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(54) LIGHT EMITTING ELEMENT AND PRODUCTION METHOD THEREFOR

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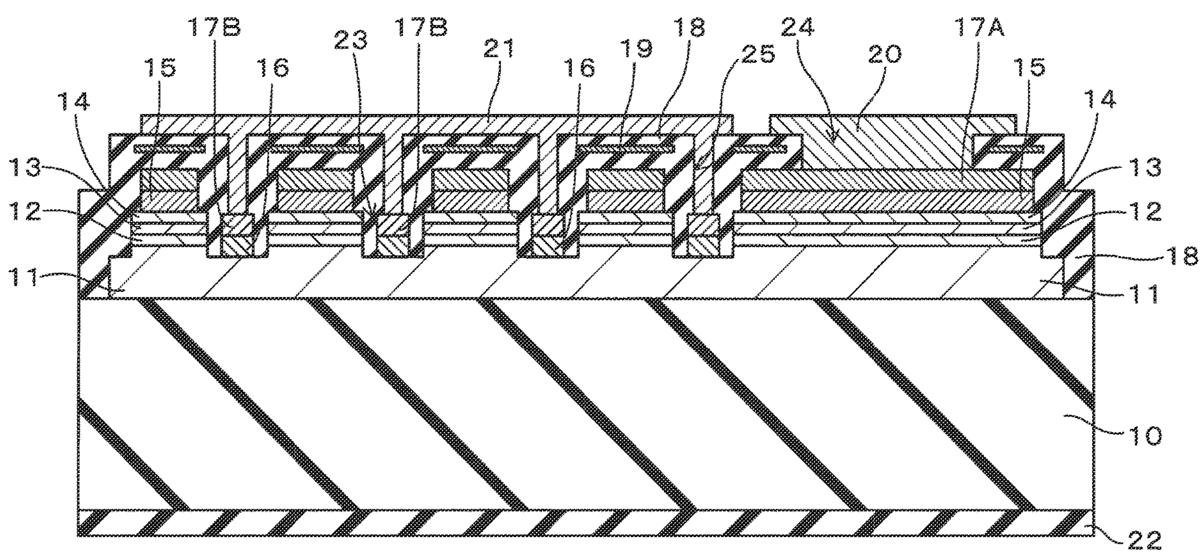
(57) ABSTRACT

A method for producing a light emitting element, includes: stacking an n layer, a light emitting layer, and a p layer in this order, on a substrate; forming a hole having a depth reaching the n layer at a predetermined region of a surface of the p layer; forming, over the p layer, a p electrode having a Ru layer in contact with the p layer; forming an n electrode as defined herein; and performing a heat treatment as defined herein to reduce a contact resistance of the p electrode and the n electrode and to activate a p-type impurity in the p layer, and a pattern of the hole and a pattern of the p electrode are set such that a proportion of an area of the p electrode to a total area of the hole and the p layer is 70% or more.



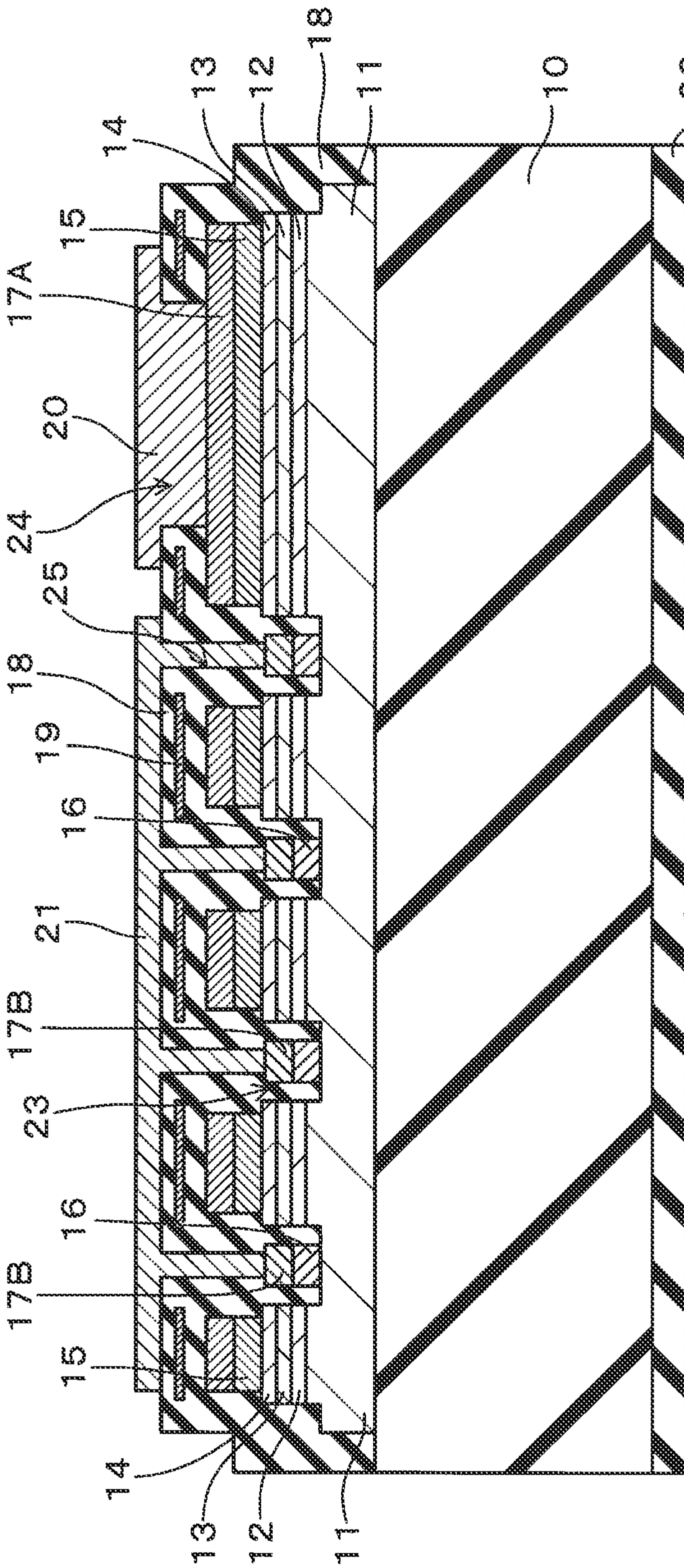

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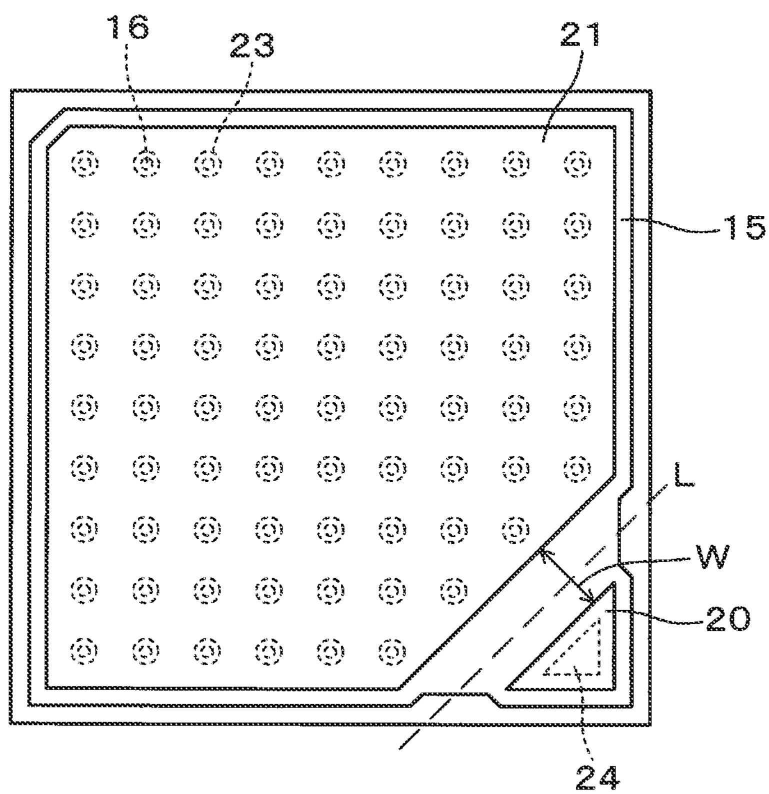
FIG. 1

