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Manabe et al.

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[45] **Reissued Date of Patent: Jun. 27, 2000**

[54] **LIGHT-EMITTING DEVICE OF GALLIUM NITRIDE COMPOUND SEMICONDUCTOR**

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[73] Assignees: **Toyoda Gosei Co., Ltd**; **Kabushiki Kaisha Toyota Chuo Kenkyusho**, both of Aichi-ken, Japan

[21] Appl. No.: **08/844,386**

[22] Filed: **Apr. 18, 1997**

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Filed: **Jan. 22, 1993**

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[51] **Int. Cl.**^{7} **H01L 27/14**; H01L 31/00; H01L 29/00; H01L 49/00

[52] **U.S. Cl.** **257/431**; 257/11; 257/21; 257/22; 257/76; 257/94; 257/103; 257/189; 257/453; 257/613; 257/615; 257/745; 257/766

[58] **Field of Search** 257/431, 103, 257/76, 94, 189, 200, 201, 86, 613, 615, 21, 22, 11, 453, 745, 766

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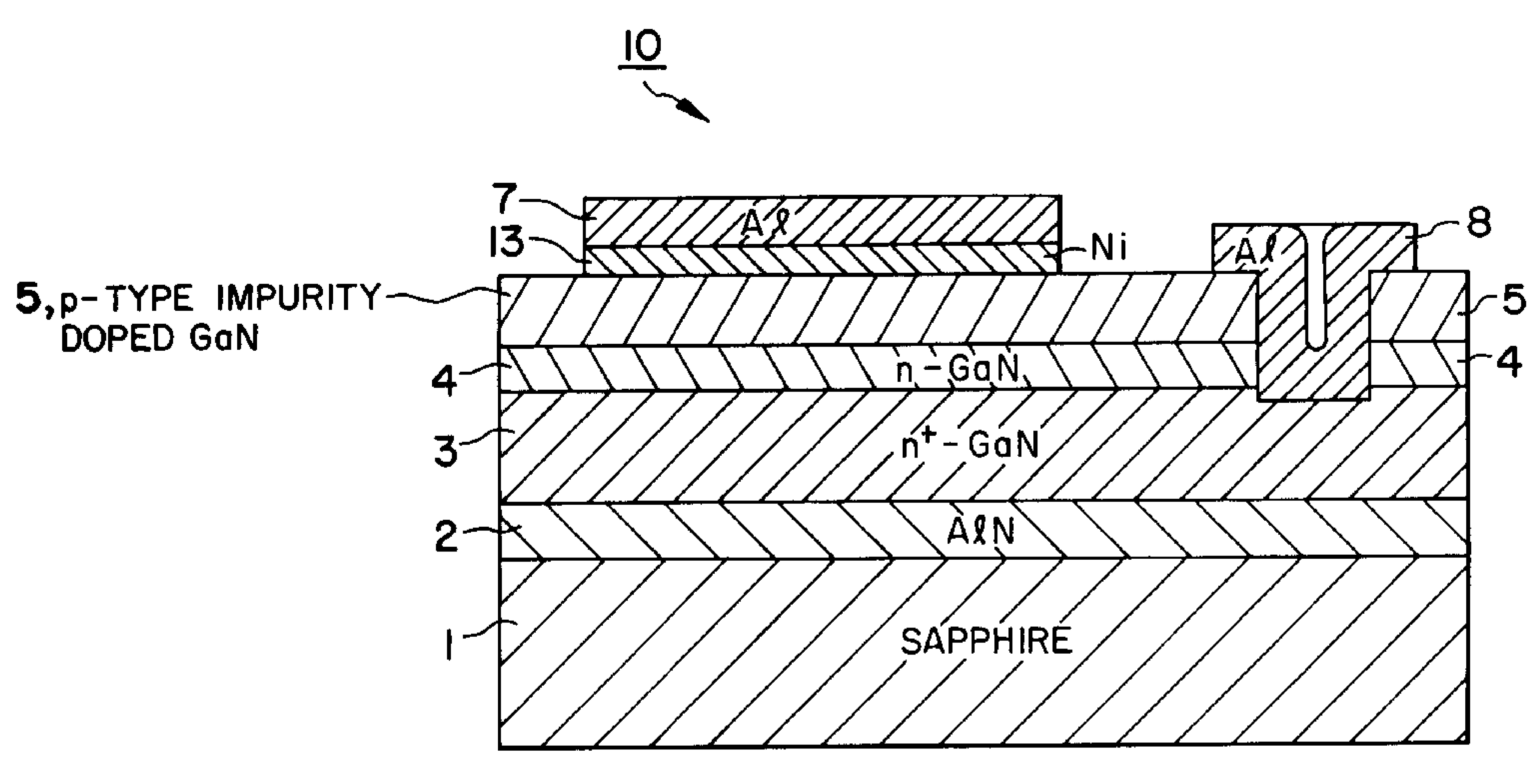
Primary Examiner—Teresa M. Arroyo
Attorney, Agent, or Firm—Pillsbury Madison & Sutro LLP

[57] **ABSTRACT**

A light-emitting diode of GaN compound semiconductor emits a blue light from a plane rather than dots for improved luminous intensity. This diode includes a first electrode associated with a high-carrier density n^+ layer and a second electrode associated with a high-impurity density **[**i_H-layer**]** *H-layer*. These electrodes are made up of a first Ni layer (110 Å thick), a second Ni layer (1000 Å thick), an Al layer (1500 Å thick), a Ti layer (1000 Å thick), and a third Ni layer (2500 Å thick). The Ni layers of dual structure permit a buffer layer to be formed between them. This buffer layer prevents the Ni layer from peeling. The direct contact of the Ni layer with GaN lowers a drive voltage for light emission and increases luminous intensity.

27 Claims, 8 Drawing Sheets



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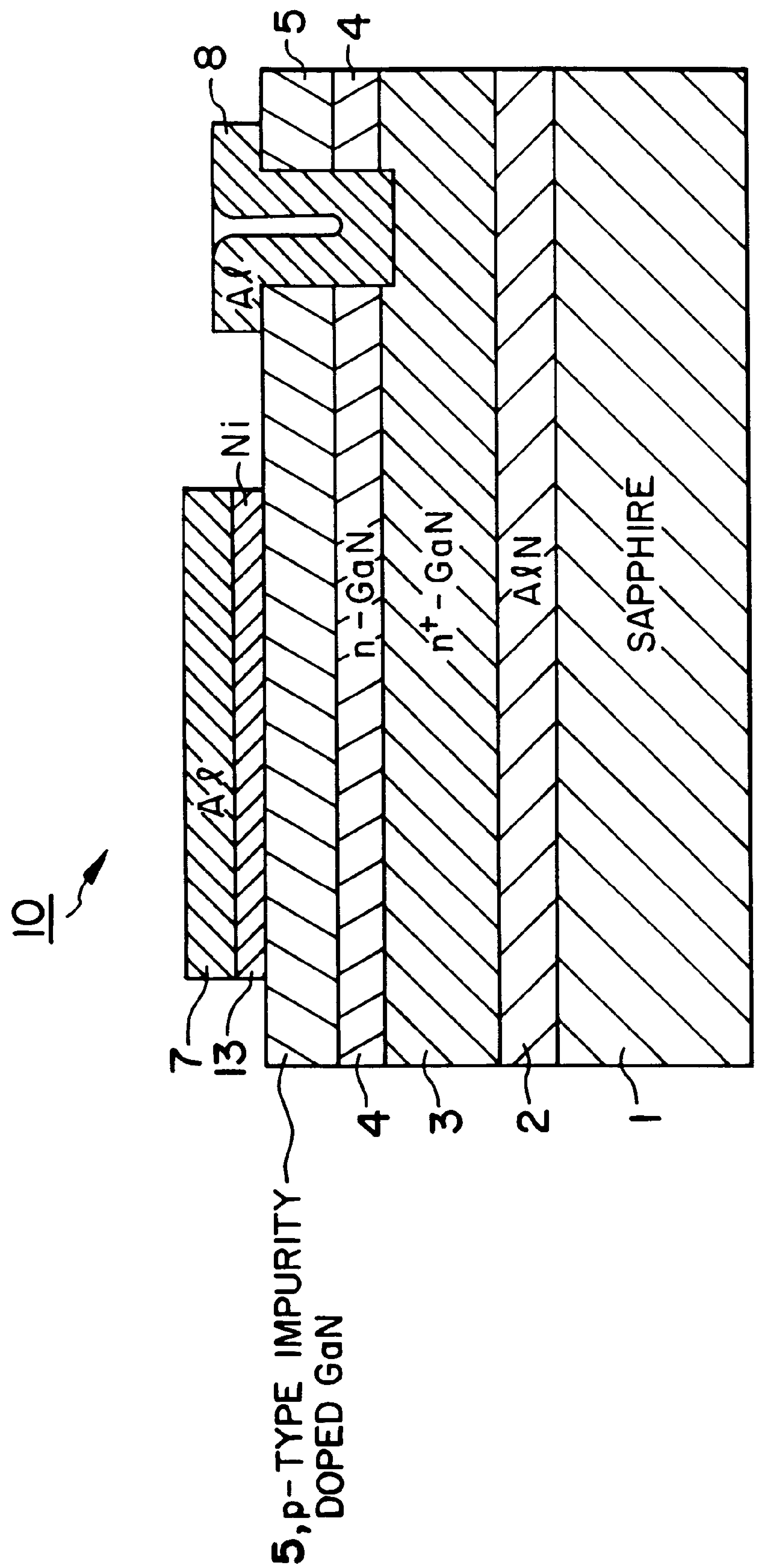
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5
4
Aℓ
Ni
Aℓ
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n+-GaN
AℓN
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7
13
4
3
2
1
5, p-TYPE IMPURITY DOPED GaN

