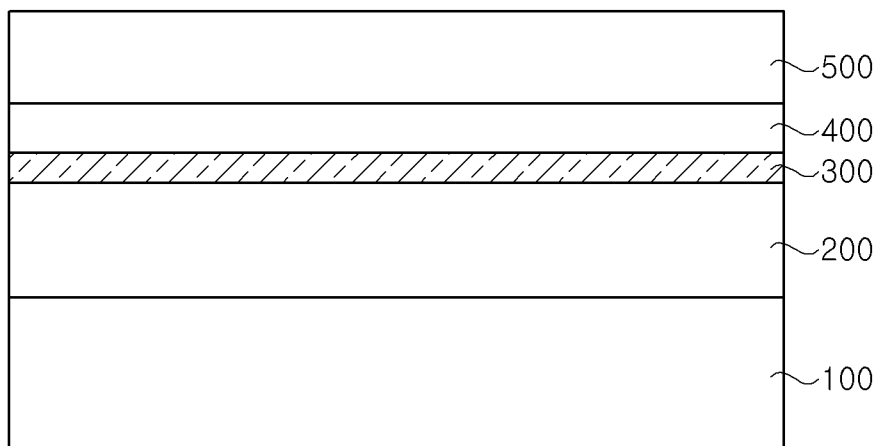
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(54) Title: LIGHT EMITTING DEVICE AND METHOD OF FABRICATING THE SAME



(57) Abstract: A light emitting device is disclosed. The light emitting device includes a first conductive type semiconductor layer having an m-plane as a growth plane; a stacking fault suppression (SFS) layer; an active layer; and a second conductive type semiconductor layer, wherein the SFS layer has lower band-gap energy than the first nitride layer and the first nitride layer, and includes a stack structure in which a second nitride layer containing In is stacked in one or more cycles, and the second nitride layer includes a lower region and an upper region, which have a relationship satisfying Equation 1 ([Equation 1] $0.8 \leq R_D < 1.0$, (R_D = standard deviation of In atomic density of the upper region per unit volume (1 nm^3)/standard deviation of In atomic density of the lower region per unit volume (1 nm^3)).



Description

Title of Invention: LIGHT EMITTING DEVICE AND METHOD OF FABRICATING THE SAME

Technical Field

- [1] Exemplary embodiments relate to a light emitting device and a method of fabricating the same, and more particularly, to a light emitting device having a crystal structure with minimized stacking fault and a method of fabricating the same.

Background Art

- [2] Recently, a nitride-based semiconductor is broadly used as a base material of a light emitting device such as a light emitting diode and is grown on a homogeneous substrate such as a gallium nitride substrate or a heterogeneous substrate such as a sapphire substrate. Some factors affecting crystallinity and luminous efficacy of such a nitride-based semiconductor relate to characteristics of a growth substrate.
- [3] In a light emitting device including a nitride-based semiconductor, since a plane in which electrons and holes are recombined is generally parallel to a growth plane, characteristics of the light emitting device vary along the growth plane of the nitride-based semiconductor. For example, a nitride-based semiconductor grown on a growth substrate having a polar-plane (for example, C-plane) as a growth plane is grown in a direction normal to the polar plane and thus exhibits spontaneous polarization and piezoelectric polarization due to difference in lattice parameter. A polarization phenomenon due to such spontaneous polarization and piezoelectric polarization causes bending of an energy band of the nitride-based semiconductor, thereby causing division of hole and electron distributions in an active layer. As a result, the light emitting device has low luminous efficacy due to reduction in recombination efficiency of electrons and holes, suffers from red shift of light emission, and has increased forward voltage (V_f).

Disclosure of Invention

Technical Problem

- [4] Exemplary embodiments provide a method of fabricating a light emitting device having improved crystallinity by suppressing indium segregation and a light emitting device fabricated by the same.

Solution to Problem

- [5] In accordance with one exemplary embodiment, a light emitting device includes: a first conductive type semiconductor layer having a non-polar or semi-polar growth plane; an SFS layer disposed on the first conductive type semiconductor layer and including indium (In); an active layer disposed on the SFS layer; and a second

- conductive type semiconductor layer disposed on the active layer, wherein the SFS layer includes a lower region and an upper region, and the lower region and the upper region have a relationship satisfying Equation 1. ([Equation 1] $0.8 \leq R_D < 1.0$, ($R_D =$ standard deviation of In atomic density of the upper region per unit volume (1 nm^3)/standard deviation of In atomic density of the lower region per unit volume (1 nm^3)))
- [6] The SFS layer may include a stack structure in which a first nitride layer and a second nitride having smaller bandgap energy than the first nitride layer and including indium are stacked in one or more cycles, and the second nitride layer may include a lower region and an upper region, wherein the lower region and the upper region of the second nitride layer have a relationship satisfying Equation 2. ([Equation 2] $0.8 \leq R_{D2} < 1.0$, ($R_{D2} =$ standard deviation of In atomic density of the upper region of the second nitride layer per unit volume (1 nm^3)/standard deviation of In atomic density of the lower region of the second nitride layer per unit volume (1 nm^3)))
- [7] The non-polar growth plane may include an m-plane and the semi-polar growth plane may include a {20-2-1} or {30-3-1} plane.
- [8] The non-polar or semi-polar growth plane may have an off-angle in the range of -10° to $+10^\circ$.
- [9] The SFS layer may have an indium concentration varying in a thickness direction thereof such that a middle section of the SFS layer has the highest indium content in the SFS layer, and an upper surface of the SFS layer has a lower indium content than the middle section of the SFS layer or the lowest indium content in the SFS layer.
- [10] The first nitride layer may include GaN and/or InGaN and the second nitride layer may include InGaN.
- [11] The second nitride layer may have an indium concentration varying in a thickness direction thereof such that a middle section of the second nitride layer has the highest indium content in the second nitride layer, and an upper surface of the second nitride layer has a lower indium content than the middle section of the second nitride layer, or has the lowest indium content in the second nitride layer.
- [12] The indium content of the upper surface of the second nitride layer may be 80% the indium content of the middle section of the second nitride layer.
- [13] The SFS layer may be doped with the same conductive type as the first conductive type semiconductor layer.
- [14] R_D may be a value in the range of $0.91 \leq R_D \leq 1.0$.
- [15] The active layer may be directly disposed on the SFS layer or may be disposed within a distance of 100 nm from the SFS layer.

Advantageous Effects of Invention

- [16] According to exemplary embodiments, a light emitting device includes an SFS layer

capable of suppressing indium segregation, whereby indium segregation is significantly reduced at an interface between layers and stacking faults are effectively reduced, thereby improving reliability by securing further improved properties in terms of internal quantum efficiency and electrostatic discharge resistance than typical non-polar light emitting devices.