FIG. 2



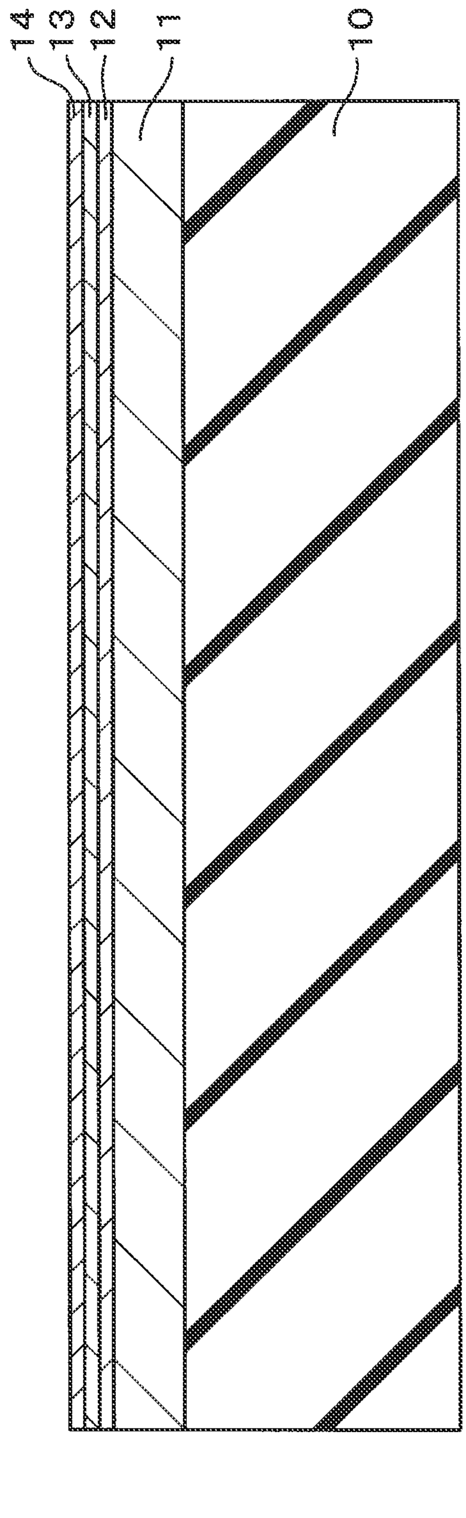


FIG. 3

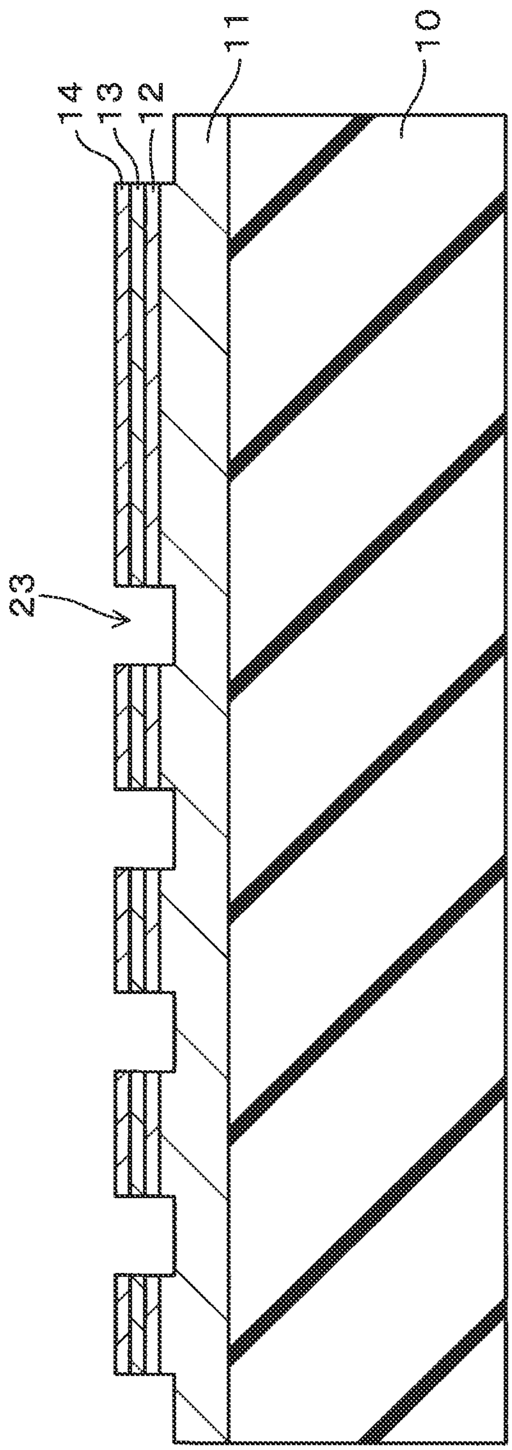


FIG. 4

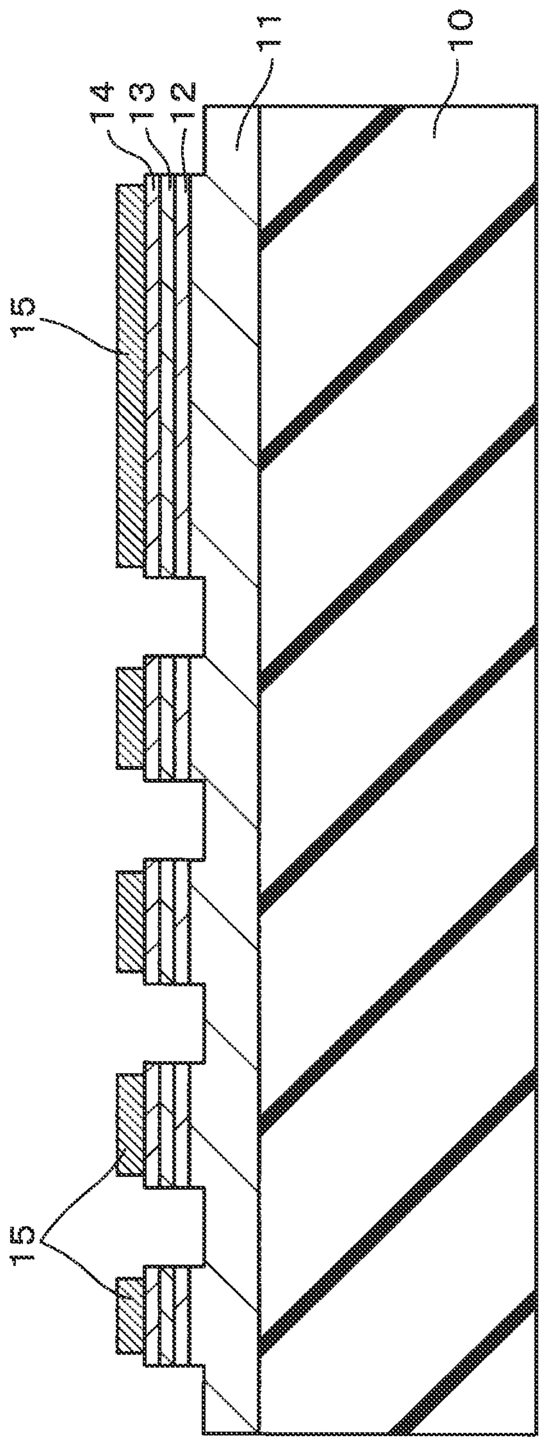


FIG. 5

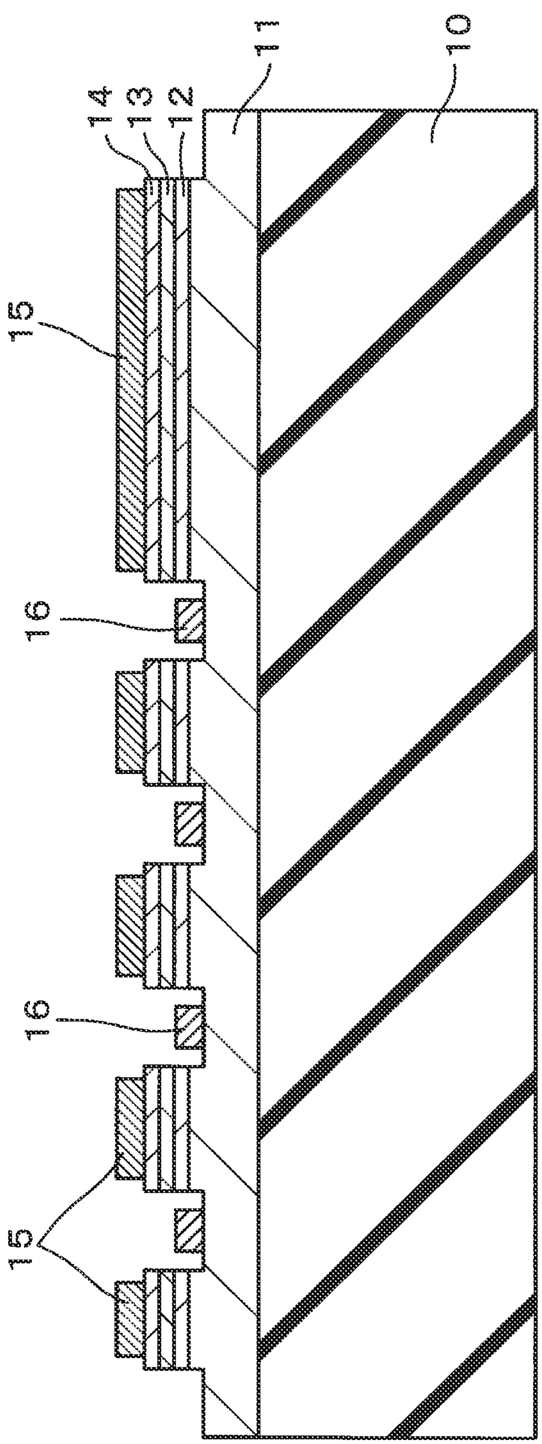


FIG. 6