FIG. 1

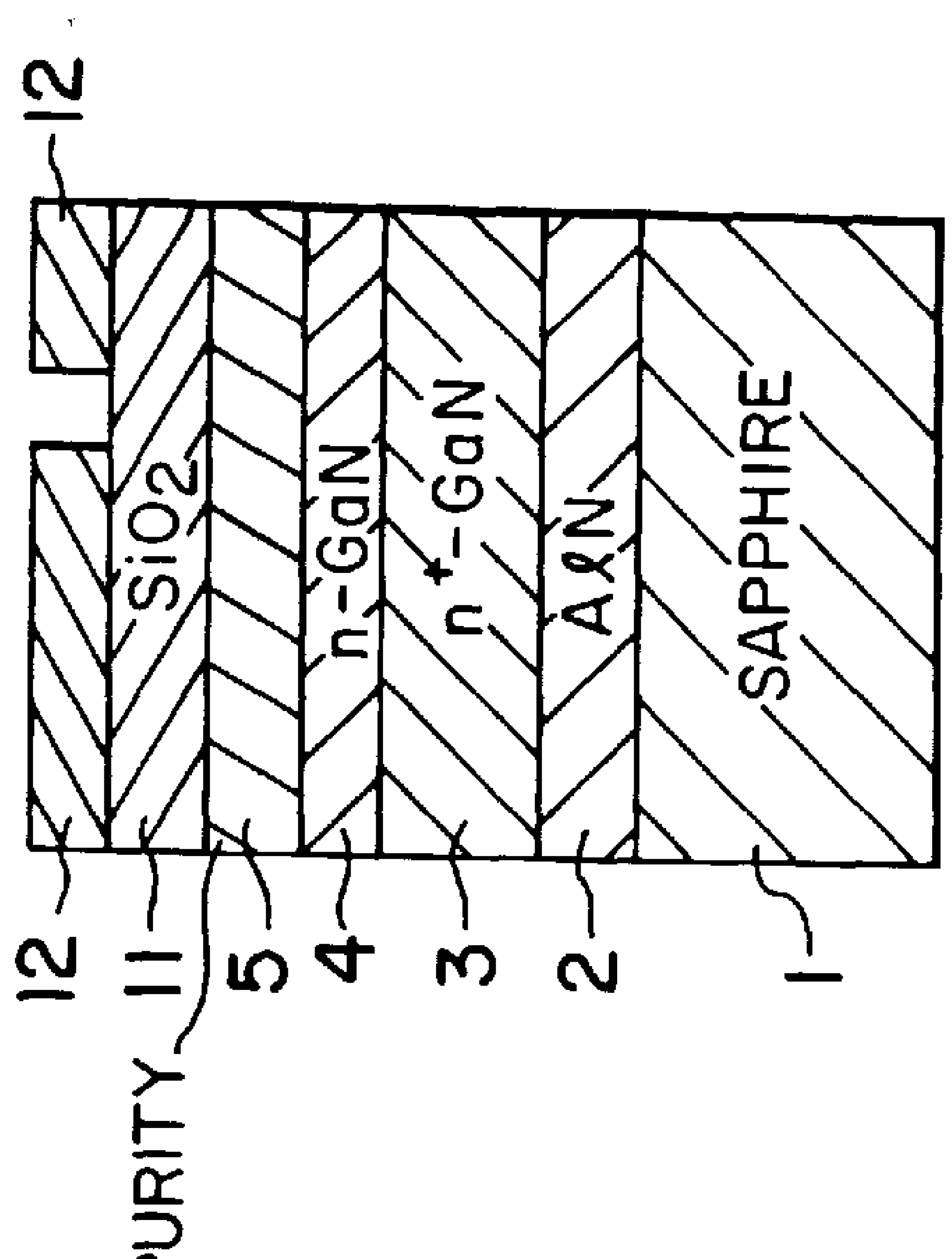


FIG. 2(b)

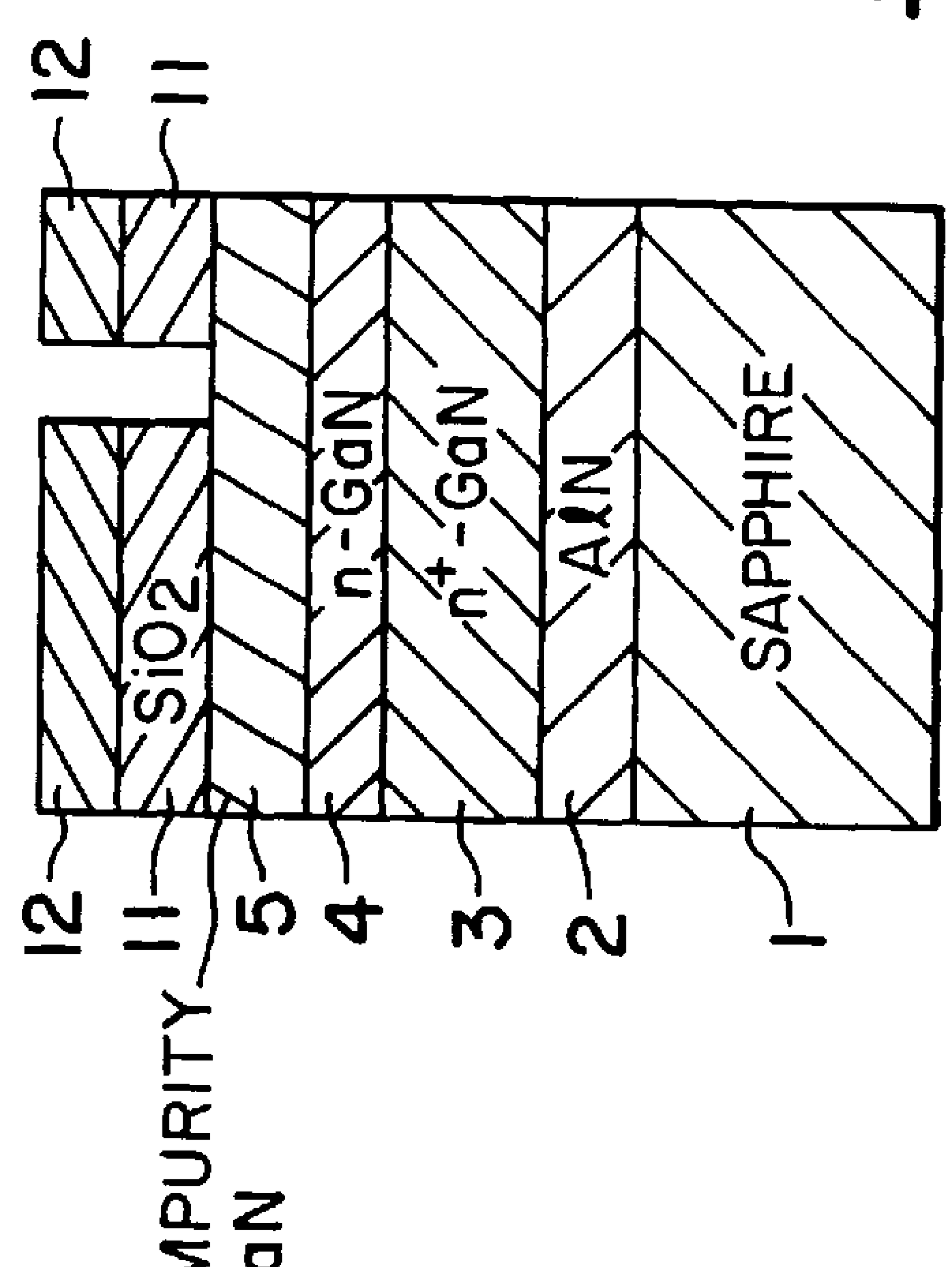


FIG. 2(c)

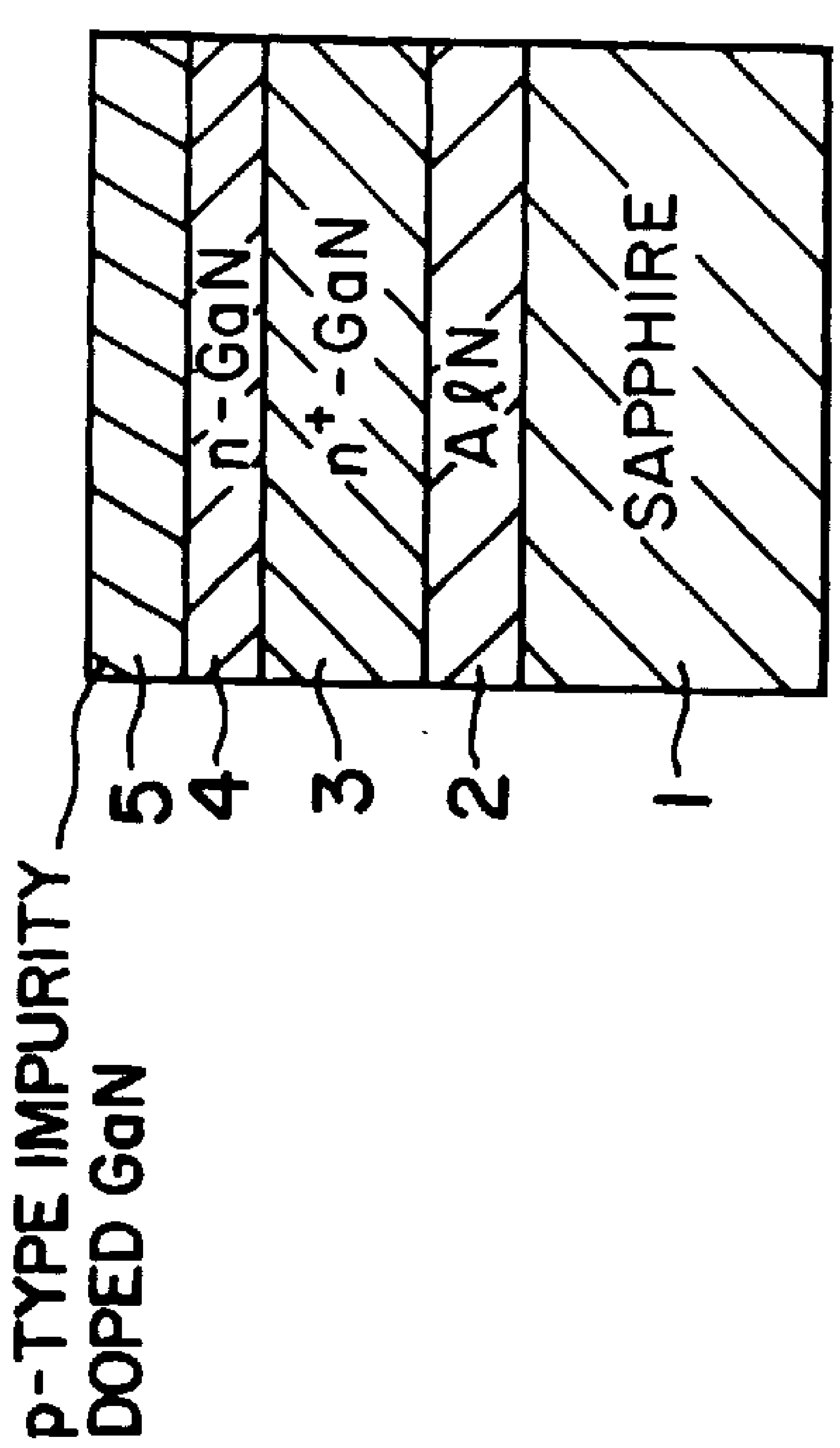


FIG. 2(a)