Brief Description of Drawings

- [17] Figure 1 to Figure 5 are sectional views illustrating a light emitting device and a method of fabricating a light emitting device according to one exemplary embodiment.
- [18] Figure 6 and Figure 7 are graphs depicting variation of the indium (In) content in a growth direction in an inventive example and a comparative example using an atom probe.
- [19] Figure 8 and Figure 9 are plan-view graphs two-dimensionally depicting distribution of indium (In) atoms in a thickness direction in an inventive example and a comparative example, respectively.

Mode for the Invention

- [20] In order to solve a problem occurring in a nitride-based semiconductor due to polarity of a growth plane of a growth substrate, a method of growing a non-polar or semi-polar nitride-based semiconductor on a homogeneous substrate has been studied and developed. When the non-polar or semi-polar nitride-based semiconductor is grown on the homogeneous substrate, it is possible to minimize efficiency deterioration due to spontaneous polarization and piezoelectric polarization. The nitride-based semiconductor includes an a-plane ($\{11\bar{2}0\}$) and an m-plane ($\{1\bar{1}00\}$) as non-polar planes, and various light emitting devices fabricated by growing nitride-based semiconductor layers on an m-plane non-polar substrate are disclosed in the art.
- [21] However, a non-polar nitride-based semiconductor layer grown on the m-plane exhibits different growth and optical characteristics than a non-polar nitride-based semiconductor layer grown on the c-plane. Accordingly, there is a limit in direct application of a technique of growing a nitride-based semiconductor layer on the c-plane to fabrication of a nitride-based semiconductor layer having the m-plane as a growth plane.
- [22] Particularly, in the nitride-based semiconductor having the m-plane as a growth plane, stacking faults occur and cause generation of two-dimensional defects, thereby significantly deteriorating crystallinity of the semiconductor layer. Such stacking faults can often include pits and current leakage can occur along a boundary between the pits. Stacking faults act as a more detrimental crystal defect with respect to the nitride-based semiconductor having the m-plane as a growth plane than a nitride-based semiconductor having the c-plane as a growth plane.

- [23] Hereinafter, exemplary embodiments of the present disclosure will be described in detail with reference to the accompanying drawings. The following embodiments are provided by way of example so as to fully convey the spirit of the present disclosure to those skilled in the art to which the present disclosure pertains. Accordingly, the present disclosure is not limited to the embodiments disclosed herein and can also be implemented in different forms. In the drawings, widths, lengths, thicknesses, and the like of elements can be exaggerated for clarity and descriptive purposes. Further, when an element or layer is referred to as being "disposed above" or "disposed on" another element or layer, it can be directly "disposed above" or "disposed on" the other element or layer or intervening elements or layers can be present. Throughout the specification, like reference numerals denote like elements having the same or similar functions.
- [24] Figure 1 to Figure 5 are sectional views illustrating a light emitting device and a method of fabricating a light emitting device according to one exemplary embodiment.
- [25] Referring to Figure 1, a substrate 100 is prepared.
- [26] The substrate 100 may be selected from any substrate that allows growth of nitride-based semiconductors thereon, and may include, for example, a heterogeneous substrate such as a sapphire substrate, a silicon substrate, a silicon carbide substrate and a spinel substrate, or a homogeneous substrate such as a gallium nitride substrate and an aluminum nitride substrate. The substrate 100 has a non-polar or semi-polar growth plane. For example, the substrate 100 may be a non-polar nitride substrate and the growth plane of the substrate may be an a-plane or the m-plane. Particularly, in this exemplary embodiment, the substrate 100 may be a nitride substrate having the m-plane as a growth plane. In the following exemplary embodiments, the substrate 100 will be described as having the m-plane as the growth plane, it should be understood that the present disclosure is not limited thereto, and a light emitting device formed on a substrate having a non-polar or semi-polar (for example, {20-2-1} or {30-3-1}) growth plane is also within the scope of the present disclosure.
- [27] Furthermore, an upper surface of the substrate 100, that is, the growth plane of the substrate 100 may have an off-cut angle in a c-direction ($\langle 0001 \rangle$ family direction) and/or the a-direction ($\langle 11\bar{2}0 \rangle$ family direction) with reference to the m-plane. Here, the c-direction and the a-direction are normal directions with respect to the c-plane and the a-plane, respectively. The off-cut angle may range, for example, from -10° to $+10^\circ$, without being limited thereto. The growth plane having an off-cut angle may be a non-polar or semi-polar plane. Accordingly, nitride-based semiconductor layers grown on the growth plane of the substrate 100 can also exhibit non-polar or semi-polar characteristics.
- [28] In the substrate 100, the growth plane of which is the m-plane having an off-cut angle, a fine step is formed on the surface thereof due to the off-cut angle, and the c-

plane may be exposed to a side surface of the step. When growth atoms are settled and grown as a crystal on the surface of the substrate in the course of growing a nitride semiconductor on the substrate 100 through vapor deposition, the step has high bonding energy, thereby promoting crystal growth. Accordingly, the growth rate of the nitride semiconductor layer can be increased by adjusting the off-cut angle.

- [29] The nitride semiconductor layer grown on the substrate 100, the growth plane of which has an off-cut angle, can have a smoother surface than a nitride-based semiconductor layer grown on the m-plane that does not have an off-cut angle. That is, by growing the nitride semiconductor layer on the substrate 100, the growth plane of which has the off-cut angle, it is possible to reduce surface defects while improving crystallinity. However, it should be understood that the present disclosure is not limited to the aforementioned off-cut direction and angle.
- [30] Herein, the "m-plane as a growth plane" is illustrated as including a plane having an off-cut angle with respect to the m-plane. In other exemplary embodiments, the substrate 100 may include a plane having an off-cut angle with respect to other non-polar planes or semi-polar planes as well as the m-plane.
- [31] Referring to Figure 2, a first conductive type semiconductor layer 200 is formed on the substrate 100.
- [32] The first conductive type semiconductor layer 200 includes a nitride-based semiconductor such as (Al, Ga, In)N and may be grown by MOCVD, MBE, HVPE, and the like. Upon growth of the first conductive type semiconductor layer 200 by MOCVD, the first conductive type semiconductor layer 200 may be grown at a predetermined growth rate and a growth temperature of about 1050°C to 1200°C. Further, the first conductive type semiconductor layer 200 may be doped with n-type dopants including at least one of Si, C, Ge, Sn, Te, and Pb to be an n-type conductive semiconductor layer. Alternatively, the present disclosure is not limited thereto and the first conductive type semiconductor layer 200 may be doped with p-type dopants to be a p-type conductive semiconductor layer.
- [33] The first conductive type semiconductor layer 200 grown on the substrate 100 having a non-polar growth plane, particularly, the m-plane as a growth plane (including a plane having an off-cut angle with respect to the m-plane) exhibits non-polar characteristics, and the surface of the first conductive type semiconductor layer 200 may be a non-polar plane (or semi-polar plane). Accordingly, other nitride-based semiconductor layers grown on the first conductive type semiconductor layer 200 by subsequent processes also have non-polar (or semi-polar) growth planes.
- [34] In some exemplary embodiments, a buffer layer (not shown) may be further formed on the substrate 100 before growth of the first conductive type semiconductor layer 200. The buffer layer may include a nitride semiconductor such as GaN and may be