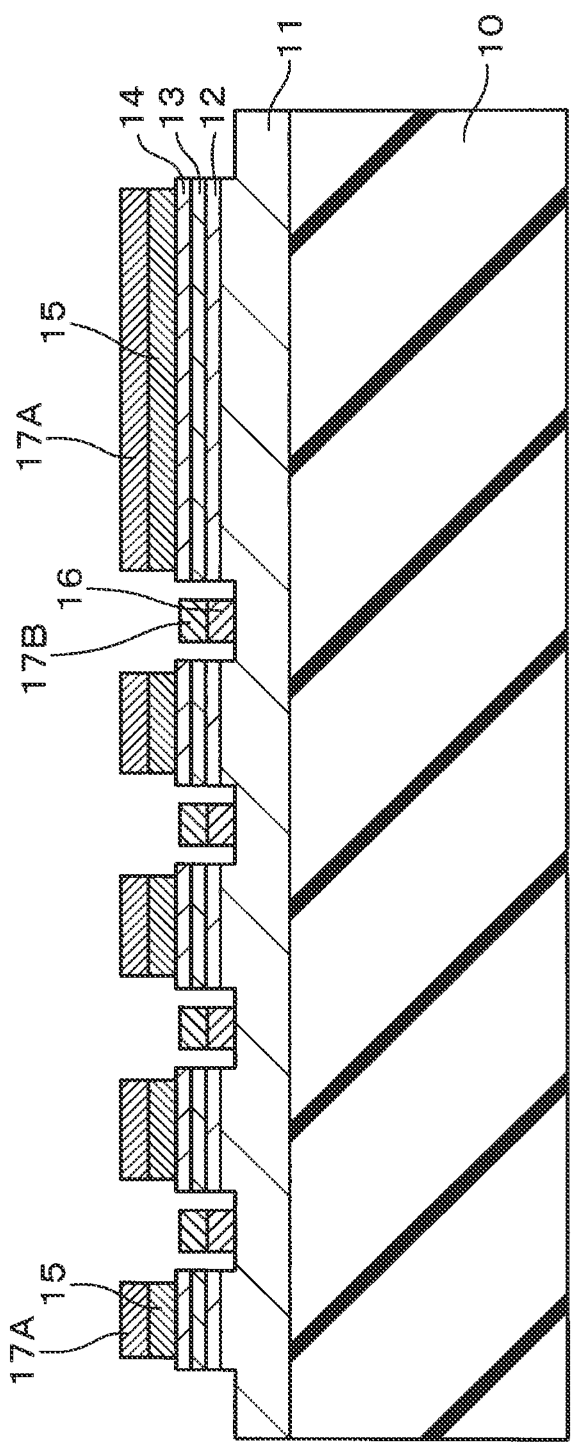


FIG. 7

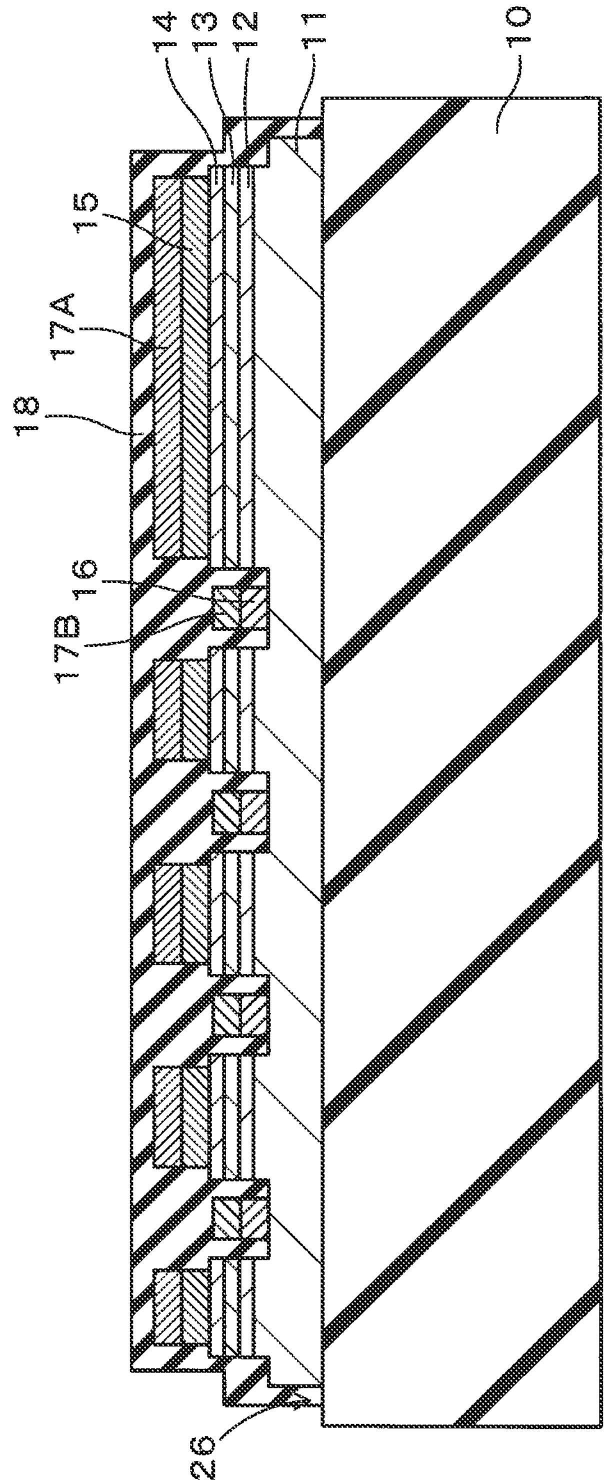


FIG. 8

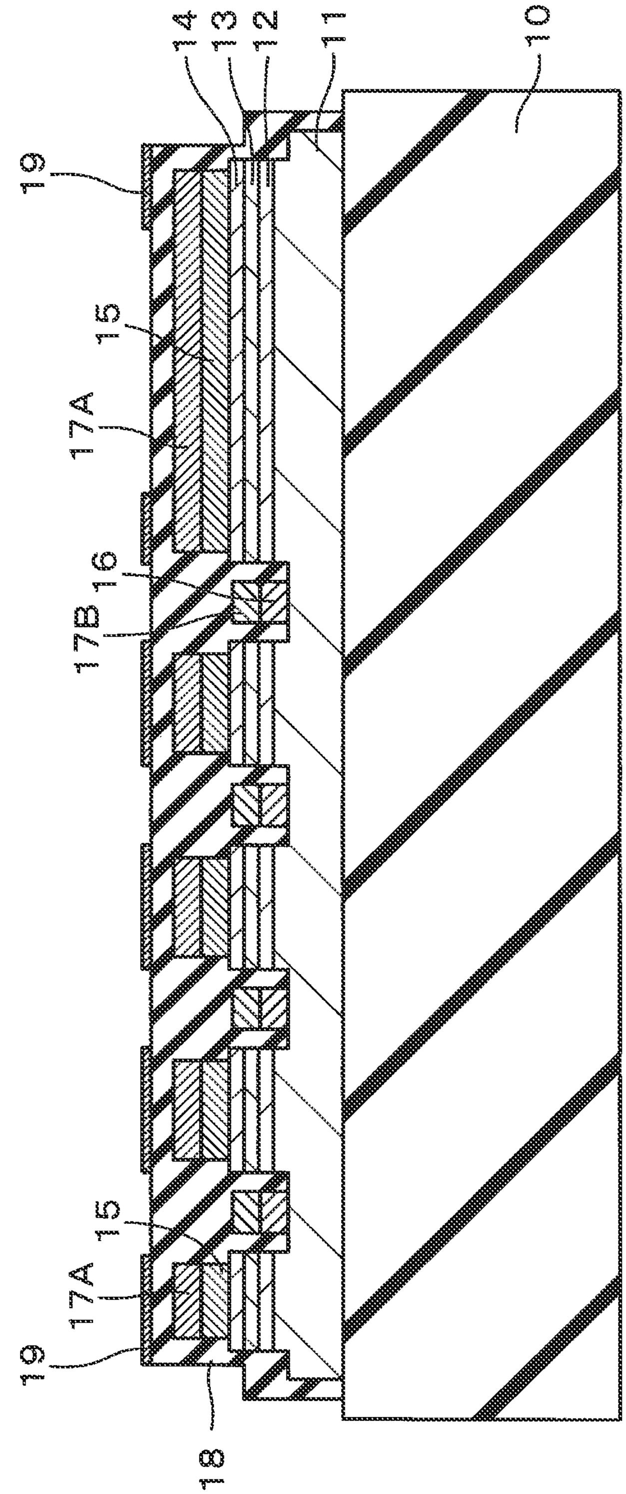


FIG. 9

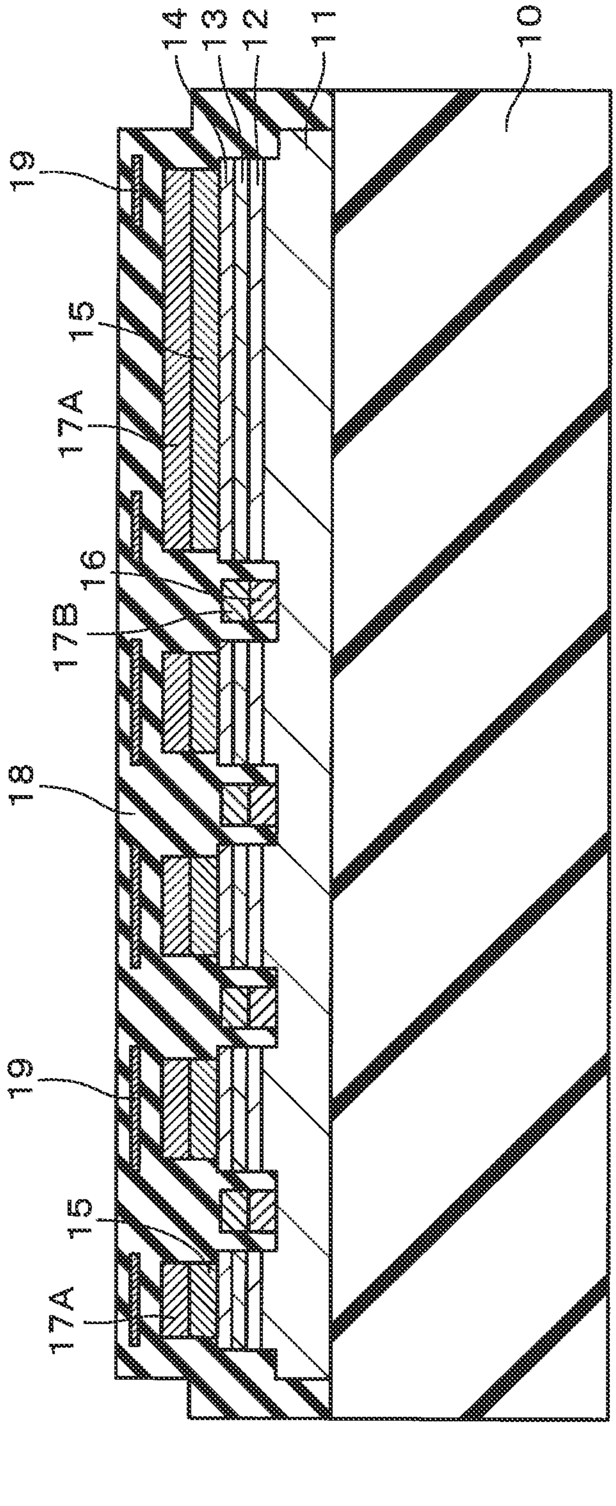


FIG. 10