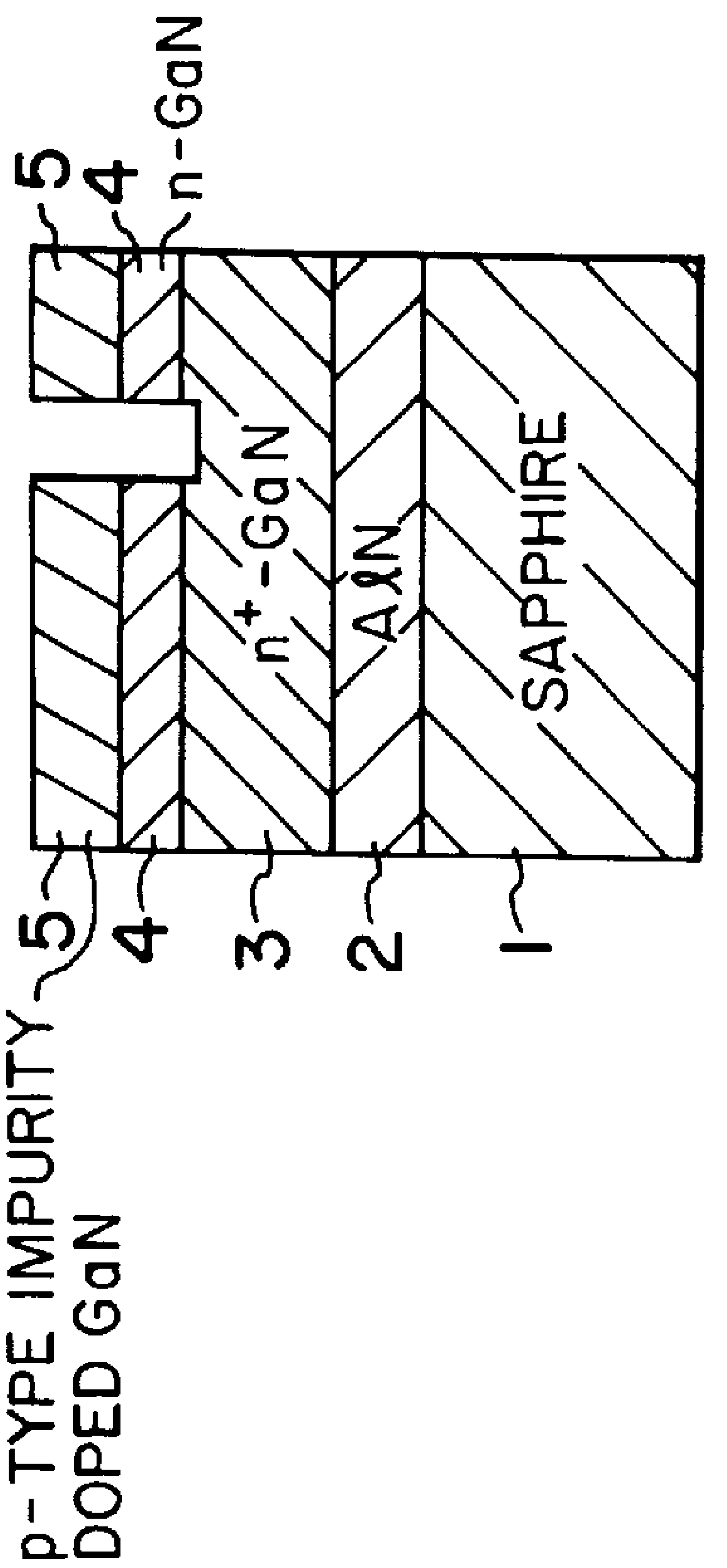


FIG. 3(b)

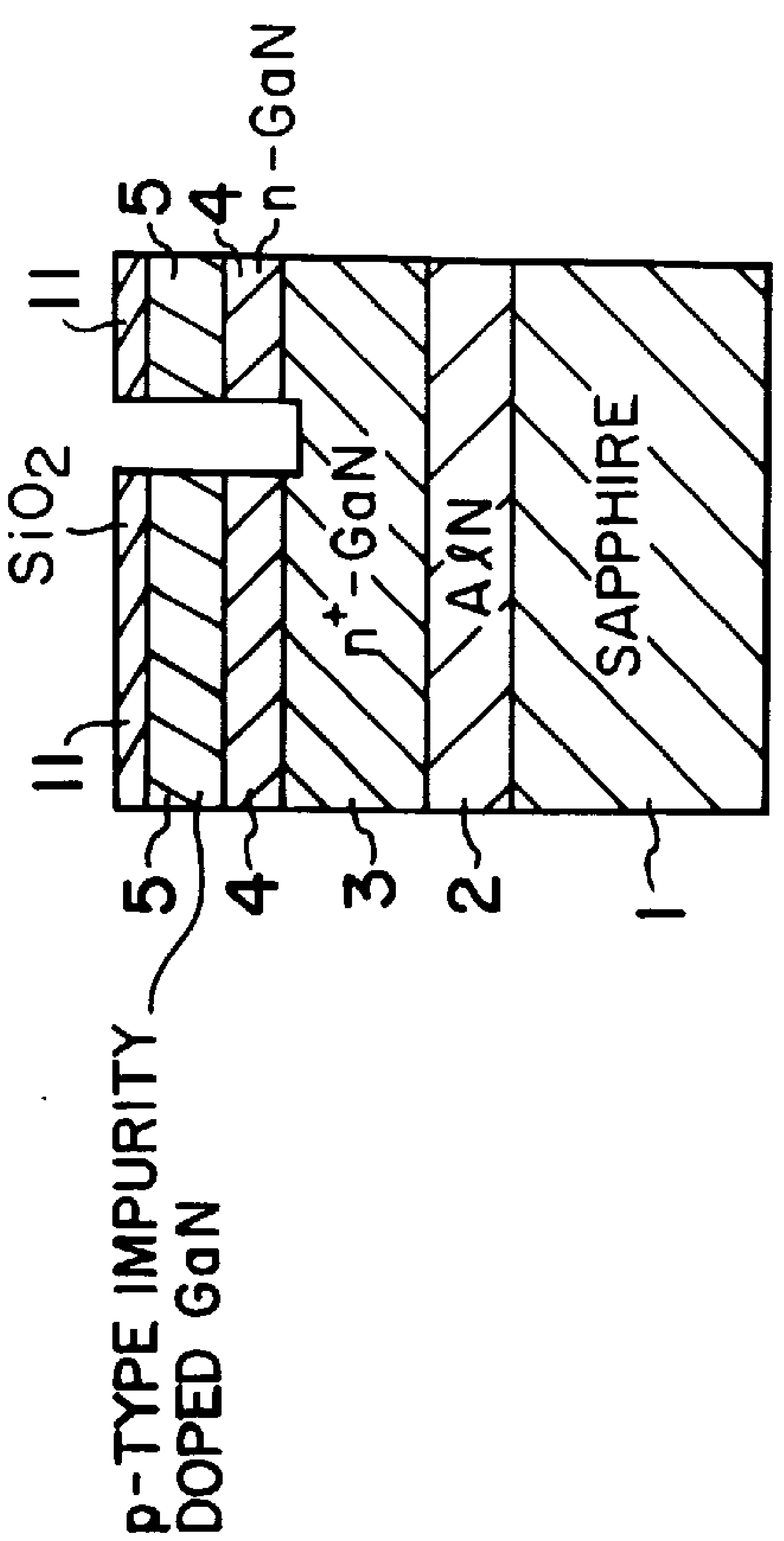


FIG. 3(a)

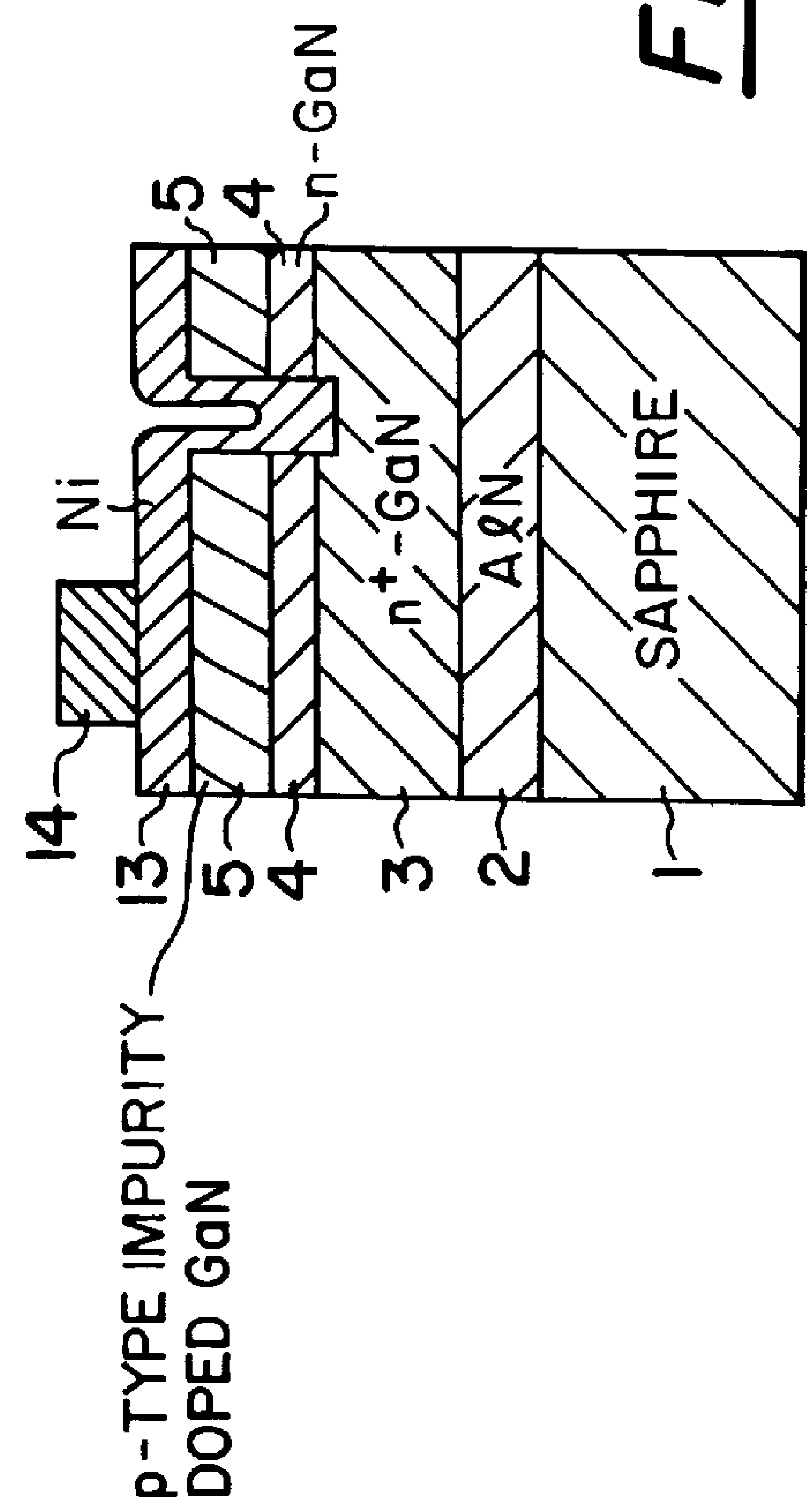


FIG. 3(c)