may be grown by MOCVD at a growth temperature of about 450°C to 600°C. The buffer layer improves crystallinity of semiconductor layers to be grown on the substrate 100 by subsequent processes.

[35] Then, referring to Figure 3 to Figure 4b, a stacking fault suppression (SFS) layer 300 is formed on the first conductive type semiconductor layer 200.

[36] The SFS layer 300 includes a nitride-based semiconductor such as (Al, Ga, In)N, and particularly, may include indium (In). The SFS layer 300 may be composed of a single layer or multiple layers.

[37] First, as shown in Figure 4a, the SFS layer 300 may have an upper region 300b having a relatively low standard deviation of In atomic density and a lower region 300a having a relatively high standard deviation of In atomic density. The upper region 300b may be disposed on the lower region 300a. The lower region 300a and the upper region 300b satisfy the condition of the following Equation 1.

[38] [Equation 1]

[39] $0.8 \leq R_D < 1.0$,

[40]
$$\text{where } R_D = \frac{\text{Standard deviation of In atomic density of upper region 300b per unit volume (1 nm}^3\text{)}}{\text{Standard deviation of In atomic density of lower region 300a per unit volume (1 nm}^3\text{)}}$$

[41] Equation 1 can be obtained through various methods. For example, the number of In atoms per unit volume (1 nm³) is measured using an atom probe, and distribution data according to locations of obtained density values can be obtained through normal distribution. A high standard deviation value indicates that there are many regions having a higher In atom density than surroundings and a low standard deviation value indicates uniformity of the In atom density throughout a corresponding region. However, it should be understood that the present disclosure is not limited thereto and the number of In atoms can be obtained using other measurement instruments.

[42] On the other hand, formation of the SFS layer 300 may include supplying a Group III atom source (for example, TMGa and/or TMIIn) and a Group V atom source (for example, NH₃) into an MOCVD chamber while supplying N₂ and H₂ as atmosphere gases into the growth chamber to grow a nitride layer including In. During growth of the SFS layer 300, the atmosphere gases include not only N₂, but also H₂. As a result, it is possible to suppress indium segregation on the surface of the SFS layer 300 during growth of the SFS layer 300. On the other hand, it should be noted that the upper region 300b and the lower region 300a are divided for convenience of description and are not formed to be distinguished from each other by separate processes in practice.

[43] Specifically, during growth of the nitride-based semiconductor layer containing In,

there is a high possibility of indium segregation on a growth surface through agglomeration of indium instead of being provided to a lattice. Particularly, growth of the nitride-based semiconductor having the m-plane as a growth plane provides a higher possibility of indium segregation than growth of the nitride-based semiconductor having the c-plane as a growth plane. When such indium segregation occurs on the surface of the nitride-based semiconductor layer, stacking faults occur at a portion of the nitride-based semiconductor layer continuously growing due to indium segregation. Particularly, most defects of the nitride-based semiconductor layer having the c-plane as a growth plane are one-dimensional linear defects, whereas stacking faults of the nitride-based semiconductor layer having a non-polar or semi-polar growth plane such as the m-plane cause two-dimensional defects, thereby significantly deteriorating crystallinity of the light emitting device. Accordingly, current leakage occurs and significantly increases along the two-dimensional defects, thereby deteriorating electrostatic discharge resistance and internal quantum efficiency of the light emitting device.

- [44] However, since the atmosphere gases include N_2 and H_2 , H_2 gas promotes vaporization of In such that In on the growth surface of the nitride-based semiconductor layer is partially vaporized. Particularly, bonding force between In atoms in indium agglomerates on the growth surface thereof is weak, thereby allowing the In atoms to be easily evaporated by H_2 gas. Accordingly, it is possible to suppress indium segregation on the growth surface of the SFS layer 300 having a non-polar or semi-polar growth plane by decreasing the density of In atoms in the upper region 300b. Thus, it is possible to achieve substantial decrease of a possibility of stacking faults in the light emitting device due to indium segregation.
- [45] As the SFS 300 satisfies Equation 1, it is possible to suppress indium segregation on the SFS layer 300 and at an interface between layers disposed above the SFS layer 300. Specifically, as the SFS layer 300 includes indium to reduce band-gap of the SFS layer 300, there is a difference in lattice parameter between upper and lower layers with respect to the SFS layer 300. As a result, stacking faults can occur at an interface between the SFS layer 300 and the upper layer. However, according to exemplary embodiments, since a region having a low standard deviation of In atomic density is placed above a region having a high standard deviation of In atomic density, it is possible to suppress indium segregation on the SFS layer 300 and at an interface between the layers disposed above the SFS layer 300, thereby suppressing generation of local stacking faults.
- [46] By way of example, referring to Figure 6 to Figure 9, the density of In atoms in the SFS layer 300 according to the exemplary embodiment will be described.
- [47] Figure 6 is a graph depicting variation of the indium (In) content in a growth

direction in an inventive example, as measured using an atom probe, and Figure 8 shows atom probe-plan views depicting distribution of In atoms in the upper region 300b and the lower region 300a of the SFS layer 300. Figure 7 is a graph depicting variation of the indium (In) content in a growth direction in a comparative example, as measured using an atom probe, and Figure 9 shows atom probe-plan views depicting distribution of In atoms in the upper region 300b and the lower region of the SFS layer.

[48] The SFS layer 300 of Figure 6 was formed using N_2 and H_2 as the atmosphere gases, and the SFS layer of Figure 7 was formed using N_2 as the atmosphere gas.

[49] Referring to Figure 6 and Figure 7, for the SFS layer, an upper interface corresponds to "2" in the horizontal axis and a lower interface corresponds to "8" in the horizontal axis. Accordingly, the upper region 300b corresponds to a region from "2" to "5" in the horizontal axis and the lower region 300a corresponds to a region from "5" to "8" in the horizontal axis. Further, in Figure 8 and Figure 9, bright portions (appearing white) indicate regions having a high indium density, and dark portions (appearing black) indicate regions having a low indium density. That is, in Figure 8 and Figure 9, a difference in indium density is shown by contrast between light and darkness, and a brighter color means a higher indium density.