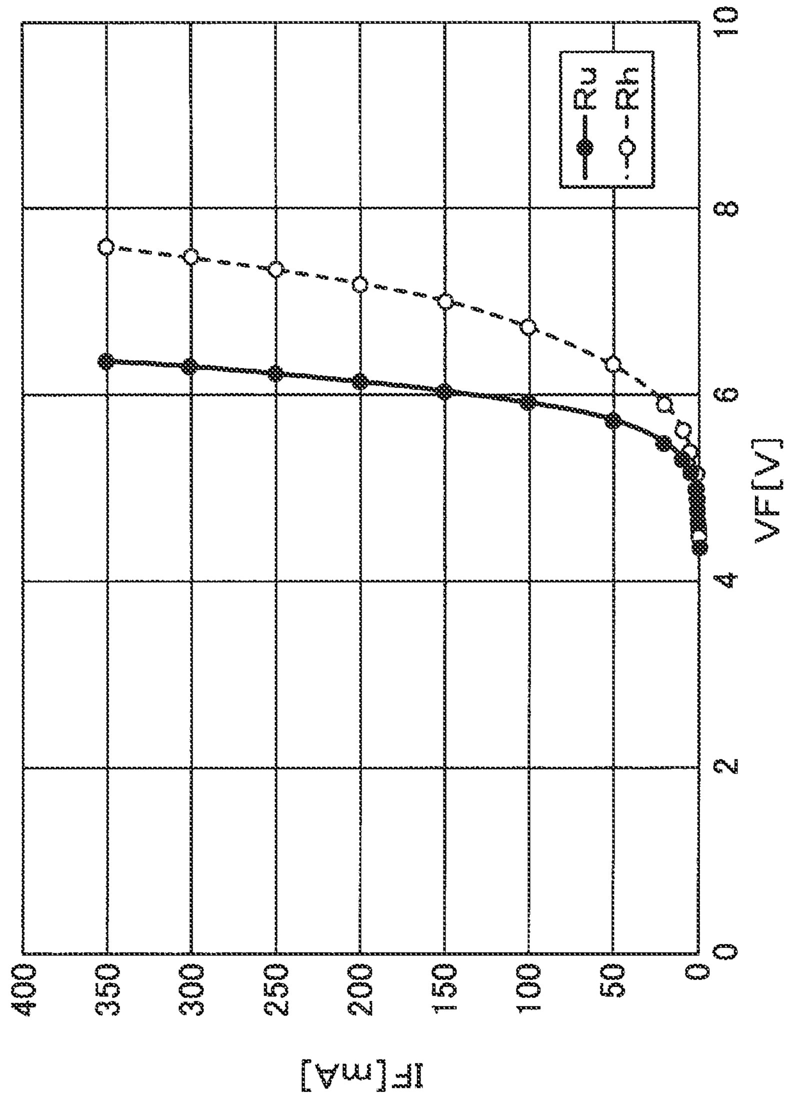


FIG. 11

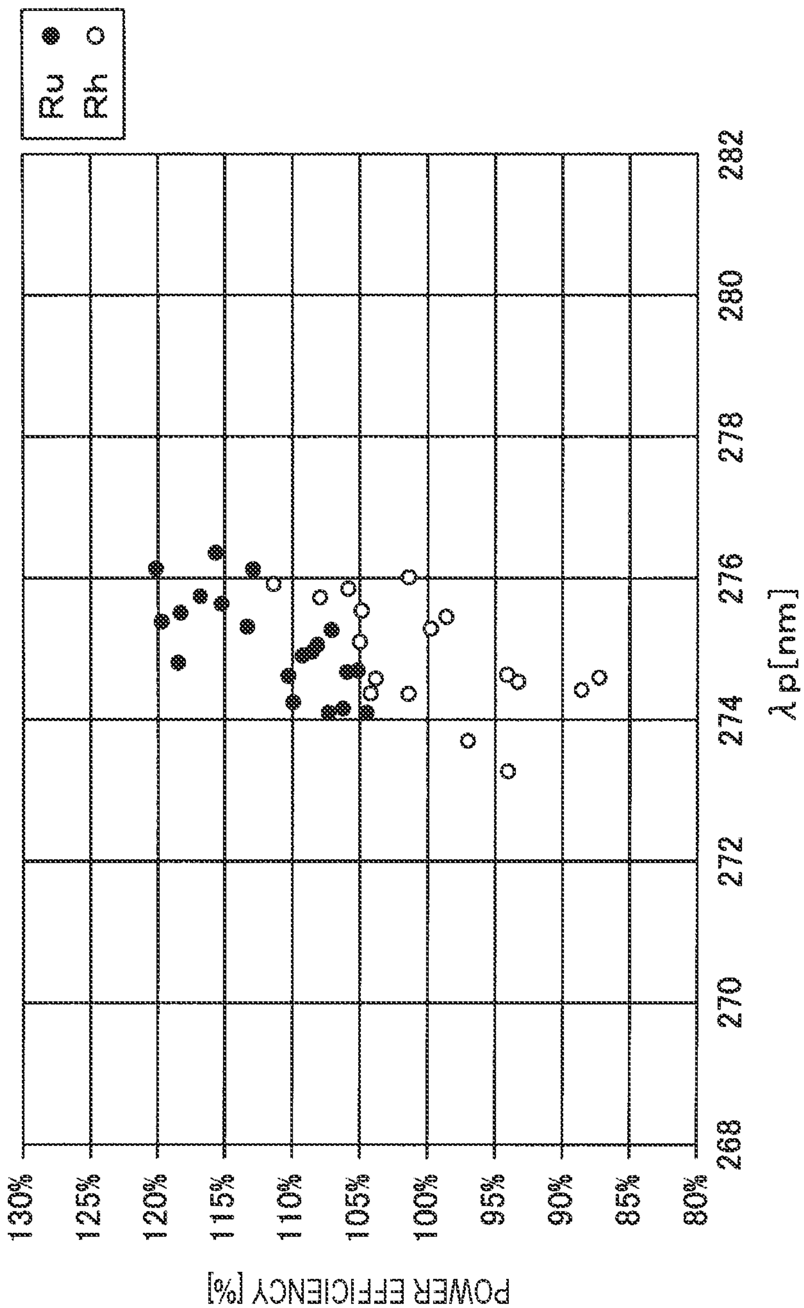

Ru
Rh
POWER EFFICIENCY [%]
130%
125%
120%
115%
110%
105%
100%
95%
90%
85%
80%
268
270
272
274
276
278
280
282
λp [nm]