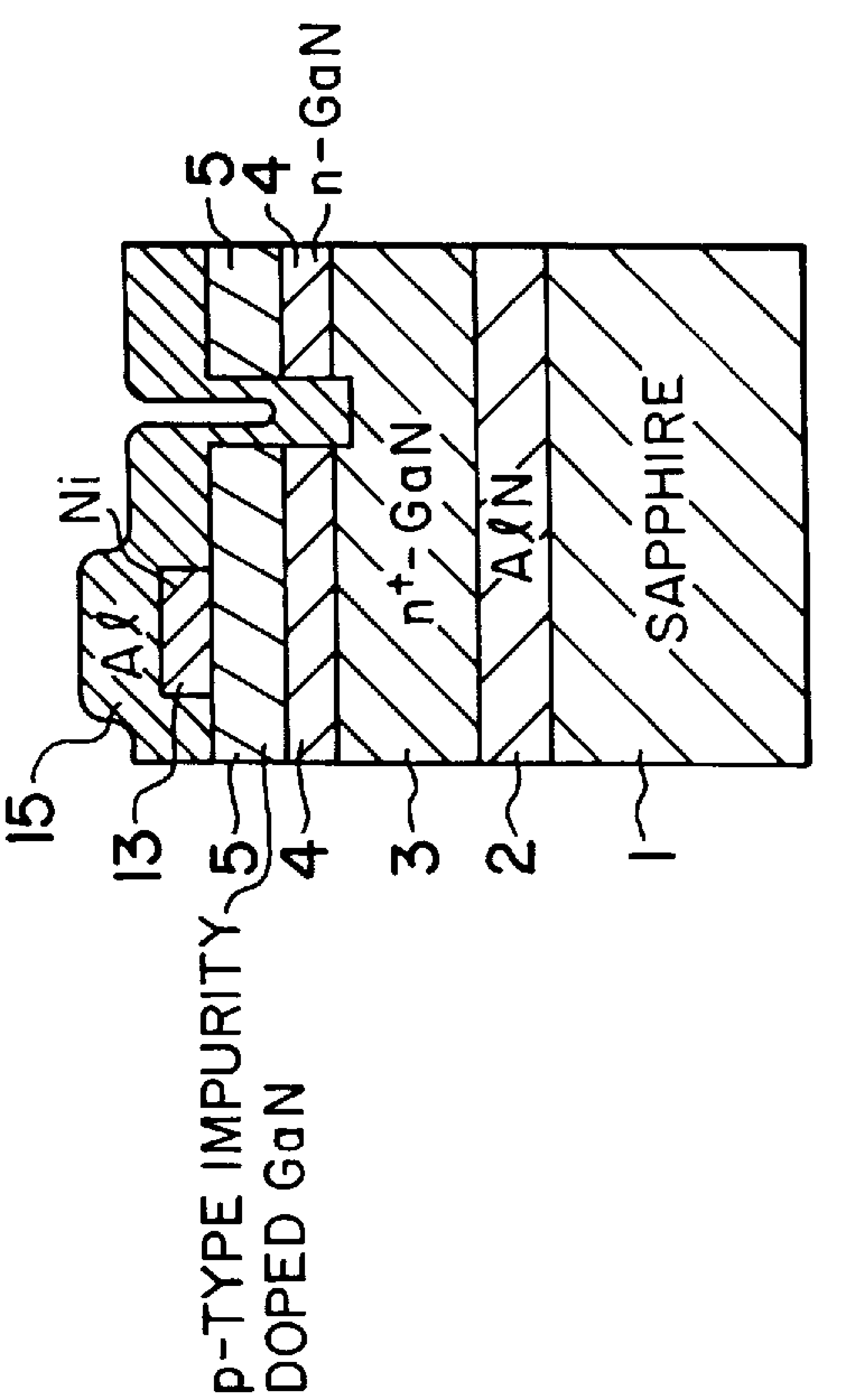


FIG. 4(b)

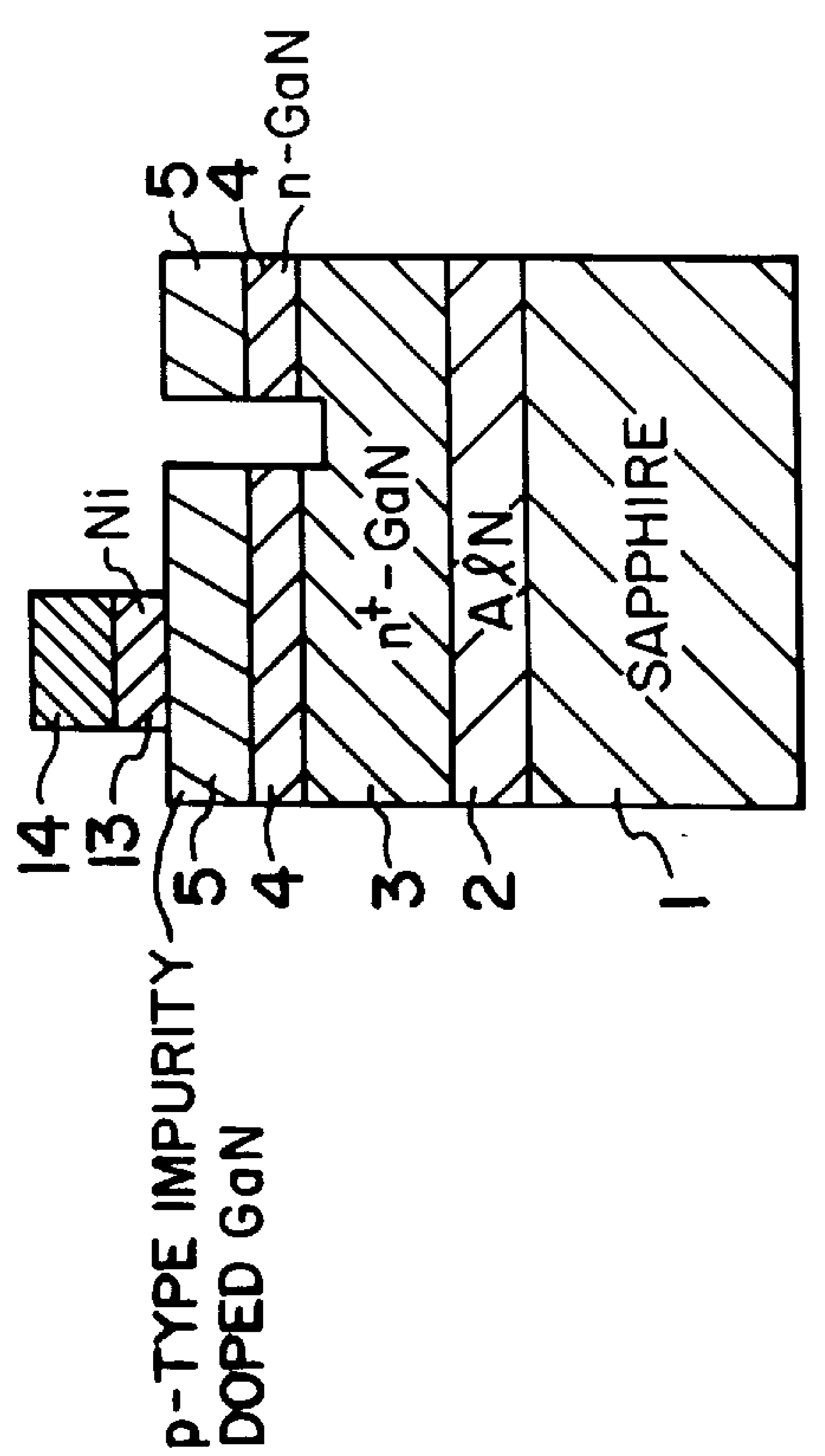


FIG. 4(a)

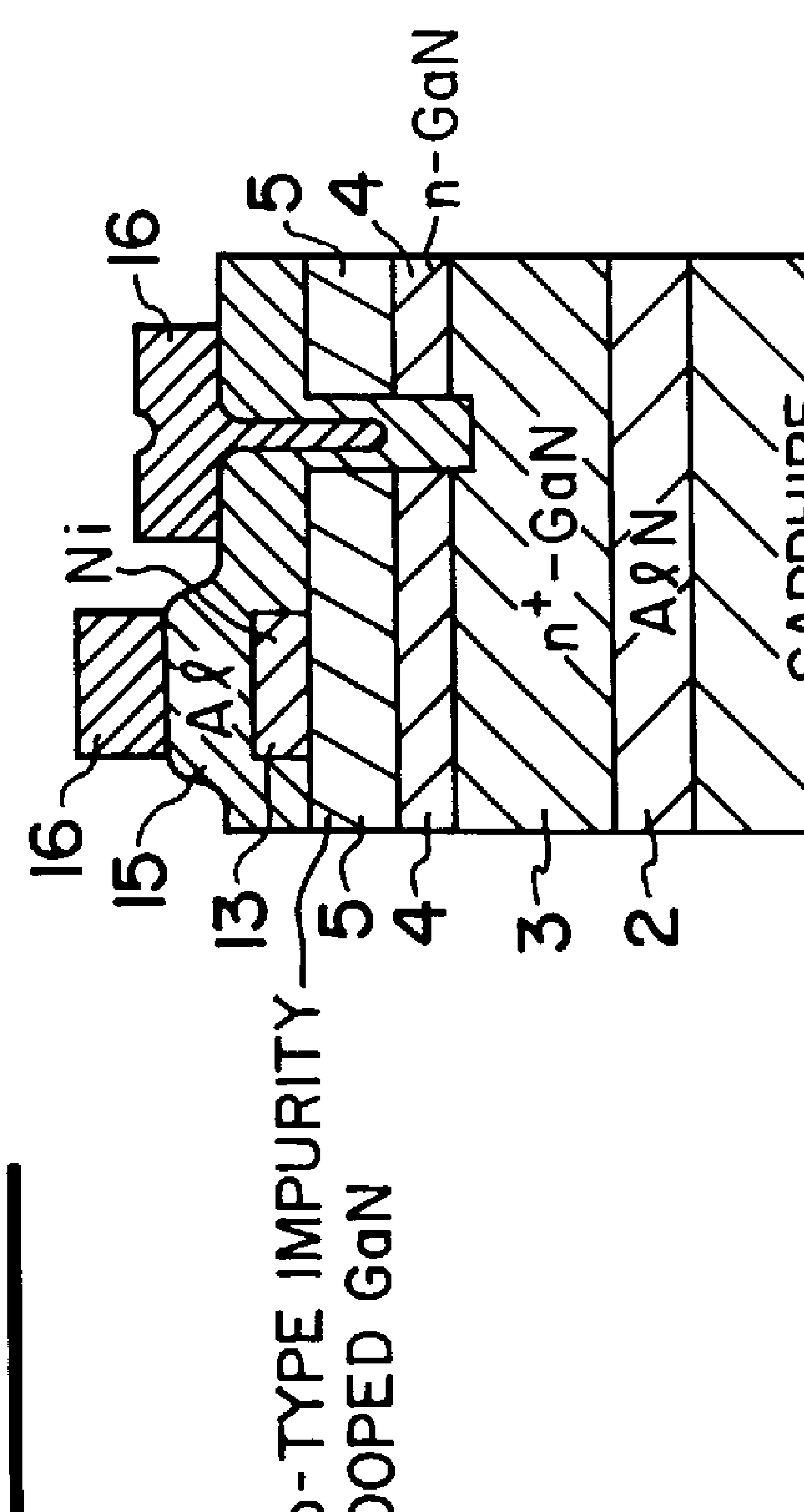
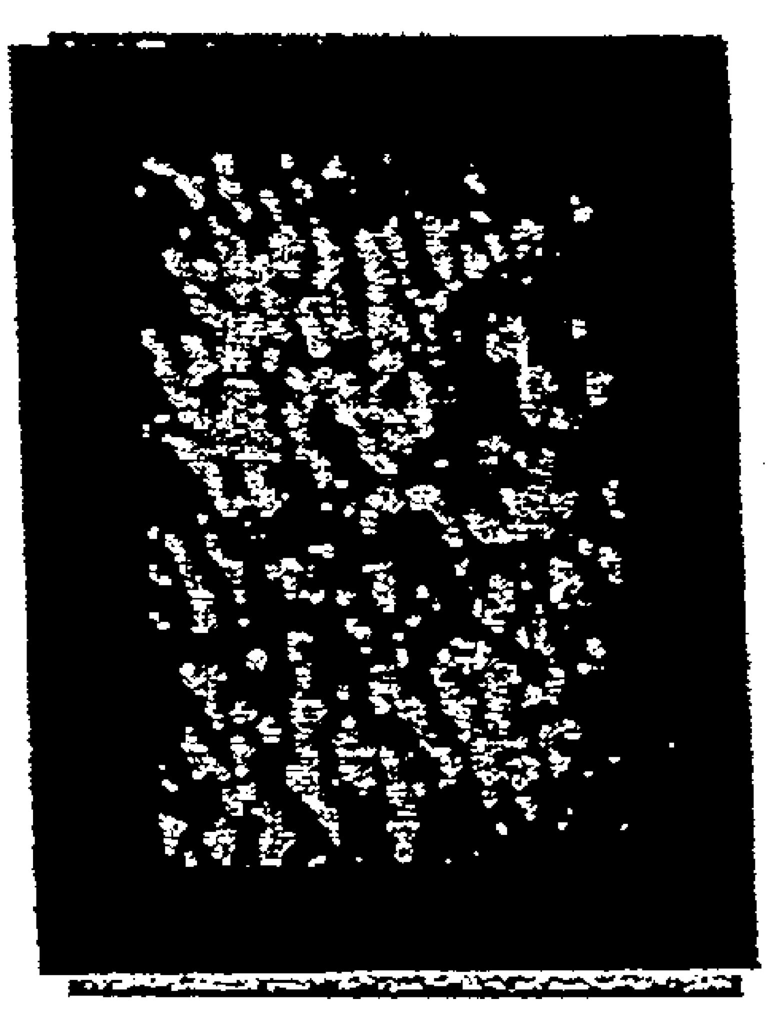