[50] As shown in Figure 6, the upper interface of the SFS layer 300 according to the inventive example has an indium content of about 0.06 at% and the lower interface of the SFS layer has an indium content of about 0.08 at%. That is, it can be seen that the indium content at the upper interface is lower than the indium content at the lower interface. Particularly, a middle section of the SFS layer 300 has the highest indium content in the SFS layer 300 and the upper surface of the SFS layer 300 has a lower indium content than the middle section of the SFS layer, or has the lowest indium content in the SFS layer. For example, the indium content of the upper surface of the SFS layer 300 may be about 80% or less the indium content of the middle section of the SFS layer 300.

[51] Figures 8 (a) and (b) show the upper region and the lower region of the SFS layer 300 according to the inventive example, respectively. In Figure 8, it can be seen that the upper region 300b has a much lower indium density than the lower region 300a.

[52] On the contrary, as shown in Figure 7, the upper interface of the SFS layer according to the comparative example has an indium content of about 0.08 at% and the lower interface of the SFS layer has an indium content of about 0.06 at%. That is, it can be seen that the indium content at the upper interface is higher than the indium content at the lower interface. Figures 9 (a) and (b) show the upper region and the lower region of the SFS layer according to the comparative example, respectively. In Figure 9, it can be seen that the indium density of the upper region is higher than that of the lower region.

- [53] As such, it can be seen that introduction of H₂ gas as an additional atmosphere gas upon growth of the SFS layer 300 further reduces the concentration of indium on the upper surface thereof as compared with the comparative example. Accordingly, when H₂ is further supplied during growth of the SFS layer 300, the indium content on the upper surface thereof is generally decreased, thereby suppressing indium segregation.
- [54] Further, as shown in Figure 4b, the SFS layer 300 may be composed of multiple layers, and may include a first nitride layer 310 and a second nitride layer 320. The first nitride layer 310 and the second nitride layer 320 may be repeatedly stacked one above another in one or more cycles. Here, the first nitride layer 310 may have higher band-gap energy than the second nitride layer 320. Thus, when the first and second nitride layers 310, 320 are repeatedly stacked one above another in two or more cycles, the second nitride layer 320 may correspond to a well layer and the first nitride layer 310 may correspond to a barrier layer in a band-gap diagram. Each of the first and second nitride layers 310, 320 may have a thickness of about 1 nm to about 10 nm, without being limited thereto. In this structure, the SFS layer 300 may include a superlattice structure in which the first and second nitride layers 310, 320 are repeatedly stacked one above another.
- [55] The first nitride layer 310 may include GaN or InGaN, and the second nitride layer 320 may include indium, for example, InGaN. Thus, the SFS layer 300 may include a stack structure of InGaN/GaN or a stack structure of InGaN/InGaN. In other exemplary embodiments, the first nitride layer 310 may include InGaN and the second nitride layer 320 may also include InGaN such that the indium content of the second nitride layer 320 is higher than that of the first nitride layer 310, whereby the second nitride layer 320 can have lower band-gap energy than the first nitride layer 310.
- [56] On the other hand, the second nitride layer 320 may include a lower region 321 and an upper region 323. Next, the method of growing the SFS layer 300 will be described in more detail with reference to the lower and upper regions 321, 323. Here, it should be noted that the upper region 323 and the lower region 321 of the second nitride layer 320 are divided for convenience of description and are not formed to be distinguished from each other by separate processes in practice.
- [57] Formation of the SFS layer 300 may include growing the first nitride layer 310 including GaN and/or InGaN by supplying a Group III atom source (for example, TMGa and/or TMIIn) and a Group V atom source (for example, NH₃) into an MOCVD chamber while supplying N₂ as an atmosphere gas into the growth chamber, followed by growing the second nitride layer 320 including InGaN by supplying a Group III atom source (for example, TMGa and TMIIn) and a Group V atom source (for example, NH₃) into the MOCVD chamber while supplying N₂ and H₂ as atmosphere gases into the growth chamber. Thickness of each of the first nitride layer 310 and the second

nitride layer 320 can be adjusted by adjusting growth rate. Furthermore, formation of the SFS layer 300 may further include repeating growth of the first and second nitride layers 310, 320 by one or more cycles to form a superlattice structure in which the first and second nitride layers 310, 320 are repeatedly stacked one above another in one or more cycles.

[58] On the other hand, during growth of the second nitride layer 320, the atmosphere gases include not only N_2 , but also H_2 . As a result, it is possible to suppress indium segregation on the surface of the second nitride layer 320 during growth of the second nitride layer 320. This effect is generally similar to suppression of indium segregation in the upper region 300b of the SFS layer 300 described with reference to Figure 4a, and a detailed description thereof will be omitted.

[59] As such, by introduction of H_2 gas as the atmosphere gas, it is possible to suppress indium segregation on the second nitride layer 320 while reducing the indium density on the growth surface of the second nitride layer 320. The lower region 321 and the upper region 323 of the second nitride layer 320 satisfy the condition of the following Equation 2.

[60] [Equation 2]

[61] $0.8 \leq R_{D2} < 1.0$,

[62]
$$\text{where } R_{D2} = \frac{\text{Standard deviation of In atomic density of upper region 323 per unit volume (1 nm}^3\text{)}}{\text{Standard deviation of In atomic density of lower region 321 per unit volume (1 nm}^3\text{)}}$$

[63] Equation 2 can be obtained through various methods. For example, the number of In atoms per unit volume (1 nm^3) is measured using an atom probe, and distribution data according to locations of obtained density values can be obtained through normal distribution. A high standard deviation value indicates that there are many regions having a higher In atom density than surroundings and a low standard deviation value indicates uniformity of the In atom density throughout a corresponding region. However, it should be understood that the present disclosure is not limited thereto and the number of In atoms can be obtained using other measurement instruments.

[64] As indicated by Equation 2, when R_D is less than 1.0, it is possible to suppress indium segregation on the surface of the second nitride layer 320. In other exemplary embodiments, the R_D value may be set in the range of $0.91 \leq R_D < 1.0$. Further, according to this exemplary embodiment, the upper region 323 and the lower region 321 of the second nitride layer 320 may have a similar indium content profile, as shown in Figure 6. Furthermore, indium density plan views similar to the patterns shown in Figure 8 can be obtained through measurement of the indium density of the upper region 323

and the lower region 321 using an atom probe. Repetition of detailed descriptions of these drawings is omitted herein.