FIG. 12

FIG. 13

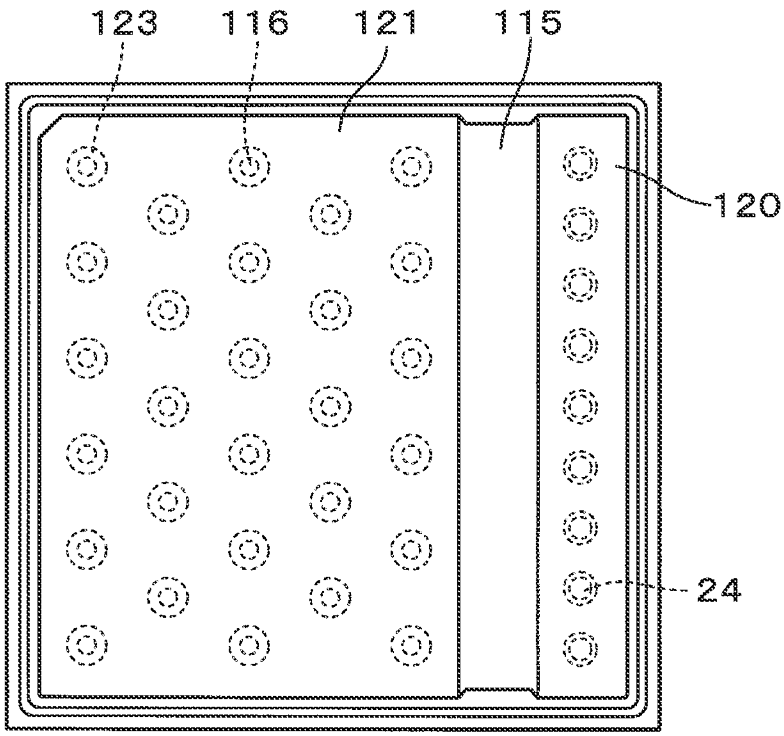


FIG. 14

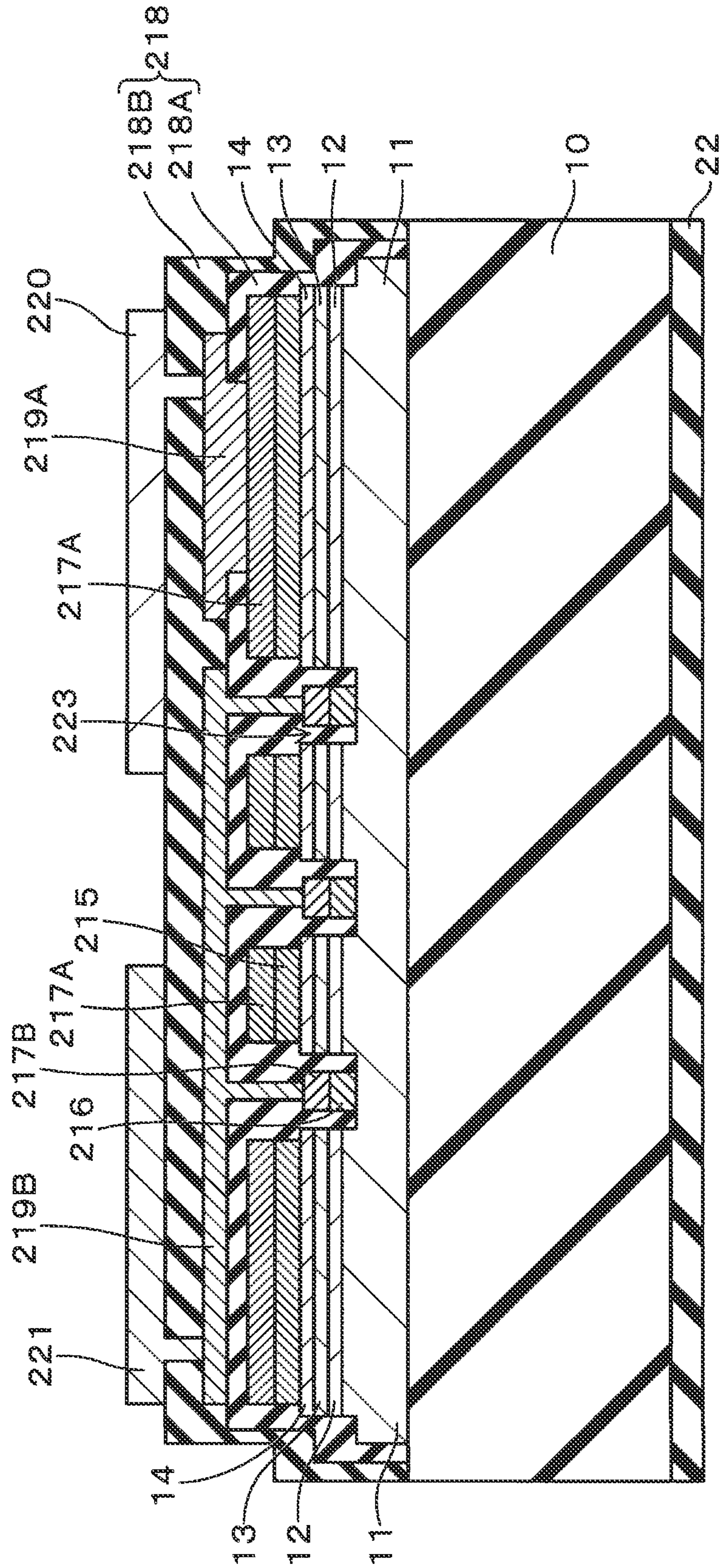

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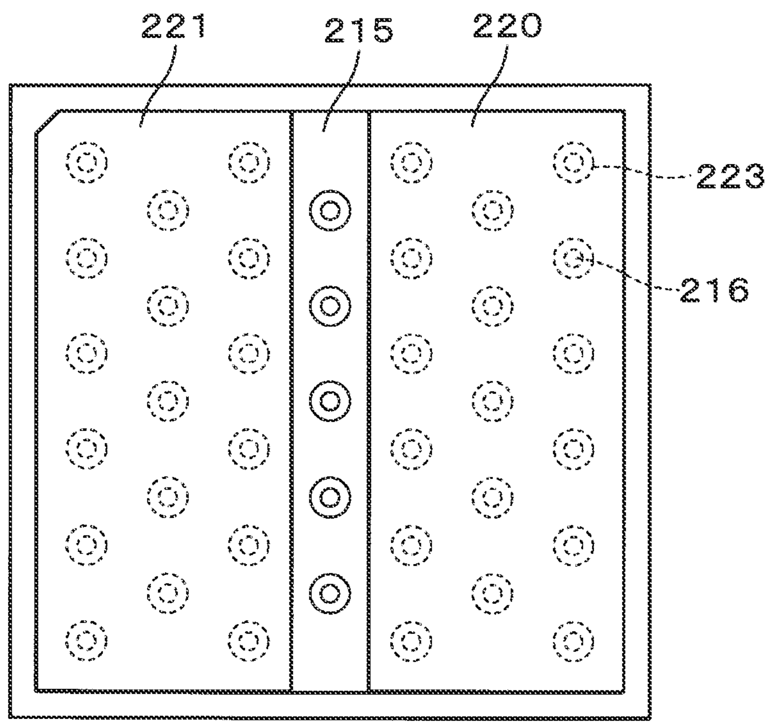
FIG. 15



LIGHT EMITTING ELEMENT AND PRODUCTION METHOD THEREFOR

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application is based on and claims priority under 35 USC 119 from Japanese Patent Application No. 2023-047893 filed on Mar. 24, 2023.

TECHNICAL FIELD

[0002] The present invention relates to a light emitting element and a production method therefor.

BACKGROUND ART

[0003] In recent years, the use of ultraviolet LEDs for sterilization and disinfection of water, air, and the like is attracting attention, and research and development toward higher efficiency of ultraviolet LEDs are actively conducted.

[0004] In a conventional light emitting element made of a group III nitride semiconductor, ITO or Ni/Au is widely used as a p electrode in contact with a p layer. These materials have a low reflectance in UVC (200 nm to 280 nm). Therefore, in UVC light emitting elements, studies have been made to using Rh or Ru, which has a high reflectance, as a p electrode (JP2020-64955A). In addition, Ti/Al is widely used as an n electrode in contact with the n layer, and it is also known to use V as in JP2003-77862A.

SUMMARY OF INVENTION

[0005] However, the UVC light emitting elements have low power efficiency, and improvements have been required. In order to increase the power efficiency, it is necessary to both improve light extraction efficiency and reduce a forward voltage Vf, which has been difficult to achieve.

[0006] The present invention has been made in view of such a background, and an object thereof is to provide a UVC light emitting element having high power efficiency, and a production method therefor.

[0007] An aspect of the present invention is directed to a method for producing a light emitting element which includes a group III nitride semiconductor containing Al and has an emission wavelength of 200 nm to 280 nm, comprising:

[0008] a semiconductor layer forming step of stacking an n layer, a light emitting layer, and a player in this order, on a substrate;

[0009] a hole forming step of forming a hole having a depth reaching the n layer at a predetermined region of a surface of the p layer;

[0010] a p electrode forming step of forming, over the p layer, a p electrode having a Ru layer in contact with the p layer;

[0011] an n electrode forming step of forming an n electrode over the n layer exposed on a bottom surface of the hole, the n electrode having a V layer that is in contact with the n layer, that has a thickness of 5 nm or more and 15 nm or less, and that comprises V or a metal containing V as a main component, and an Al layer that is on and in contact with the V layer and that comprises Al or a metal containing Al as a main component; and

[0012] a heat treatment step of performing a heat treatment at a temperature of 500° C. to 650° C. for 1 to 10 minutes to reduce a contact resistance of the p electrode and the n electrode and to activate a p-type impurity in the p layer, wherein

[0013] a pattern of the hole and a pattern of the p electrode are set such that a proportion of an area of the p electrode to a total area of the hole and the p layer is 70% or more.

[0014] Another aspect of the present invention is directed to a light emitting element which comprises a group III nitride semiconductor containing Al and has an emission wavelength of 200 nm to 280 nm, the light emitting element comprising:

[0015] a substrate;

[0016] a semiconductor layer, in which an n layer, a light emitting layer, and a p layer are stacked in this order over the substrate;

[0017] a hole provided at a predetermined region of a surface of the p layer and having a depth reaching the n layer;

[0018] a p electrode having a Ru layer provided on and in contact with the p layer; and

[0019] an n electrode provided over the n layer exposed on a bottom surface of the hole, the n electrode having a first layer that is located in contact with the n layer, that comprises AlN_x or $Al_yGa_{1-y}N_x$ having a higher Al composition than the n layer, and that has a thickness of 1 nm or more and 3 nm or less, and a second layer that is located on and in contact with the first layer, that comprises a metal mainly containing Al and containing V, and that has a thickness of 50 nm or more and 500 nm or less, wherein

[0020] a pattern of the hole and a pattern of the p electrode are set such that a proportion of an area of the p electrode to a total area of the hole and the player is 70% or more.

[0021] According to the above aspects, when the area of the p electrode made of Ru is increased, it is possible to increase reflection of ultraviolet rays by the p electrode and improve the light extraction efficiency. In addition, both the p electrode and the n electrode have low contact resistance and the forward voltage can be reduced. Therefore, the power efficiency of the UVC light emitting element can be improved.

BRIEF DESCRIPTION OF DRAWINGS

[0022] FIG. **1** is a diagram showing a configuration of a light emitting element according to an embodiment, and is a cross-sectional view perpendicular to a substrate.

[0023] FIG. **2** is a diagram showing a plane pattern of an electrode.

[0024] FIG. **3** is a diagram showing a process for producing the light emitting element according to the embodiment.

[0025] FIG. **4** is a diagram showing the process for producing the light emitting element according to the embodiment.

[0026] FIG. **5** is a diagram showing the process for producing the light emitting element according to the embodiment.

[0027] FIG. **6** is a diagram showing the process for producing the light emitting element according to the embodiment.

[0028] FIG. **7** is a diagram showing the process for producing the light emitting element according to the embodiment.

[0029] FIG. **8** is a diagram showing the process for producing the light emitting element according to the embodiment.

[0030] FIG. **9** is a diagram showing the process for producing the light emitting element according to the embodiment.

[0031] FIG. **10** is a diagram showing the process for producing the light emitting element according to the embodiment.

[0032] FIG. **11** is a graph showing I-V characteristics of light emitting elements.

[0033] FIG. **12** is a graph (scatter diagram) showing emission wavelengths and power efficiency of light emitting elements.

[0034] FIG. **13** is a diagram showing an electrode pattern according to a first modification.

[0035] FIG. **14** is a diagram showing a configuration of a light emitting element according to a second modification of the embodiment, and is a cross-sectional view perpendicular to a substrate.

[0036] FIG. **15** is a diagram showing an electrode pattern according to the second modification.

DETAILED DESCRIPTION OF THE INVENTION

[0037] A method for producing a light emitting element according to the present invention is a method for producing a light emitting element which includes a group III nitride semiconductor containing Al and has an emission wavelength of 200 nm to 280 nm. The method includes: a semiconductor layer forming step of stacking an n layer, a light emitting layer, and a player in this order, on a substrate; a hole forming step of forming a hole having a depth reaching the n layer in a predetermined region on a surface of the p layer; a p electrode forming step of forming, on the p layer, a p electrode having a Ru layer in contact with the p layer; an n electrode forming step of forming an n electrode on the n layer exposed on a bottom surface of the hole, the n electrode having a V layer that is in contact with the n layer, that has a thickness of 5 nm or more and 15 nm or less, and that contains V or a metal containing V as a main component, and an Al layer that is on and in contact with the V layer and contains Al or a metal containing Al as a main component; and a heat treatment step of performing a heat treatment at a temperature of 500° C. to 650° C. for 1 to 10 minutes to reduce contact resistance of the p electrode and the n electrode and to activate a p-type impurity in the player. A pattern of the hole and a pattern of the p electrode are set such that a proportion of an area of the p electrode to a total area of the hole and the p layer is 70% or more.

[0038] The hole may be formed at plural locations, an arrangement pattern of the holes may be a square lattice, an equilateral triangular lattice, or a honeycomb shape, and the n electrode may be formed on a bottom surface of each hole.