FIG. 4(c)

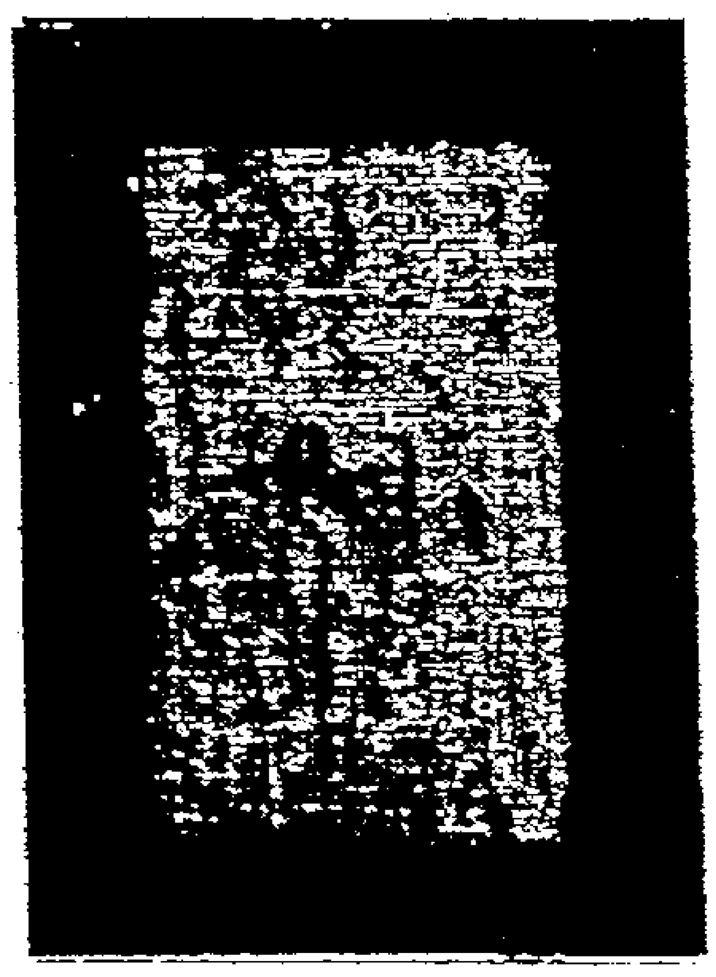
(x120)



Aℓ

FIG. 5(a)

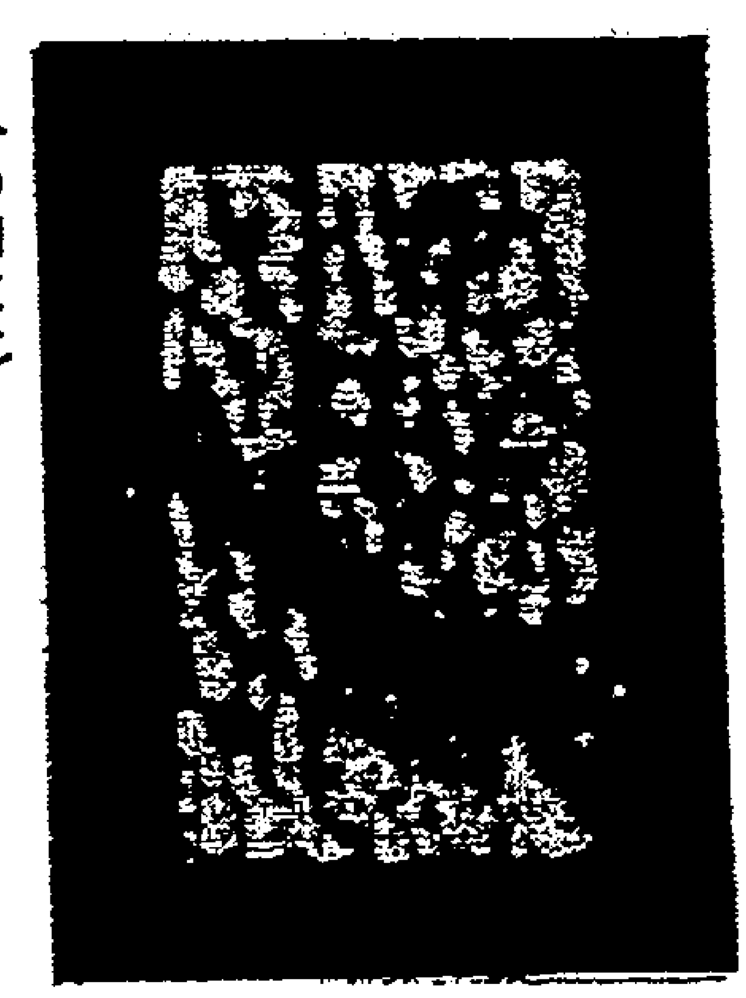
(x120)



Ni

FIG. 5(b)

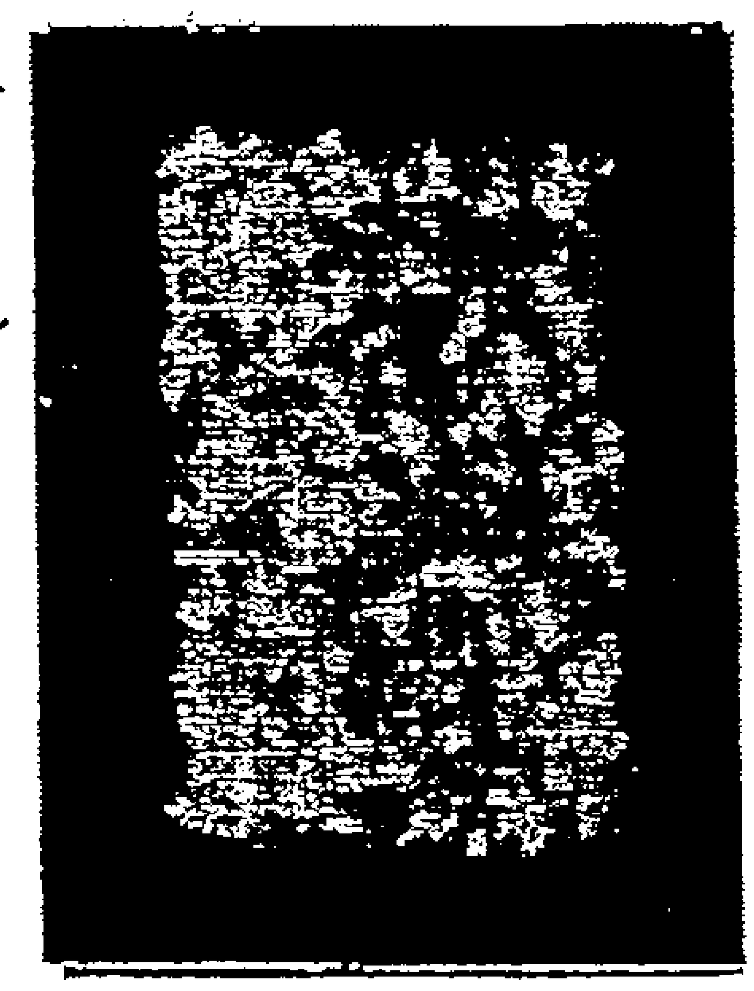
(x120)



Ag

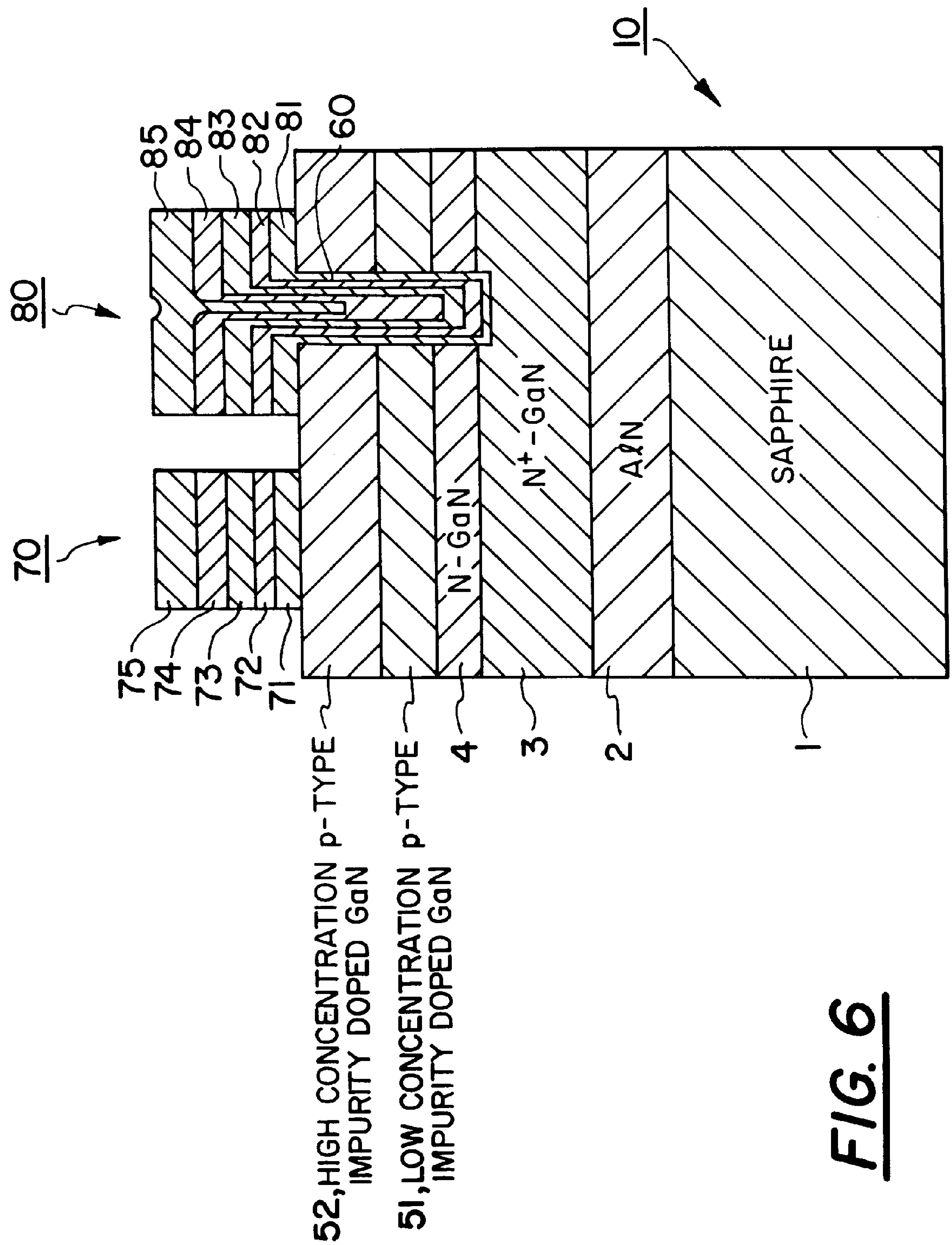
FIG. 5(c)