- [65] In this way, as the SFS layer 300 includes the second nitride layer 320, the SFS layer 300 can suppress stacking faults in the light emitting device. Furthermore, the SFS layer 300 may include a superlattice structure of the first and second nitride layers 310, 320, thereby preventing defects generated at a lower end of the SFS layer 300 from propagating to the active layer 400.
- [66] Particularly, with the structure wherein the light emitting device including semiconductor layers having a non-polar growth plane or a semi-polar growth plane such as the m-plane includes the SFS layer 300, the light emitting device can effectively prevent stacking faults and thus has further improved internal quantum efficiency and electrostatic discharge resistance than a typical non-polar light emitting device, thereby providing improved reliability.
- [67] The SFS layer 300 may be an undoped layer or may be doped with the same conductive type layer as the first conductive type semiconductor layer 200. For example, the SFS layer 300 may be doped with an n-type dopant including Si to be an n-type conductive semiconductor layer. The SFS layer 300 may have a constant dopant concentration in the thickness direction thereof, or the dopant concentration of the SFS layer 300 may regularly or irregularly vary in the thickness direction thereof.
- [68] Then, referring to Figure 5, the active layer 400 and a second conductive type semiconductor layer 500 may be formed, thereby providing a light emitting device, as shown in Figure 5.
- [69] The active layer 400 may include a nitride semiconductor such as (Al, Ga, In)N, and may be grown on the SFS layer 300 by MOCVD, MBE, or HVPE. Further, the active layer 400 may include a multi-quantum well (MQW) structure, and elements and composition of semiconductor layers constituting the multi-quantum well structure may be adjusted such that the semiconductor layers of the multi-quantum well (MQW) structure can emit light of a desired peak wavelength. The active layer 400 may have a non-polar or semi-polar growth plane, particularly, the m-plane as a growth plane.
- [70] Further, the active layer 400 may be formed on the SFS layer 300, particularly, directly on the SFS layer 300. However, the present disclosure is not limited thereto and other layers (for example, an electron injection layer) may be further interposed between the SFS layer 300 and the active layer 400. In this exemplary embodiment, the SFS layer 300 may be separated from the active layer 400 by a distance of about 5 nm to about 200 nm. When the SFS layer 300 is separated from the active layer 400 by a farther distance than this distance, stacking faults or pits can be generated in the active layer 400 due to strain relaxation of the active layer 400. However, it should be understood that the present disclosure is not limited thereto.

- [71] As the active layer 400 has a non-polar growth plane or a semi-polar growth plane such as the m-plane, spatial separation between electrons and holes due to spontaneous polarization can be relieved, thereby minimizing red shift of light emission. Further, with the structure wherein the SFS layer 300 is disposed at the lower end of the active layer 400, the light emitting device can minimize stacking faults within the active layer 400 while reducing the density of defects such as dislocations. Accordingly, the active layer 400 has improved crystallinity to provide improved internal quantum efficiency and is prevented from being damaged by electrostatic discharge, thereby improving reliability of the light emitting device.
- [72] The second conductive type semiconductor layer 500 may include a nitride-based semiconductor such as (Al, Ga, In)N and may be grown on the active layer 400 by MOCVD, MBE, or HVPE. The second conductive type semiconductor layer 500 may be doped to be a conductive type semiconductor layer opposite the conductive type of the first conductive type semiconductor layer 200. For example, the second conductive type semiconductor layer 500 may be doped with p-type dopants including Mg to be a p-type conductive semiconductor layer. However, it should be understood that the present disclosure is not limited thereto and doping may be performed in reverse order to that described above. The second conductive type semiconductor layer 500 may have a non-polar or semi-polar growth plane, which corresponds to the growth plane of the substrate 100.
- [73] The light emitting device of Figure 5 may be applied to various light emitting devices through additional processes. For example, a lateral type or flip-chip type light emitting device may be formed by mesa etching the light emitting device of Figure 5 such that the first conductive type semiconductor layer 200 is partially exposed, followed by forming first and second electrodes (not shown) on the first and second conductive type semiconductor layers, 200, 500, respectively. Alternatively, a vertical type light emitting device may be realized by separating and removing the substrate 100 from the first conductive type semiconductor layer 200, followed by electrically connecting first and second electrodes (not shown) to the surfaces of the first and second conductive type semiconductor layers 200, 500, respectively.
- [74] Conventionally, a superlattice structure provides various effects such as suppression of polarization of the active layer during growth of the c-plane, supply of electrons to the active layer, and the like, and is applied not only to a light emitting device including a polar semiconductor layer but also to a light emitting device including a non-polar or semi-polar semiconductor layer. However, upon growth of the superlattice structure, stacking faults occur at an interface between the layers due to a difference in lattice parameter therebetween and expand to the active layer, thereby causing technical difficulty such as current leakage. Particularly, segregation of indium

intensifies side effects and acts as a major factor in efficiency deterioration, thereby providing difficulty in practical application of the superlattice structure. However, according to the exemplary embodiments, the light emitting device includes the SFS layer capable of minimizing indium segregation while significantly minimizing stacking faults, and thus has improved efficiency and reliability.

[75] Next, an R_D value obtained using N_2 gas alone as an atmosphere gas upon growth of the second nitride layer 320 of the SFS layer 300 will be compared with an R_D value obtained using both H_2 and N_2 as the atmosphere gas. It should be understood that the following experimental data are provided for understanding of the present disclosure and do not limit the scope of the present disclosure.

[76] In an inventive example and a comparative example, light emitting devices were fabricated within an MOCVD chamber. First, the light emitting device of the inventive example includes an SFS layer, and H_2 gas and N_2 gas were introduced as atmosphere gases into the growth chamber upon growth of the second nitride layer of the SFS layer. Although the light emitting device of the comparative example also includes an SFS layer, N_2 gas was introduced as an atmosphere gas into the growth chamber upon growth of the second nitride layer of the SFS layer. For each of the light emitting devices of the inventive example and the comparative example, the standard deviation of In atomic density of the upper region of the second nitride layer per unit volume (1 nm^3) and the standard deviation of In atomic density of the lower region of the second nitride layer per unit volume (1 nm^3) were measured using an atom probe. In each of the inventive example and the comparative example, standard deviations of In atomic density of three second nitride layers were measured to calculate the R_D value, and results are shown in the following Table 1.