[0039] The method may further includes: a pn electrode forming step of forming a first pn electrode and a second pn electrode on the p electrode and the n electrode, respectively, after the heat treatment step; a protective film forming step of forming a protective film, which is an insulator, to cover an entire upper surface of the element; and a pad electrode forming step of providing holes at predetermined positions of the protective film, and forming, over the protective film, a p pad electrode connected to the first pn electrode via one of the holes, and forming an n pad electrode connected to the second pn electrode via other of the holes and spaced apart from the p pad electrode.

[0040] The light emitting element is made of a group III nitride semiconductor and has an emission wavelength of 200 nm to 280 nm. The light emitting element includes: a substrate; a semiconductor layer, in which an n layer, a light emitting layer, and a p layer are stacked in this order, on a substrate; a hole provided in a predetermined region on a surface of the p layer and having a depth reaching the n layer; a p electrode having a Ru layer provided on and in contact with the p layer; and an n electrode provided on the n layer exposed on a bottom surface of the hole, the n electrode having a first layer that is located in contact with the n layer, that is made of AlN_x or $Al_yGa_{1-y}N_x$ having a higher Al composition than the n layer, and that has a thickness of 1 nm or more and 3 nm or less, and a second layer that is located in contact with the first layer, that is made of a metal mainly containing Al and containing V, and that has a thickness of 50 nm or more and 500 nm or less. A pattern of the hole and a pattern of the p electrode are set such that a proportion of an area of the p electrode to a total area of the hole and the p layer is 70% or more.

[0041] The hole may be formed in plural, an arrangement pattern of the holes may be a lattice, and the n electrode may be formed on a bottom surface of each hole.

[0042] The light emitting element may further includes: a first pn electrode and a second pn electrode provided on the p electrode and the n electrode, respectively; a protective film, which is an insulator, configured to cover an entire upper surface of the element; a p pad electrode provided on the protective film and connected to the first pn electrode via a hole provided in the protective film; and an n pad electrode provided on the protective film, connected to the second pn electrode via a hole provided in the protective film, and spaced apart from the p pad electrode.

Embodiment

[0043] FIG. **1** is a diagram showing a configuration of a light emitting element according to an embodiment, and is a cross-sectional view perpendicular to a substrate. FIG. **2** is a diagram showing a plane pattern of an electrode of the light emitting element according to the embodiment. The light emitting element according to the embodiment is a flip-chip type ultraviolet light emitting element, and has an emission wavelength of UVC, for example, 200 nm to 280 nm.

1. Configuration of Light Emitting Element

[0044] As shown in FIG. **1**, the light emitting element according to the embodiment includes a substrate **10**, an n layer **11**, a light emitting layer **12**, an electron blocking layer **13**, a p layer **14**, a p electrode **15**, n electrodes **16**, pn electrodes **17**A and **17**B, a protective film **18**, a reflective film **19**, a p pad electrode **20**, an n pad electrode **21**, and an antireflection film **22**. Hereinafter, each configuration will be described.

[0045] The substrate **10** is a substrate made of sapphire and having a c plane as a main surface. Other than sapphire, any material may be used as long as the material has a high transmittance with respect to the emission wavelength and can grow a group III nitride semiconductor.

[0046] The antireflection film **22** is provided on a back surface (a surface opposite to the n layer **11**, a light extraction side) of the substrate **10**. By providing the antireflection film **22**, it is possible to prevent ultraviolet rays from being reflected on the back surface of the substrate **10** and returning to an element side, thereby improving light extraction. The antireflection film **22** is, for example, SiO_2 having a thickness of ¼ of the emission wavelength.

[0047] The n layer **11** is located on the substrate **10** with a buffer layer (not shown) interposed therebetween. The n layer **11** is made of n-AlGaN. An n-type impurity is Si, and a Si concentration is $5\times10^{18}/cm^3$ to $5\times10^{19}/cm^3$. The n layer **11** may include a plurality of layers.

[0048] The light emitting layer **12** is located on the n layer **11**. The light emitting layer **12** has an MQW structure in which a well layer and a barrier layer are alternately and repeatedly stacked. The number of repetitions is, for example, 2 to 5. The well layer is made of AlGaN, and an Al composition thereof is set according to a desired emission wavelength. The barrier layer is made of AlGaN having an Al composition higher than that of the well layer. AlGaInN having band gap energy larger than that of the well layer may also be used. The light emitting layer **12** may have an SQW structure.

[0049] The electron blocking layer **13** is located on the light emitting layer **12**. The electron blocking layer **13** is made of p-AlGaN having an Al composition ratio higher than that of the barrier layer of the light emitting layer **12**. The electron blocking layer **13** prevents electrons injected from the n electrode **16** from passing beyond the light emitting layer **12** and diffusing toward the p layer **14**.

[0050] The p layer **14** is located on the electron blocking layer **13**. The p layer **14** is made of p-AlGaN. In the light emitting element according to the embodiment, all semiconductor layers from the n layer **11** to the p layer **14** are made of AlGaN, and accordingly absorption of ultraviolet rays by the semiconductor layers is prevented. The Al composition in the p layer **14** is, for example, 5% to 80%. A p-type impurity is Mg. A Mg concentration is $1\times10^{19}/cm^3$ or more. The p layer **14** may include a plurality of layers having different Al compositions and Mg concentrations. In this case, a layer in contact with the p electrode **15** is made of p-AlGaN having an Al composition of 5% to 80%. The p layer **14** is not limited to AlGaN, and may be made of a group III nitride semiconductor containing Al, and may be made of AlGaInN.

[0051] A hole **23** having a depth reaching the n layer **11** is formed in a partial region on a surface of the p layer **14**. The hole **23** is dot-shaped, and a plurality of holes **23** are arranged in a lattice pattern (see FIG. **2**). However, the hole **23** is not provided in a region corresponding to a lower part of the p electrode **15**. The n layer **11** is exposed on a bottom surface of the hole **23**. When the holes **23** for exposing the n layer **11** are formed in a dot-shaped arrangement pattern, a reduction in a light emitting area (an area of the p layer **14**) due to the holes **23** is reduced as much as possible while in-plane light emission is ensured, and a light output is improved.

[0052] A plane pattern of each hole **23** is, for example, a circle. Alternatively, a polygon such as a regular hexagonal shape may be used. In the case of a regular hexagonal shape, a side surface of the hole **23** is preferably an m plane. The arrangement pattern of the holes **23** is an equilateral triangular lattice. In addition, for example, a square lattice or a honeycomb-shaped pattern may be used.

[0053] The p electrode **15** is provided on the p layer **14**. The p electrode **15** is provided on the surface of the p layer **14** except for a region where the hole **23** is not provided and the vicinity of edges of the p layer **14** (see FIG. **2**), thereby ensuring a wide light emitting area. The p electrode **15** is a reflective electrode that increases light extraction efficiency by reflecting ultraviolet rays emitted from the light emitting layer **12** toward the substrate **10**. A material of the p electrode **15** is Ru. An alloy containing Al as a main component may also be used. Ru has a high reflectance in UVC and low contact resistance to the player **14** made of p-AlGaN, and is thus suitable as the p electrode **15** in a UVC light emitting element.

[0054] A proportion of an area of the p electrode **15** to an area of an upper surface of the element (a total area of the holes **23** and the p layer **14**) is 70% or more. Plane patterns of the holes **23** and the p electrode **15** are set to satisfy the above. For example, a diameter, the number of arrays, and an arrangement interval of the holes **23** are adjusted. When the area of the p electrode **15** made of Ru is increased, it is possible to increase reflection of ultraviolet rays by the p electrode **15** and improve the light extraction efficiency. It is more preferably 75% or more. The n electrode **16** is provided on the n layer **11** exposed on the bottom surface of each hole **23**. Therefore, the n electrodes **16** also have a dot-shaped arrangement pattern (see FIG. **2**). A material of the n electrode **16** is a V/Al/Ti structure subjected to a heat treatment. In addition, Ti/Al/Ti can be used. Specifically, the V/Al/Ti structure subjected to a heat treatment has a structure in which a layer made of AlN_x, a layer made of a metal mainly containing Al and containing V and Ti, and a layer made of Ti are stacked in this order.

[0055] The layer made of AlN_x has a thickness of 1 nm to 3 nm. x is, for example, 0.4 to 0.7. In addition, x may decrease as a distance from the n layer **11** increases in a thickness direction. In this case, an average of x in the thickness direction is 0.4 to 0.7. Ga may be diffused from the n layer **11**, and in this case, $Al_yGa_{1-y}N_x$ ($0.4\leq x\leq 0.7$) having a higher Al composition ratio than the n layer **11** is used. When the Al composition ratio in the n layer **11** is a, $a<y\leq 1$. y is, for example, 0.7 or more. In this case, x may also decrease as the distance from the n layer **11** increases in the thickness direction, and y may increase as the distance from the n layer **11** increases in the thickness direction.

[0056] The layer made of a metal mainly containing Al and containing V and Ti has a thickness of 50 nm to 500 nm. The ratio of Al, V, and Ti is, for example, 50 mol % to 85 mol % for Al, 5 mol % to 20 mol % for V, and 10 mol % to 30 mol % for Ti.

[0057] In the n electrode **16** having the above structure, the contact resistance to the n layer **11** is reduced. For example, the contact resistance of the n electrode **16** to the n layer **11** is $4\times10^{-4}\ \Omega\cdot cm^2$ or less. A reason for this is considered to be, firstly, that the layer made of AlN_x functions as a good contact layer for the n layer **11**. Secondly, it is considered that nitrogen vacancies are generated in a surface of the n layer **11**, and the contact resistance is reduced because of being n-type.

[0058] The layer made of Ti is provided as a cover to prevent Al in the n electrode **16** from evaporating during alloying. In addition to Ti, TiN, Ni, Pt, Au, or the like can be used.

[0059] The pn electrodes **17**A and **17**B are provided on the p electrode **15** and the n electrode **16**, respectively. A plane pattern of the pn electrode **17**A is the same as the plane pattern of the p electrode **15**. A plane pattern of the pn electrode **17**B is the same as the plane pattern of the n electrode **16**, and is a pattern in which a plurality of dots are arranged. A material of the pn electrodes **17**A and **17**B is, for example, Ti/Ni/Au/Al.