(x120)



Ti

FIG. 5(d)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52, HIGH CONCENTRATION p-TYPE IMPURITY DOPED GaN
51, LOW CONCENTRATION p-TYPE IMPURITY DOPED GaN
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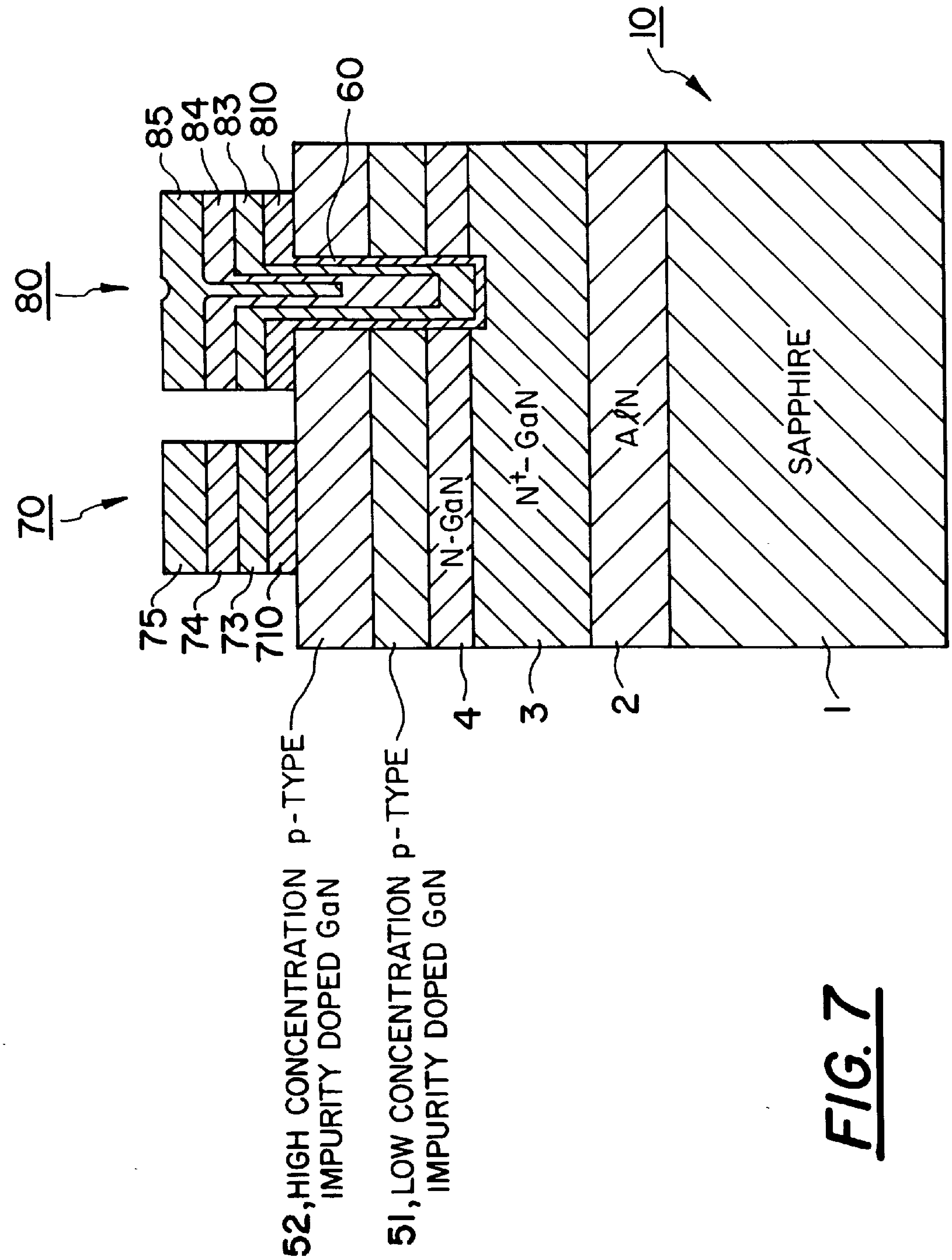
1

FIG. 6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810
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74
73
710
N-GaN
N+-GaN
AℓN
SAPPHIRE
52, HIGH CONCENTRATION p-TYPE IMPURITY DOPED GaN
51, LOW CONCENTRATION p-TYPE IMPURITY DOPED GaN
4
3
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1

FIG. 7

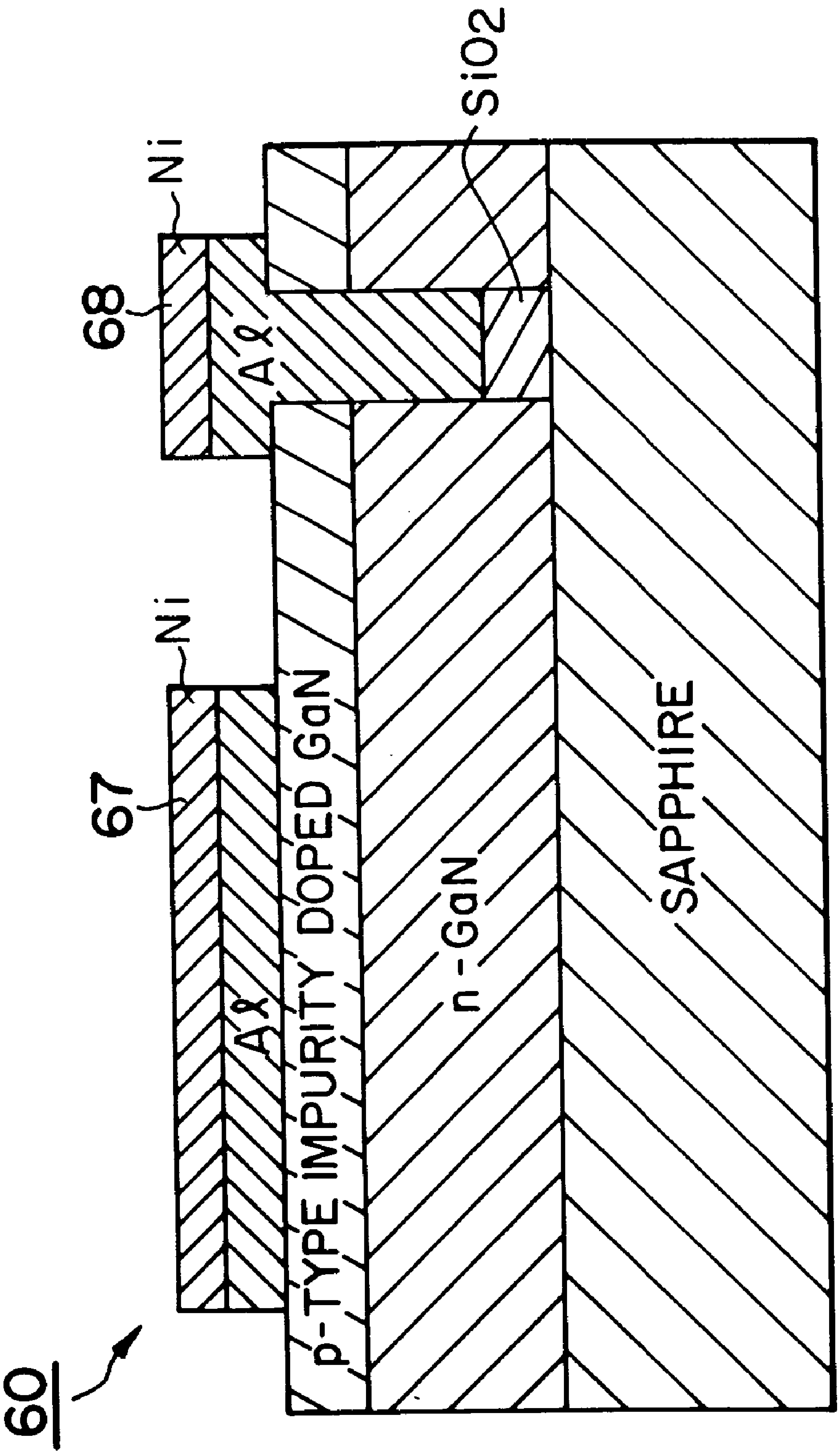

FIG. 8 (PRIOR ART)

LIGHT-EMITTING DEVICE OF GALLIUM NITRIDE COMPOUND SEMICONDUCTOR

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a light-emitting device of gallium nitride compound semiconductor which emits a blue light.

2. Description of the Prior Art

Among the conventional light-emitting diodes which emit a blue light is the gallium nitride compound semiconductor. It attracts attention because of its high luminous efficiency resulting from the direct transition and its ability to emit a blue light, one of the three primary colors of light.

The light-emitting diode of gallium nitride compound semiconductor is made up of a sapphire substrate, an n-layer grown on the substrate from a GaN compound semiconductor of n-type conduction, with or without a buffer layer of aluminum nitride interposed between them, and [an i-layer] *a p-type impurity doped layer* grown on the n-layer from a GaN compound semiconductor which is made [i-type] by doping with a p-type impurity. (Japanese Patent Laid-open Nos. 119196/1987 and 188977/1988)

It is known that the above-mentioned light-emitting diode will be improved in luminous intensity when the [i-layer] *p-type impurity doped layer* is provided with an electrode of large area because light emission takes place directly under or near the [i-layer] *p-type impurity doped layer.*

Much has been reported on the study of crystal growth for light-emitting diodes of GaN compound semiconductors. However, only a little has been reported on the process of producing such light-emitting diodes. This is true particularly of the electrode for the [i-layer] *p-type impurity doped layer* in a light-emitting diode [having a MIS (metal insulator semiconductor) structure]. It has been disclosed only in Japanese Patent Laid-open No. 46669/1982, and nothing has so far been discussed about how the electrode for the [i-layer] *p-type impurity doped layer* is associated with light emission.

The electrode for the i-layer has the layer structure as shown in vertical section in FIG. **8** which is a reproduction from the Japanese patent just given above. Referring to FIG. **8**, there is shown a light-emitting diode **60**, which has an electrode **67** for the [i-layer] *p-type impurity doped layer* and an electrode **68** for the n-layer. The electrode **67** is formed from nickel deposited on an aluminum substrate deposited directly on the [i-layer] *p-type impurity doped layer.* The electrode **68** is also formed from nickel deposited on an aluminum substrate deposited in a hole penetrating the [i-layer] *p-type impurity doped layer.*

A disadvantage of forming the electrode on aluminum in direct contact with the [i-layer] *p-type impurity doped layer* is that light is emitted from coarse dots rather than a uniform plane, as shown in FIG. **5**(a). The resulting light-emitting diode does not have increased luminous intensity despite its large light-emitting area.

SUMMARY OF THE INVENTION

The present invention was completed to address the above-mentioned problem. It is an object of the present invention to provide a light-emitting diode of GaN compound semiconductor which emits a blue light from a plane, rather than dots, to improve luminous intensity.