[77]

[78] [Table 1]

Comparative Example						
Second nitride layer	1		2		3	
Location	Lower portion	Upper portion	Lower portion	Upper portion	Lower portion	Upper portion
Standard deviation	0.007847	0.008348	0.008483	0.009728	0.008613	0.009048
R _D	1.06		1.15		1.05	
Inventive Example						
Second nitride layer	1		2		3	
Location	Lower portion	Upper portion	Lower portion	Upper portion	Lower portion	Upper portion
Standard deviation	0.007847	0.007168	0.007477	0.006525	0.007378	0.007363
R _D	0.91		0.87		0.99	

[79] According to the results shown in Table 1, it can be seen that the inventive example provided lower RD values than the comparative examples, and the second nitride layers of the inventive example had an RD value of less than 1. From these results, it can be seen that indium segregation was suppressed in the second nitride layers of the inventive example.

[80] Characteristic data of the light emitting devices of the examples and the comparative examples are shown in the following Table 2.

[81]

[82] [Table 2]

	Forward voltage (V)	Light emission power (mW)	Reverse current (I _R , mA)	Reverse voltage (V _R , V)
Comparative Example	3.77	15.62	0.18	10.84
Inventive Example	3.09	23.77	0.10	18.01

[83] As shown in Table 2, the light emitting device of the inventive example had lower forward voltage and higher light emission power than the light emitting device of the

comparative example. That is, it can be seen that luminous efficacy of the light emitting device of the inventive example was much higher than luminous efficacy of the light emitting device of the comparative example. Furthermore, the light emitting device of the inventive example had a lower reverse current and thus could more effectively prevent current leakage than the light emitting device of the comparative example, and had a higher reverse voltage and thus further improved reliability than the light emitting device of the comparative example.

- [84] It should be understood that various modifications, variations and alterations can be made without departing from the spirit and scope of the present disclosure, and the scope and spirit of the present disclosure should be defined only by the accompanying claims and equivalents thereof.

Claims

- [Claim 1] A light emitting device comprising:
a first conductive type semiconductor layer having a non-polar or semi-polar growth plane;
an SFS layer (stacking fault suppressed layer) disposed on the first conductive type semiconductor layer and including indium (In);
an active layer disposed on the SFS layer; and
a second conductive type semiconductor layer disposed on the active layer,
wherein the SFS layer includes a lower region and an upper region, the lower region and the upper region having a relationship satisfying Equation 1.
([Equation 1]
 $0.8 \leq R_D < 1.0$,
(R_D = standard deviation of In atomic density of the upper region per unit volume (1 nm³)/standard deviation of In atomic density of the lower region per unit volume (1 nm³))
- [Claim 2] The light emitting device of claim 1, wherein the SFS layer includes a stack structure in which a first nitride layer and a second nitride having smaller bandgap energy than the first nitride layer and including indium are stacked in one or more cycles, and
the second nitride layer includes a lower region and an upper region, the lower region and the upper region of the second nitride layer having a relationship satisfying Equation 2.
([Equation 2]
 $0.8 \leq R_{D2} < 1.0$,
(R_{D2} = standard deviation of In atomic density of the upper region of the second nitride layer per unit volume (1 nm³)/standard deviation of In atomic density of the lower region of the second nitride layer per unit volume (1 nm³))
- [Claim 3] The light emitting device of claim 1, wherein the non-polar growth plane includes an m-plane and the semi-polar growth plane includes a {20-2-1} or {30-3-1} plane.
- [Claim 4] The light emitting device of claim 1, wherein the non-polar or semi-polar growth plane has an off-angle in the range of -10° to +10°.
- [Claim 5] The light emitting device of claim 1, wherein the SFS layer has an indium concentration varying in a thickness direction thereof such that

a middle section of the SFS layer has the highest indium content in the SFS layer, and an upper surface of the SFS layer has a lower indium content than the middle section of the SFS layer or the lowest indium content in the SFS layer.

[Claim 6] The light emitting device of claim 2, wherein the first nitride layer includes GaN and/or InGaN, and the second nitride layer includes InGaN.

[Claim 7] The light emitting device of claim 6, wherein the second nitride layer has an indium concentration varying in a thickness direction thereof such that a middle section of the second nitride layer has the highest indium content in the second nitride layer, and an upper surface of the second nitride layer has a lower indium content than the middle section of the second nitride layer, or has the lowest indium content in the second nitride layer.

[Claim 8] The light emitting device of claim 7, wherein the indium content of the upper surface of the second nitride layer is 80% or less the indium content of the middle section of the second nitride layer.

[Claim 9] The light emitting device of claim 1, wherein the SFS layer is doped with the same conductive type as the first conductive type semiconductor layer.

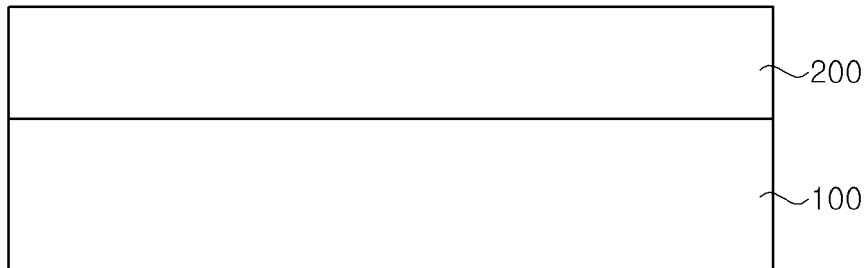
[Claim 10] The light emitting device of claim 1, wherein R_D is a value in the range of $0.91 \leq R_D \leq 1.0$.

[Claim 11] The light emitting device of claim 1, wherein the active layer is directly disposed on the SFS layer, or disposed within a distance of 100 nm from the SFS layer.

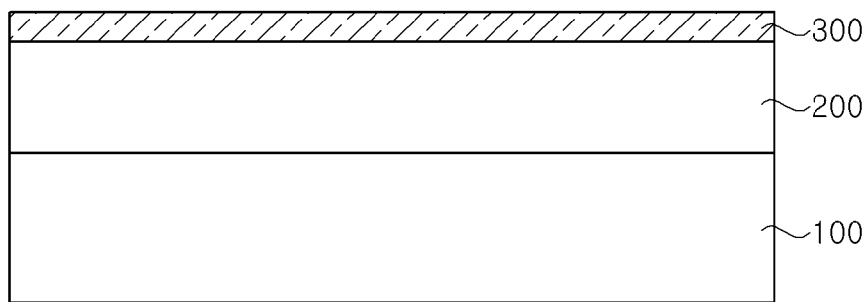
[Fig. 1]