[0060] The protective film **18** is provided to cover the entire upper surface of the element. That is, it is provided continuously on side surfaces and surfaces of the p electrode **15** and the n electrode **16**, surfaces and side surfaces of the semiconductor layers, side surfaces of an element isolation groove **26**, and insides of the holes **23**.

[0061] The protective film **18** is an insulator, for example SiO_2. In addition, SiN, Al_2O_3, TiO_2, and AlN, can be used. The protective film **18** may be obtained by stacking a plurality of materials.

[0062] The reflective film **19** made of Al is provided in the protective film **18**. The reflective film **19** is entirely provided except for regions where holes **24** and **25**, which will be described later, are present. Light is reflected toward the substrate **10** by the reflective film **19** to improve the light extraction efficiency. In addition, heat dissipation of the protective film **18** is improved. A reason why the reflective film **19** is embedded in the protective film **18** is to prevent migration.

[0063] A material of the reflective film **19** is not limited to Al, and may be any material that has a high reflectance in the emission wavelength. An alloy containing mainly Al may be used.

[0064] The p pad electrode **20** and the n pad electrode **21** are spaced apart from each other on the protective film **18**. The p pad electrode **20** is connected to the pn electrode **17**A via the hole **24** formed in the protective film **18**. The n pad electrode **21** is connected to the pn electrode **17**B via the hole **25** formed in the protective film **18**. A material of the p pad electrode **20** and the n pad electrode **21** is, for example, Ti/Pt/Au/AuSn.

[0065] For plane patterns of the p pad electrode **20** and the n pad electrode **21**, a rectangular pattern slightly inside a rectangular pattern of the element is divided into two by a linear region having a width W along a straight line L forming an angle of 45° with respect to sides of the rectangle at a corner of the rectangle, one part forming an isosceles right triangle pattern is the p pad electrode **20**, and the other part (a pentagon with the corner of the rectangle cut off) is the n pad electrode **21**.

[0066] The angle of the linear region is not limited to 45°, and is preferably close to 45°, and is preferably, for example, 30° to 60°, and more preferably 40° to 50° in order to increase a sum of areas of the p pad electrode **20** and the n pad electrode **21** as much as possible.

[0067] The position and the width W of the linear region is preferably set such that the sum of the areas of the p pad electrode **20** and the n pad electrode **21** is 90% or more of the light emitting area (the area of the p electrode **15**). Of course, the width W is set to such a width that no short circuit occurs between the p pad electrode **20** and the n pad electrode **21**. For example, the width W is 100 μm or more. Further, the p pad electrode **20** has a size that allows good bonding to a sub-mount side. For example, the length of two equal sides of the isosceles right triangle for the p pad electrode **20** is 200 μm or more.

[0068] When the plane patterns of the p pad electrode **20** and the n pad electrode **21** are set as described above, the sum of the areas of the p pad electrode **20** and the n pad electrode **21** can be increased, and the heat dissipation performance can be improved.

[0069] In the above light emitting element according to the embodiment, Ru is used as the material of the p electrode **15**, and the proportion of the area of the p electrode **15** to the area of the upper surface of the element is 70% or more, and accordingly, the light extraction is improved. In addition, both the p electrode **15** and the n electrode **16** have low contact resistance and a forward voltage can be reduced. Therefore, the power efficiency of the light emitting element can be improved.

2. Process for Producing Light Emitting Element

[0070] A process for producing the light emitting element according to the embodiment will be described with reference to the drawings.

[0071] First, the substrate **10** made of sapphire is prepared. Then, the n layer **11**, the light emitting layer **12**, the electron blocking layer **13**, and the p layer **14** are formed in this order on the substrate **10** by a MOCVD method (see FIG. **3**).

[0072] Next, predetermined regions in the p layer **14** are dry-etched to form a plurality of holes **23** having a depth reaching the n layer **11** (see FIG. **4**).

[0073] Next, the p electrode **15** is formed on the p layer **14** by sputtering or vapor deposition (see FIG. **5**). Next, a V layer, an Al layer, and a Ti layer are stacked in this order on the n layer **11** exposed on the bottom surface of the hole **23** by sputtering or vapor deposition to form the n electrode **16** (see FIG. **6**). Although the n electrode **16** may be formed before the p electrode **15**, in the embodiment, the p electrode **15** is formed first because it is desired to form the p electrode **15** with the surface of the p layer **14** as clean as possible.

[0074] Next, a heat treatment is performed at a temperature of 500° C. to 650° C. for 1 to 10 minutes. The heat treatment is preferably performed under a reduced pressure in an inert gas atmosphere such as nitrogen, for example, at a pressure of 1×10^2 Pa to 1×10^4 Pa. The heat treatment temperature is preferably 500° C. to 560° C.

[0075] This heat treatment also serves both to activate Mg in the p layer **14** and to reduce the contact resistance of the p electrode **15** and the n electrode **16**.

[0076] In the embodiment, by using V/Al/Ti as the n electrode **16**, the heat treatment temperature is lowered, and the Mg activation treatment of the p layer **14** and the reduction of the contact resistance of the p electrode **15** and the n electrode **16** are shared and performed at the same time, thereby reducing the number of heat treatments. As a result of lowering the heat treatment temperature and reducing the number of heat treatments, deterioration of electrical characteristics of the light emitting element can be prevented.

[0077] Here, the n electrode **16** changes to the following structure by the heat treatment. In V/Al/Ti that is the n electrode **16**, V diffuses into Al and does not diffuse into the n layer **11** or Ti. As a result of this diffusion, the V layer disappears. In addition, Al in V/Al/Ti reacts with N in the n layer **11**, and AlN_x is formed at an interface between the n layer **11** and the Al layer. Vis considered to act as a catalyst that promotes the reaction between Al and N. As a result of this heat treatment, the structure of the n electrode **16** changes to a three-layer structure including a layer made of

AlN_x, a layer made of a metal mainly containing Al and containing V and Ti, and a layer made of Ti.

[0078] By changing the n electrode **16** to such a structure, the contact resistance of the n electrode **16** with respect to the n layer **11** is reduced. The reason is as described above. That is, firstly, it is considered that the layer made of AlN_x functions as a good contact layer with respect to the n layer **11**, and secondly, it is considered that the conversion of the n layer **11** into an n-type is further promoted due to the generation of nitrogen vacancies in the n layer **11** due to the formation of AlN_x.

[0079] Next, the pn electrodes **17**A and **17**B are formed on the p electrode **15** and the n electrode **16** respectively by sputtering or vapor deposition (see FIG. **7**).

[0080] Next, the element isolation groove **26** is formed. The element isolation groove **26** has a depth such that the substrate **10** is exposed. Next, the protective film **18** covering the entire upper surface of the element is formed (see FIG. **8**). The protective film **18** is formed by vapor deposition, sputtering, CVD, or the like. Sputtering or CVD is preferred from the viewpoint of denseness of the film.

[0081] Next, the reflective film **19** made of Al is formed on the protective film **18** in a region excluding the regions where the holes **24** and **25** are to be formed later (see FIG. **9**). The reflective film **19** is formed by vapor deposition or sputtering, and patterned by wet etching.

[0082] Next, the protective film **18** is formed again on the protective film **18** and the reflective film **19** (see FIG. **10**). Accordingly, a structure in which the reflective film **19** is embedded in the protective film **18** is obtained. Note that, it is preferable that the protective film **18** is not formed on a bottom surface of the element isolation groove **26** and the protective film **18** is separated for each element. This is to prevent a force from being applied to the protective film **18** or a change in stress of the protective film **18** when the protective film **18** is divided for each element.

[0083] Next, a predetermined region on the protective film **18** is dry-etched to form the hole **24** and the hole **25** reaching the pn electrodes **17**A and **17**B. Then, the p pad electrode **20** and the n pad electrode **21** are formed on the protective film **18**, the p pad electrode **20** is connected to the pn electrode **17**A via the hole **24**, and the n pad electrode **21** is connected to the pn electrode **17**B via the hole **25**. The patterns of the p pad electrode **20** and the n pad electrode **21** are as shown in FIG. **2**. The p pad electrode **20** and the n pad electrode **21** are formed by vapor deposition or sputtering, and patterned by lift-off. Next, the antireflection film **22** is formed on the back surface of the substrate **10**. Next, the substrate **10** is divided into individual elements. With the above, the light emitting element according to the embodiment shown in FIG. **1** is produced.

3. Experiment Results

[0084] Various experiment results according to the embodiment will be described.

Experiment 1

[0085] The light emitting element according to the embodiment having an emission wavelength of 275 nm and including the p electrode **15** made of Ru was prepared. For comparison, a light emitting element including the p electrode **15** made of Rh instead of Ru was also prepared.

[0086] FIG. **11** is a graph showing I-V characteristics of the light emitting elements. As shown in FIG. **11**, it has been found that a drive voltage can be lower in a case where Ru is used as the p electrode **15** than a case where Rh is used as the p electrode **15**. This is because Ru has contact resistance to the p layer **14** lower than that of Rh.

Experiment 2

[0087] A plurality of light emitting elements according to the embodiment having the composition of the light emitting layer **12** set to have an emission wavelength of 275 nm and including the p electrode **15** made of Ru were prepared. For comparison, a plurality of light emitting elements in which the material of the p electrode **15** was changed from Ru to Rh were also prepared.

[0088] FIG. **12** is a graph (scatter diagram) showing emission wavelengths and power efficiency of the light emitting elements. The power efficiency is a value normalized by setting average power efficiency when the p electrode **15** is made of Rh as 100%. As shown in FIG. **12**, it has been found that the power efficiency tends to be higher in a case where Ru is used as the p electrode **15** than a case where Rh is used as the p electrode **15**. This is considered to be because, although both Ru and Rh have a high ultraviolet reflectance, the contact resistance of Ru is lower than that of Rh. It is also found that a variation in power efficiency is smaller for Ru than for Rh. As a result of Experiments 1 and 2, it is found that Ru is more preferred than Rh as the p electrode **15** of the UVC light emitting element.