The present invention is embodied in a light-emitting device of gallium nitride compound semiconductor having an n-layer of n-type gallium nitride compound semiconductor ($Al_xGa_{1-x}N$, $x \geqq 0$) and [an i-layer of i-type] *a p-type impurity doped layer of* gallium nitride compound semiconductor ($Al_xGa_{1-x}N$, $x \geqq 0$) [doped with a p-type impurity], characterized in that said [i-layer] *p-type impurity doped layer* has a Ni layer in contact therewith which functions as an electrode therefor.

The present invention is also embodied in a light-emitting device of gallium nitride compound semiconductor as defined above, wherein the n-layer has a Ni layer in contact therewith which functions as an electrode therefor.

The present invention is also embodied in a light-emitting device of gallium nitride compound semiconductor material as defined above, wherein the electrode for the [i-layer] *p-type impurity doped layer* is of multi-layer structure composed of a first Ni layer (which is thin), a second Ni layer (which is thicker than the first Ni layer), an Al layer, a Ti layer, and a third Ni layer (which is thick), all of which are arranged upward in the order mentioned.

The present invention is also embodied in a light-emitting device of gallium nitride compound semiconductor material having an n-layer of n-type gallium nitride compound semiconductor ($Al_xGa_{1-x}N$, $x \geqq 0$) material and [an i-layer of i-type] *a p-type impurity doped layer of* gallium nitride compound semiconductor ($Al_xGa_{1-x}N$, $x \geqq 0$) material [doped with a p-type impurity], characterized in that the n-layer and [i-layer] *p-type impurity doped layer* have their respective electrodes on the same surface, with the electrode for the n-layer being made of Al or an alloy containing Al, and the electrode for the [i-layer] *p-type impurity doped layer* being made of Ni, Ag, or Ti, or an alloy containing any of them.

According to the present invention, the electrode for the [i-layer] *p-type impurity doped layer* is in contact with the [i-layer] *p-type impurity doped layer* through a Ni layer. This structure permits the light-emitting device to emit light from a plane rather than dots, which leads to improved luminous intensity. In addition, it decreases the driving voltage, alleviating thermal degradation and improving reliability.

In the present invention, the nickel electrode for the n-layer only slightly increases the driving voltage for light emission and it poses no problems (normally associated with a decrease in luminous intensity) even when it is made in the same structure as the electrode for the [i-layer] *p-type impurity doped layer.* Making the electrodes for both the n-layer and [i-layer] *p-type impurity doped layer* from nickel simplifies the production of the light-emitting diode.

According to the present invention, the electrode is of multi-layer structure composed of a first Ni layer (which is thin), a second Ni layer (which is thicker than the first Ni layer), an Al layer, a Ti layer, and a third Ni layer (which is thick). This produces the following two effects.

(1) Forming a first Ni layer (which is thin) directly on the [i-layer] *p-type impurity doped layer* and a second Ni layer (which is thick) subsequently permits a thermal stress buffer layer to be formed between the two Ni layers, and it prevents the peeling of the Ni layers due to thermal expansion and contraction at the time of soldering and reflowing.

(2) The formation of an Al layer, a Ti layer, and a third Ni layer on the second Ni layer permits the electrode to be connected by soldering.

According to the present invention, the n-layer and [i-layer] *p-type impurity doped layer* have their respective electrodes on the same surface, with the electrode for the n-layer being made of Al or an alloy containing Al, and the electrode for the [i-layer] *p-type impurity doped layer* having a lower layer made of Ni, Ag, or Ti, or an alloy containing any of them and a higher layer made of Al or an alloy containing Al. This structure permits the light-emitting diode to emit light from a plane rather than dots.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a vertical sectional view showing the structure of the light-emitting diode pertaining to first embodiment of the present invention.

FIGS. **2**(A) to **4**(C) are vertical sectional views showing the steps of producing the light-emitting diode pertaining to the first embodiment of the present invention.

FIGS. **5**(A) to **5**(d) are photomicrographs showing the metal surface structure (as the light-emitting pattern) of each substrate metal of the electrode for the i-layer.

FIG. **6** is a vertical sectional view showing the structure of the light-emitting diode pertaining to a second embodiment of the present invention.

FIG. **7** is a vertical sectional view showing the structure of the light-emitting diode pertaining to yet a further embodiment of the present invention.

FIG. **8** is a vertical sectional view showing the structure of a conventional light-emitting diode.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Example 1

The present invention will be described in more detail with reference to a first disclosed embodiment. FIG. **1** shows a vertical section of a light-emitting diode **10** pertaining to the present invention. It has a sapphire substrate **1**, on which there are successively formed a buffer layer **2** of AlN (500 Å thick), a high-carrier density n^+-layer **3** of GaN (2.2 μm thick), a low-carrier density n-layer **4** of GaN (1.5 μm thick), an [i-layer] *a p-type impurity doped layer* **5** of GaN (0.1 μm thick), an electrode **7** of aluminum, and an electrode **8** of aluminum (in contact with the high-carrier density n^+-layer **3**).

This light-emitting diode **10** is produced by the steps which are explained below with reference to FIGS. **2**(A) to **4**(C).

The entire process was carried out using NH_3, H_2 (carrier gas), trimethyl gallium $Ga(CH_3)_3$ (TMG for short), trimethyl aluminum $Al(CH_3)_3$ (TMA for short), silane SiH_4 and diethyl zinc (DEZ for short).

Firstly, sapphire substrate **1** of single crystal (with the a-plane (i.e., $\{11\bar{2}0\}$ as the principal plane) was cleaned by washing with an organic solvent and by subsequent heat treatment. Then, it was placed on the susceptor in the reaction chamber for metal-organic vaporphase epitaxy (MOVPE). H_2 was fed to the reaction chamber under normal pressure at a flow rate of 2 L/min to perform vapor phase etching on the sapphire substrate **1** at 1100° C.

With the temperature lowered to 400° C., the reaction chamber was supplied with H_2, NH_3, and TMA at a flow rate of 20 L/min, 10 L/min, and 1.8×10^{-5} mol/min, respectively, to form the buffer layer **2** of AlN (500 Å thick).

With the temperature of the sapphire substrate **1** kept at 1150° C., the reaction chamber was supplied with H_2, NH_3,

TMG, and SiH_4 (diluted to 0.86 ppm with H_2) at a flow rate of 20 L/min, 10 L/min, 1.7×10^{-4} mol/min, and 200 mL/min, respectively, for 30 minutes to form the high-carrier density n^+-layer **3** of GaN (2.2 μm thick), with a carrier density of $1.5\times10^{18}/cm^3$.

With the temperature of the sapphire substrate **1** kept at 1150° C., the reaction chamber was supplied with H_2, NH_3, and TMG at a flow rate of 20 L/min, 10 L/min, and 1.7×10^{-4} mol/min, respectively, for 20 minutes to form the low-carrier density n-layer **4** of GaN (1.5 μm thick), with a carrier density of $1\times10^{15}/cm^3$.

With the temperature of the sapphire substrate **1** kept at 900° C., the reaction chamber was supplied with H_2, NH_3, TMG, and DEZ at a flow rate of 20 L/min, 10 L/min, 1.7×10^{-4} mol/min, and 1.5×10^{-4} mol/min, respectively, for 1 minute to form the [i-layer] *p-type impurity doped layer* **5** of GaN (0.1 μm thick).

In this way there was obtained the multi-layer structure as shown in FIG. **2**(a).

On the [i-layer] *p-type impurity doped layer* **5** was formed the SiO_2 layer **11** (2000 Å thick) by sputtering, as shown in FIG. **2**(b). The SiO_2 layer **11** was coated with a photoresist **12**, which was subsequently patterned by photolithography after the configuration of the electrode for the high-carrier density n^+-layer **3**. The exposed part of the SiO_2 layer **11** was removed by etching with hydrofluoric acid, as shown in FIG. **2**(c). The exposed part of the [i-layer] *p-type impurity doped layer* **5**, the underlying part of the low-carrier density n-layer **4**, and the underlying upper part of the high-carrier density n^+-layer **3** were removed by dry etching with BCl_3 gas fed at a flow rate of 10 mL/min at 0.04 Torr in conjunction with a high-frequency power of 0.44 W/cm^2, followed by Ar dry etching, as shown in FIG. **3**(A). The SiO_2 layer **11** remaining on the [i-layer] *p-type impurity doped layer* **5** was removed with the aid of hydrofluoric acid, as shown in FIG. **3**(B).

With the temperature kept at 225° C. and the degree of vacuum kept at 8×10^{-7} Torr, the sample was entirely coated with the Ni layer **13** (3000 Å thick) by vapor deposition, as shown in FIG. **3**(C). The Ni layer **13** was coated with a photoresist **14**, which was subsequently patterned by photolithography after the configuration of the electrode for the [i-layer] *p-type impurity doped layer* **5**.

The unmasked part of the Ni layer **13** was etched off using nitric acid and the photoresist **14** was removed by acetone, so that the Ni layer **13** partly remained on which the electrode for the [i-layer] *p-type impurity doped layer* **5** was formed afterward, as shown in FIG. **4**(A).

With the temperature kept at 225° C. and the degree of vacuum kept at 8×10^{-7} Torr, the sample was entirely coated with the Al layer **15** (3000 Å thick) by vapor deposition, as shown in FIG. **4**(B).

The Al layer **15** was coated with a photoresist **16**, which was subsequently patterned by photolithography after the configuration of the respective electrodes for the high-carrier density n^+-layer **3** and the [i-layer] *p-type impurity doped layer* **5**, as shown in FIG. **4**(C).

The exposed part of the Al layer **15** was etched off using nitric acid and the remaining photoresist **16** was removed by acetone, Thus there were formed the electrode **7** for the [i-layer] *p-type impurity doped layer* **5** and the electrode **8** for the high-carrier density n^+-layer **3**.

In this way there was obtained the GaN light-emitting device of MIS structure as shown in FIG. **1**.

Incidentally, the undercoating layer **13** on the [i-layer] *p-type impurity doped layer* **5** may be formed from Ag or Ti or an alloy thereof in place of Ni. Also, the electrode **7** for the [i-layer] *p-type impurity doped layer* **5** and the electrode **8** for the high-carrier density n^+-layer **3** may be formed from any metal such as Ti, in place of Al, which permits ohmic contact.

The thus prepared light-emitting diode **10** was tested for luminous intensity and drive voltage by applying current (10 mA) across the electrodes. The results were compared with those of the conventional one having the Al layer formed directly on the [i-layer] *p-type impurity doped layer* **5**, which gave a luminous intensity of 30 mcd. The results vary depending on the metal used for the undercoating of the electrode for the [i-layer] *p-type impurity doped layer* as shown in the table below. The data of luminous intensity and drive voltage are given in terms of index values compared with those of a conventional sample.

Undercoating metal	Luminous intensity	Drive voltage	Light-emitting pattern
Ni	1.5	0.82	FIG. 5(b)
Ag	1.4	0.90	FIG. 5(c)
Ti	1.05	0.95	FIG. 5(d)

It is noted that the light-emitting diode pertaining to the present invention has a higher luminous intensity and a lower drive voltage than conventional diodes.

Example 2

A light-emitting diode was prepared in the same manner as in Example 1. As shown in FIG. **6**, it is composed of a sapphire substrate **1**, a buffer layer **2** of AlN, a high-carrier density n^+-layer **3** of GaN, a low-carrier density n-layer **4** (1.1 μm thick) having a carrier density of $1\times10^{15}/cm^3$, a low-impurity density [i_L-layer] *L-layer* **51** (1.1 μm thick) having a Zn density of $2\times10^{18}/cm^3$, and a high-impurity density [i_H-layer] *H-layer* **52** (0.2 μm thick) having a Zn density of $1\times10^{20}/cm^3$. It should be noted that the [i-layer] *p-impurity doped layer* is of dual structure with **51** and **52**.