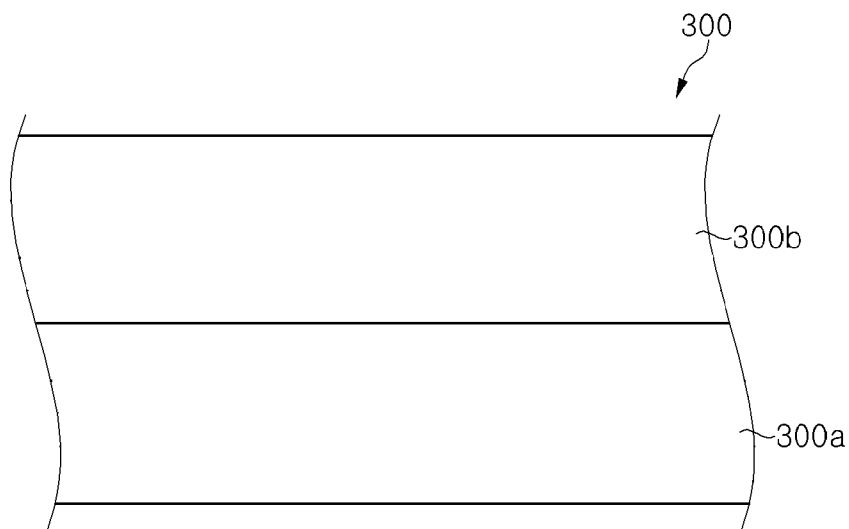
[Fig. 2]



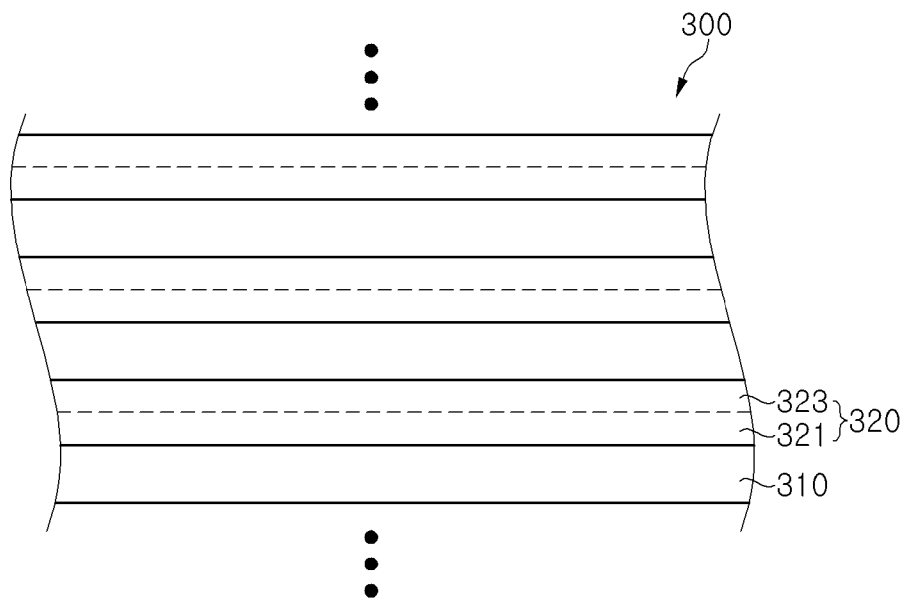
[Fig. 3]



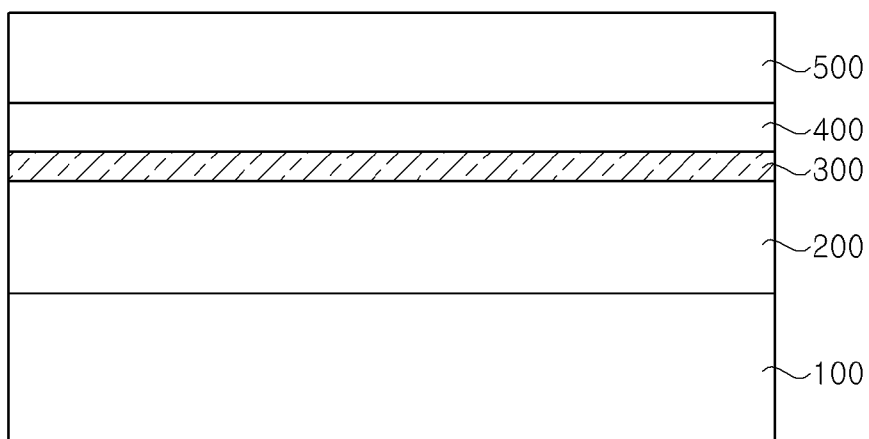
[Fig. 4a]



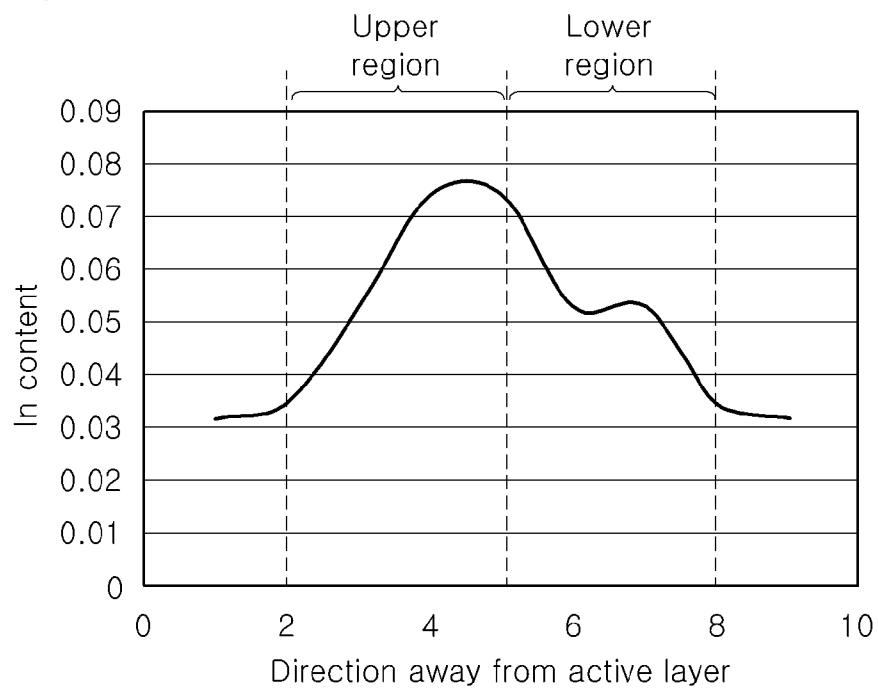
[Fig. 4b]