4. Modifications of Embodiment

[0089] Light emitting elements according to various modifications of the embodiment will be described.

First Modification

[0090] The electrode pattern shown in the embodiment is an example, and other patterns may be used as long as the proportion of the area of the p electrode **15** to the area of the upper surface of the element is 70% or more. For example, a pattern as in the following first modification may be used.

[0091] A light emitting element according to the first modification of the embodiment has the electrode pattern changed as follows: a p electrode **115**, an n electrode **116**, a p pad electrode **120**, an n pad electrode **121**, and a hole **123** are provided instead of the p electrode **15**, the n electrode **16**, the p pad electrode **120**, the n pad electrode **121**, and the hole **23** in the embodiment.

[0092] FIG. **13** is a diagram showing the electrode pattern of the light emitting element according to the first modification of the embodiment. As shown in FIG. **13**, the p pad electrode **120** and the n pad electrode **121** have patterns in which a pattern slightly inside a rectangular pattern of the element is divided into two by a band-shaped linear region along a straight line parallel to sides of the rectangle. The linear region is located near one side of the rectangle, and among the two patterns obtained by division by the linear region, the one having a smaller area is the p pad electrode **120**, and the one having a larger area is the n pad electrode **121**.

[0093] The hole **123** provided instead of the hole **23** is located below the n pad electrode **121**, and a plurality of holes **123** are arranged in a triangular lattice. The hole **123** is not arranged in a region below the p pad electrode **120**.

The n electrode **116** and the pn electrode **17**B are provided in this order on a bottom surface of the hole **123**, and the pn electrode **17**B and the n pad electrode **121** are connected to each other via the hole **25** made in the protective film **18**. Note that, a pattern of the hole **25** is almost the same as a pattern of the n electrode **116**, and is not shown in FIG. **13**.

[0094] The p electrode **115** provided instead of the p electrode **15** has a pattern obtained by removing the holes **123** from a pattern of the p layer **14**. The pn electrode **17**A is provided on the p electrode **115**, and the pn electrode **17**A and the p pad electrode **120** are connected to each other via the hole **24**. The hole **24** connecting the pn electrode **17**A and the p pad electrode **120** is circular, and a plurality of holes are arranged along the side of the rectangle. Note that, a pattern of a circle outside the circle of the hole **24** indicates a boundary of the reflective film **19**.

Second Modification

[0095] A light emitting element according to a second modification of the embodiment is the same as the light emitting element according to the embodiment except that the electrode structure and the electrode pattern are changed.

[0096] FIG. **14** is a diagram showing a configuration of the light emitting element according to the second modification of the embodiment, and is a cross-sectional view perpendicular to main surface of a substrate. FIG. **15** is a diagram showing the electrode pattern of the light emitting element according to the second modification of the embodiment. FIG. **15** shows a plane pattern of a p electrode **215**, an n electrode **216**, a p pad electrode **220**, and an n pad electrode **221**.

[0097] As shown in FIG. **14** and FIG. **15**, a hole **223** is provided instead of the hole **23**. The holes **223** are circular and arranged in an equilateral triangular lattice. The n electrode **216** and an pn electrode **217**B are provided in this order on a bottom surface of the hole **223**. Unlike the case in FIG. **2** or FIG. **13**, the holes **223** are arranged all over the surface, and the holes **223** are also provided below the p pad electrode **220**. The p electrode **215** is formed in a pattern obtained by excluding the region of the hole **223** from the rectangular pattern of the p layer **14**. In addition, a pn electrode **217**A is provided on the p electrode **215** in the same plane pattern as the p electrode **215**.

[0098] In addition, a protective film **218** is provided instead of the protective film **18**. The protective film **218** has a structure in which a first protective film **218**A and a second protective film **218**B are stacked in this order. The first protective film **218**A and the second protective film **218**B may be made of the same material or different materials.

[0099] Middle electrodes **219**A and **219**B are separately provided between the first protective film **218**A and the second protective film **218**B. Note that, in FIG. **15**, the middle electrodes **219**A and **219**B are not shown. The middle electrode **219**A is connected to the p electrode **215** via a hole provided in the first protective film **218**A. The middle electrode **219**B is connected to each dot-shaped n electrode **216** via a hole provided in the first protective film **218**A. These holes are also not shown in FIG. **15**.

[0100] The p pad electrode **220** and the n pad electrode **221** are spaced apart from each other on the protective film **218**B. The p pad electrode **220** is connected to the middle electrode **219**A via a hole made in the second protective film **218**B. The n pad electrode **221** is connected to the middle electrode **219**B via a hole made in the second protective film **218**B. These holes are also not shown in FIG. **15**. As shown in FIG. **15**, the p pad electrode **220** and the n pad electrode **221** have patterns in which a pattern slightly inside a rectangular pattern of the element is equally divided into two by a band-shaped linear region along a straight line parallel to sides of the rectangle.

[0101] In the second modification, the holes **223** can be arranged over the entire surface, and in-plane uniformity of light emission can be improved. In addition, the middle electrode **219**A is interposed between the p electrode **215** and the p pad electrode **220**, and the middle electrode **219**B is interposed between the n electrode **216** and the n pad electrode **221**, and accordingly, the patterns of the p pad electrode **220** and the n pad electrode **221** can be freely set.

REFERENCE SIGNS LIST

[0102] **10**: substrate
[0103] **11**: n layer
[0104] **12**: light emitting layer
[0105] **13**: electron blocking layer
[0106] **14**: p layer
[0107] **15**: p electrode
[0108] **16**: n electrode
[0109] **17**A, **17**B: pn electrode
[0110] **18**: protective film
[0111] **19**: reflective film
[0112] **20**: p pad electrode
[0113] **21**: n pad electrode

What is claimed is:

1. A method for producing a light emitting element which includes a group III nitride semiconductor containing Al and has an emission wavelength of 200 nm to 280 nm, comprising:
- stacking an n layer, a light emitting layer, and a p layer in this order, over a substrate;
- forming a hole having a depth reaching the n layer at a predetermined region of a surface of the p layer;
- forming, over the player, a p electrode having a Ru layer in contact with the p layer;
- forming an n electrode over the n layer exposed on a bottom surface of the hole, the n electrode having a V layer that is in contact with the n layer, that has a thickness of 5 nm or more and 15 nm or less, and that comprises V or a metal containing V as a main component, and an Al layer that is on and in contact with the V layer and that comprises Al or a metal containing Al as a main component; and
- performing a heat treatment at a temperature of 500° C. to 650° C. for 1 to 10 minutes to reduce a contact resistance of the p electrode and the n electrode and to activate a p-type impurity in the p layer, wherein
- a pattern of the hole and a pattern of the p electrode are set such that a proportion of an area of the p electrode to a total area of the hole and the p layer is 70% or more.

2. The method for producing a light emitting element according to claim **1**, wherein the hole is formed at plural locations, an arrangement pattern of the holes is a square lattice, an equilateral triangular lattice, or a honeycomb shape, and the n electrode is formed on a bottom surface of each of the holes.

3. The method for producing a light emitting element according to claim **1**, further comprising:

forming a first pn electrode and a second pn electrode over the p electrode and over the n electrode, respectively, after the heat treatment;

forming a protective film, which is an insulator, to cover an entire upper surface of the element; and

providing holes at predetermined positions of the protective film, and forming, over the protective film, a p pad electrode that is connected to the first pn electrode via one of the holes provided at the predetermined positions of the protective film, and an n pad electrode that is connected to the second pn electrode via other of the holes provided at the predetermined positions of the protective film and is spaced apart from the p pad electrode.

4. The method for producing a light emitting element according to claim **2**, further comprising:

forming a first pn electrode and a second pn electrode over the p electrode and over the n electrode, respectively, after the heat treatment;

forming a protective film, which is an insulator, to cover an entire upper surface of the element; and

providing holes at predetermined positions of the protective film, and forming, over the protective film, a p pad electrode that is connected to the first pn electrode via one of the holes provided at the predetermined positions of the protective film, and an n pad electrode that is connected to the second pn electrode via other of the holes provided at the predetermined positions of the protective film and is spaced apart from the p pad electrode.

5. A light emitting element which comprises a group III nitride semiconductor containing Al and has an emission wavelength of 200 nm to 280 nm, the light emitting element comprising:

a substrate;

a semiconductor layer, in which an n layer, a light emitting layer, and a p layer are stacked in this order over the substrate;

a hole provided at a predetermined region of a surface of the p layer and having a depth reaching the n layer;

a p electrode having a Ru layer provided on and in contact with the p layer; and

an n electrode provided over the n layer exposed on a bottom surface of the hole, the n electrode having a first layer that is located in contact with the n layer, that comprises AlN_x or $Al_yGa_{1-y}N_x$ having a higher Al composition than the n layer, and that has a thickness of 1 nm or more and 3 nm or less, and a second layer that is located on and in contact with the first layer, that comprises a metal mainly containing Al and containing V, and that has a thickness of 50 nm or more and 500 nm or less, wherein

a pattern of the hole and a pattern of the p electrode are set such that a proportion of an area of the p electrode to a total area of the hole and the p layer is 70% or more.

6. The light emitting element according to claim **5**, wherein the hole is formed at plural locations, an arrangement pattern of the holes is a lattice, and the n electrode is formed on a bottom surface of each of the holes.

7. The light emitting element according to claim **5**, further comprising:

a first pn electrode and a second pn electrode provided over the p electrode and over the n electrode, respectively;

a protective film which is an insulator and covers an entire upper surface of the element;

a p pad electrode provided over the protective film and connected to the first pn electrode via a hole provided at the protective film; and

an n pad electrode provided over the protective film, connected to the second pn electrode via a hole provided at the protective film, and spaced apart from the p pad electrode.

8. The light emitting element according to claim **6**, further comprising:

a first pn electrode and a second pn electrode provided over the p electrode and over the n electrode, respectively;

a protective film which is an insulator and covers an entire upper surface of the element;

a p pad electrode provided over the protective film and connected to the first pn electrode via a hole provided at the protective film; and

an n pad electrode provided over the protective film, connected to the second pn electrode via a hole provided at the protective film, and spaced apart from the p pad electrode.

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