A hole **60** was formed which penetrates the high-impurity density [i_H layer] *H-layer* **52**, the low-impurity density [i_L layer] *L-layer* **51**, and the low-carrier density n-layer **4**, reaching the high-carrier density n^+-layer **3**. In this hole **60** was formed an electrode **80** for the high-carrier density n^+-layer **3**. An electrode **70** was also formed for the high-impurity density [i_H-layer] *H-layer* **52**.

The electrode **70** is composed of a first Ni layer **71** (100 Å thick), a second Ni layer **72** (1000 Å thick), an Al layer **73** (1500 Å thick), a Ti layer **74** (1000 Å thick), and a third Ni layer **75** (2500 Å thick). The electrode **80** is also composed of a first Ni layer **81** (100 Å thick), a second Ni layer **82** (1000 Å thick), an Al layer **83** (1500 Å thick), a Ti layer **84** (1000 Å thick), and a third Ni layer **85** (2500 Å thick).

The first Ni layer **71 (81)** was formed by vacuum deposition at 225° C. The second Ni layer **72 (82)** was also formed by vacuum deposition with heating. (The two steps were separated by an interval in which the vacuum chamber was opened and the water was conditioned at normal pressure and normal temperature.) The Al layer **73 (83)**, Ti layer **74 (84)**, and third Ni layer **75 (85)** were formed successively by vacuum deposition. The Al layer **73 (83)** and Ti layer **74 (84)** permit a solder bump to be formed on the third Ni layer **75 (85)**.

The thus prepared light-emitting diode has a drive voltage for light emission which is 0.8 times that of a conventional diode having an aluminum electrode. In addition, it also exhibits a luminous intensity of 150 mcd at 10 mA current, which is 1.5 times that (100 mcd) of the conventional diode having an aluminum electrode.

It was also found that the same result as mentioned above is obtained even in the case where the electrode **70** for the high-impurity density [i_H-layer] *H-layer* **52** is made of Ni in multi-layer structure and the electrode **80** for the high-carrier density n^+-layer **3** is made of aluminum in single-layer structure.

Example 3

The light-emitting diode in this example differs from that in the previous example in that the first Ni layer **71 (81)** and second Ni layer **72 (82)** are replaced by a Ni layer **710 (810)** of single-layer structure, which is 300 Å thick, as shown in FIG. **7**. This difference in structure has nothing to do with its performance. The Ni layer **710 (810)** should preferably have a thickness in the range of 50 Å to 3000 Å. With a thickness lower than specified, it will be subject to attack by solder when a solder bump is formed. With a thickness greater than specified, it causes the light source to be localized near the electrode rather than the center and it is liable to peeling at the time of soldering in a solder bath.

What is claimed is:

1. A light-emitting device of gallium nitride compound semiconductor material comprising:

an n-layer of n-type gallium nitride compound semiconductor material ($Al_xGa_{1-x}N$, $x\geqq0$); and

[an i-layer of i-type] *a p-type impurity doped layer* gallium nitride compound semiconductor material ($Al_xGa_{1-x}N$, $x\geqq0$) [doped with a p-type impurity];

wherein a first electrode layer including Ni is formed in contact with said [i-layer] *p-type impurity doped layer* and functions as an electrode [therefore] *therefor*; and

wherein said first electrode layer is a multi-layer structure having a first Ni layer of predetermined thickness formed over said [i-layer] *p-type impurity doped layer*, a second Ni layer which is thicker than said first Ni layer and formed thereon, an Al layer formed over said second Ni layer, a Ti layer formed over said Al layer, and a third Ni layer which is thicker than said first Ni layer formed over said Ti layer.

2. A light-emitting device of gallium nitride compound semiconductor material comprising:

an n-layer of n-type gallium nitride compound semiconductor *material* ($Al_xGa_{1-x}N$, $x\geqq0$) [material]; and

[an i-layer of i-type] *a p-type impurity doped layer* gallium nitride compound semiconductor *material* ($Al_xGa_{1-x}N$, $x\geqq0$) [material doped with a p-type impurity];

wherein each of said n-layer and said [i-layer] *p-type impurity doped layer* include respective electrodes formed on a same relative surface, the electrode for said [i-layer] *p-type impurity doped layer* being composed of at least one layer with each said at least one layer being made of one of Ni, Ag, Ti, an alloy including Ni, an alloy including Ag, and an alloy including Ti; and

wherein the electrode for said [i-layer] *p-type impurity doped layer* has an over layer formed thereon which is made of one of Al and an alloy containing Al.

3. A light-emitting device of gallium nitride compound semiconductor, comprising:

at least two layers of gallium nitride compound semiconductor material ($Al_xGa_{1-x}N$, $x\geqq0$);

a first electrode layer for one layer of said at least two layers; and

a second electrode layer for another of said at least two layers;

said first and second electrode layers provide an improved luminous intensity of said light-emitting device;

wherein at least one layer of said first and second electrode layers includes a contact layer made of one of Ni, Ag, an alloy including Ni, an alloy including Ag, and an alloy including Ti, said contact layer being directly contacted with any of said at least two layers of gallium nitride compound semiconductor material ($Al_xGa_{1-x}N$, $x \geqq 0$).

4. A light-emitting device of gallium nitride compound semiconductor according to claim **3**, wherein said contact layer of said first electrode layer is uniformly formed on a light emitting surface of said one layer, said one layer being **[**an i-layer of semi-insulation doped with a p-type impurity**]** *p-type impurity doped layer* and said another layer being an n-layer with n-type conduction.

5. A light-emitting device of gallium nitride compound semiconductor according to claim **3**, wherein said second electrode layer includes a contact layer made of one of Ni, Ag, an alloy including Ni, an alloy including Ag, and an alloy including Ti, said contact layer being directly contacted with said another layer and said another layer being an n-layer with n-type conduction.

6. A light-emitting device of gallium nitride compound semiconductor according to claim **3**, wherein said first electrode layer is a multi-layer structure having a first Ni layer of predetermined thickness formed over said one layer, a second Ni layer which is thicker than said first Ni layer and formed thereon, an Al layer formed over said second Ni layer, a Ti layer formed over said Al layer, and a third Ni layer which is thicker than said first Ni layer formed over said Ti layer.

7. A light-emitting device of gallium nitride compound semiconductor according to claim **3**, wherein at least one layer of said first and second electrode layers has an over layer which is made of one of Ni, Ag, Ti, an alloy including Ni, an alloy including Ag, and an alloy including Ti.

8. A light-emitting device of gallium nitride compound semiconductor material according to claim **4**, wherein at least one layer of said first and second electrode layers has an over layer which is made of one of Ni, Ag, Ti, an alloy including Ni, an alloy including Ag, and an alloy including Ti.

9. A light-emitting device of gallium nitride compound semiconductor according to claim **3**, wherein at least one layer of said first and second electrode layers has over layer formed thereon which is made of one of Al and an alloy containing Al.

10. A light-emitting device of gallium nitride compound semiconductor according to claim **4**, wherein at least one layer of said first and second electrode layers has over layer formed thereon which is made of one of Al and an alloy containing Al.

11. A light-emitting device of gallium nitride compound semiconductor according to claim **7**, wherein at least one layer of said first and second electrode layers has over layer formed thereon which is made of one of Al and an alloy containing Al.

12. A light-emitting device of gallium nitride compound semiconductor according to claim **8**, wherein at least one layer of said first and second electrode layers has over layer formed thereon which is made of one of Al and an alloy containing Al.

13. A light-emitting device of gallium nitride compound semiconductor according to claim **4**, wherein said second electrode layer is made of one of Al and an alloy containing Al, and said first electrode has an over layer which is made of one of Ni, Ag, Ti, an alloy including Ni, an alloy including Ag, and an alloy including Ti.

14. A light-emitting device of gallium nitride compound semiconductor material according to claim **4**, wherein said first electrode layer is a multi-layer structure having a first Ni layer of predetermined thickness formed over said i-layer, a second Ni layer which is thicker than said first Ni layer and formed thereon, an Al layer formed over said second Ni layer, a Ti layer formed over said Al layer, and a third Ni layer which is thicker than said first Ni layer formed over said Ti layer.

15. A light-emitting device of gallium nitride compound semiconductor, comprising:

a first layer of gallium nitride compound semiconductor material ($Al_xGa_{1-x}N$, $x \geqq 0$) doped with p-type impurity;

a second layer of n-type gallium nitride compound semiconductor material ($Al_xGa_{1-x}N$, $x \geqq 0$);

a first electrode layer for said first layer;

a second electrode layer for said second layer; and

wherein said first electrode layer is made of at least one of Ni, Ag, an alloy including Ni, an alloy including Ag, and an alloy including Ti and said second electrode layer is made of at least one of Al, Ti, an alloy including Al, and an alloy including Ti.

16. A light-emitting device of gallium nitride compound semiconductor according to claim 15, wherein said first and second layers are formed on a buffer layer and said buffer layer is formed on a sapphire substrate.

17. A light-emitting device of gallium nitride compound semiconductor according to claim 15, wherein said second layer is gallium nitride (GaN) of low resistivity doped with silicon (Si) for uniform flow of current through said first layer.

18. A light-emitting device of gallium nitride compound semiconductor according to claim 17, wherein said first electrode layer is made of one of Ni and an alloy including Ni and second electrode layer is made of one of Al and an alloy including Al.

19. A light-emitting device of gallium nitride compound semiconductor according to claim 15, wherein said first electrode layer further comprises a multi-layer structure having at least one over layer made of metal different from metal of a layer under said over layer.

20. A light-emitting device of gallium nitride compound semiconductor according to claim 15, wherein said first electrode layer is uniformly formed on a light emitting surface of said first layer.

21. A light-emitting device of gallium nitride compound semiconductor according to claim 15, wherein at least one layer of said first and second electrode layers further comprises at least one over layer made of one of Ni, Ti, an alloy including Ni, and an alloy including Ti.

22. A light-emitting device of gallium nitride compound semiconductor according to claim 15, wherein said second electrode layer further comprises at least one over layer made of one of Al and an alloy containing Al.

23. A light-emitting device of gallium nitride compound semiconductor according to claim 18, wherein said first electrode layer further comprises at least one over layer made of metal excluding Ni.

24. A light-emitting device of gallium nitride compound semiconductor, comprising:

a first layer of gallium nitride compound semiconductor material ($Al_xGa_{1-x}N$, $x \geqq 0$) doped with p-type impurity;

a second layer of n-type gallium nitride compound semiconductor material ($Al_xGa_{1-x}N$, $x \geqq 0$);

a first electrode layer for said first layer;

a second electrode layer for said second layer; and

wherein said first electrode layer is made of at least one of Ni and an alloy including Ni and said second electrode layer is made of Al, Ti, an alloy including Al, and an alloy including Ti.

25. A light-emitting device of gallium nitride compound semiconductor according to claim 24, wherein said first electrode layer has a multi-layer structure comprising at least one over layer made of metal different from metal of a layer under said over layer.

26. A light-emitting device of gallium nitride compound semiconductor according to claim 3, wherein said improved luminous intensity is achieved by reduction of driving voltage for supplying a predetermined current.

27. A light-emitting device of gallium nitride compound semiconductor according to claim 3, wherein said at least one layer of said first and second electrode layers further comprises at least one over layer made of a metal excluding a metal of said contact layer.

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