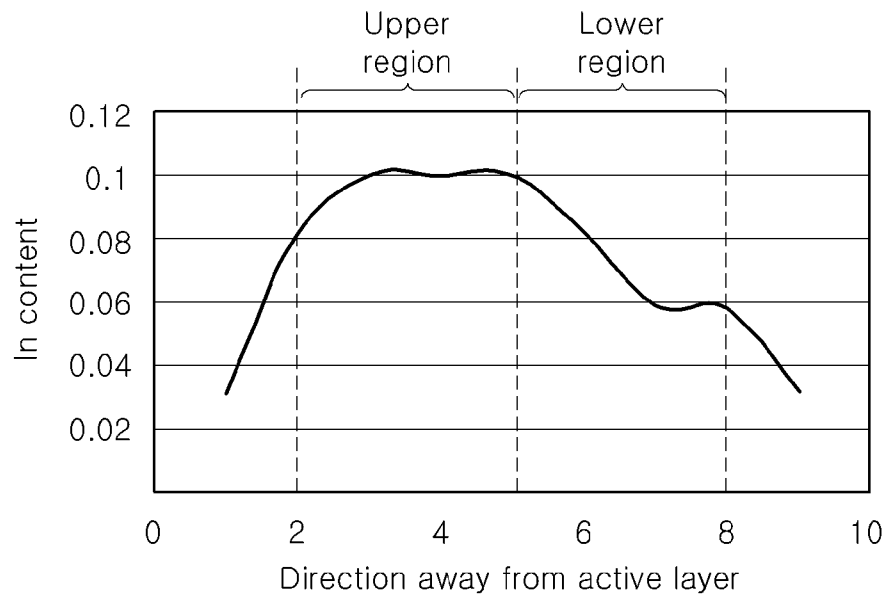
[Fig. 5]



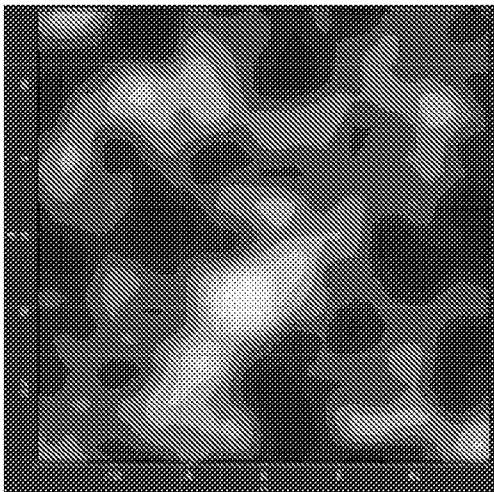
[Fig. 6]



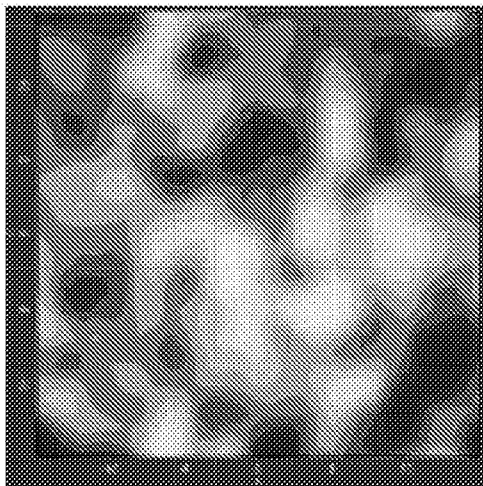
[Fig. 7]



[Fig. 8]

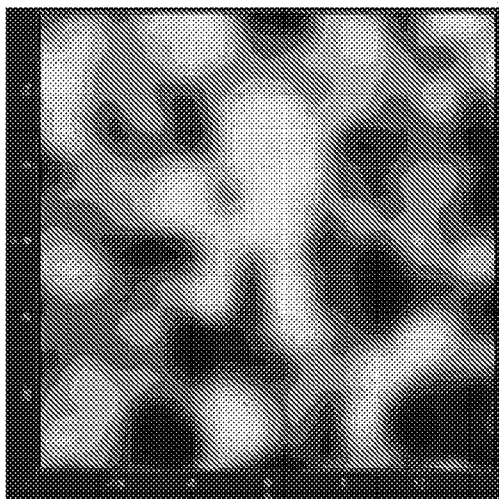


(a)

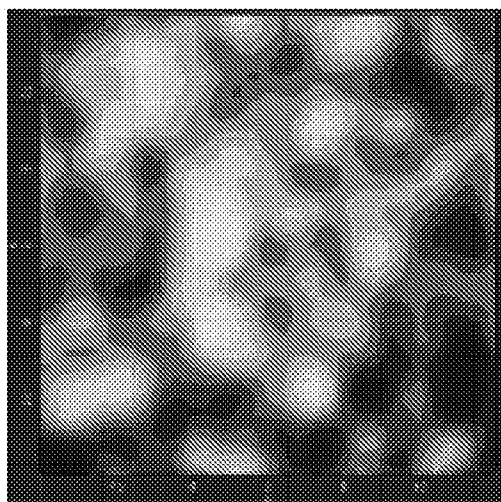


(b)

[Fig. 9]



(a)



(b)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2015/014123**A. CLASSIFICATION OF SUBJECT MATTER****H01L 33/12(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 33/12; H01L 21/324; H01L 21/20; H01L 29/04; H01L 49/00; H01L 33/32; H01L 33/00; H01L 33/02; H01L 33/04; H01L 33/06; 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: stacking fault, semi-polar, non-polar, indium, superlattice, 20-2-1 plane, 30-3-1 plane

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	KR 10-2010-0056601 A (SEOUL OPTO DEVICE CO., LTD.) 28 May 2010 See paragraphs 20-35, claims 1-10, and figure 1.	1-11
Y	US 2012-0286241 A1 (MATTHEW T. HARDY et al.) 15 November 2012 See abstract, paragraphs 85-95, claims 1-8, and figure 3.	1-11
Y	JP 5437538 B2 (PANASONIC CORP.) 20 December 2013 See paragraphs 62, 110-111, claim 1, and figures 1, 7.	3-4
A	KR 10-2013-0037265 A (KOREA PHOTONICS TECHNOLOGY INSTITUTE) 16 April 2013 See paragraphs 14-31, claims 1-4, and figure 5.	1-11
A	US 2013-0082279 A1 (JEAN-PIERRE FAURIE et al.) 04 April 2013 See paragraphs 71-75, claim 63, and figures 6A-6B.	1-11



Further documents are listed in the continuation of Box C.



See patent family annex.

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

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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Date of the actual completion of the international search

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Date of mailing of the international search report

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International Application Division

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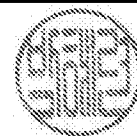
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

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