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### Semiconductor device

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#### Abstract

According to one embodiment, a semiconductor device includes first to third electrodes, first and second semiconductor regions, and a first member. The first semiconductor region includes  $\text{Al.sub.x1Ga.sub.1-x1N}$  ( $0 \leq x1 < 1$ ). The second semiconductor region includes  $\text{Al.sub.x2Ga.sub.1-x2N}$  ( $x1 < x2 \leq 1$ ). The first member includes first and second regions. The second region is between the first region and the first electrode region of the second electrode. A part of the second region is between the second semiconductor portion of the second semiconductor region and the second electrode region. The second region includes at least one first element selected from the group consisting of Ti, Al, Ga, Ni, Nb, Mo, Ta, Hf, V, and Au. The first region does not include the first element, or a concentration of the first element in the first region is lower than a concentration of the first element in the second region.

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## **Background/Summary**

### **CROSS-REFERENCE TO RELATED APPLICATIONS**

(1) This application is based upon and claims the benefit of priority from Japanese Patent Application No. 2021-202188, filed on Dec. 14, 2021; the entire contents of which are incorporated herein by reference.

### **FIELD**

(2) Embodiments described herein relate generally to semiconductor device.

### **BACKGROUND**

(3) For example, in a semiconductor device such as a transistor, stable characteristics are desired.

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## **Description**

### **BRIEF DESCRIPTION OF THE DRAWINGS**

- (1) FIG. 1 is a schematic cross-sectional view illustrating a semiconductor device according to a first embodiment;
- (2) FIGS. 2A to 2C are schematic cross-sectional views illustrating a method for manufacturing the semiconductor device according to the first embodiment;
- (3) FIG. 3 is a graph illustrating characteristics of the semiconductor device;
- (4) FIGS. 4A to 4F are analysis images of the semiconductor device according to the embodiment;
- (5) FIGS. 5A and 5B are optical micrograph images of the semiconductor device according to the embodiment;
- (6) FIG. 6 is a graph illustrating characteristics of the semiconductor device according to the embodiment;
- (7) FIGS. 7A to 7E are schematic cross-sectional views illustrating a method for manufacturing the semiconductor device according to the first embodiment;
- (8) FIG. 8 is a schematic cross-sectional view illustrating a semiconductor device according to the first embodiment;
- (9) FIGS. 9A to 9E are schematic cross-sectional views illustrating a method for manufacturing the semiconductor device according to the first embodiment;
- (10) FIG. 10 is a schematic cross-sectional view illustrating a semiconductor device according to the first embodiment;
- (11) FIG. 11 is a schematic cross-sectional view illustrating a semiconductor device according to the first embodiment;
- (12) FIG. 12 is a schematic cross-sectional view illustrating a semiconductor device according to the first embodiment;
- (13) FIG. 13 is a schematic cross-sectional view illustrating a semiconductor device according to the first embodiment;

- (14) FIG. **14** is a schematic cross-sectional view illustrating a semiconductor device according to the first embodiment;
- (15) FIG. **15** is a schematic cross-sectional view illustrating a semiconductor device according to the first embodiment;
- (16) FIG. **16** is a schematic cross-sectional view illustrating a semiconductor device according to the first embodiment; and
- (17) FIG. **17** is a schematic plan view illustrating a semiconductor device according to a second embodiment.

#### DETAILED DESCRIPTION

(18) According to one embodiment, a semiconductor device includes a first electrode, a second electrode, a third electrode, a first semiconductor region, a second semiconductor region, and a first member. A direction from the first electrode to the second electrode is along a first direction. The second electrode includes a first electrode region and a second electrode region. A position in the first direction of the third electrode is between a position in the first direction of the first electrode and a position in the first direction of the second electrode. The first semiconductor region includes  $\text{Al}_{x1}\text{Ga}_{1-x1}\text{N}$  ( $0 \leq x1 < 1$ ). The first semiconductor region includes a first partial region, a second partial region, a third partial region, a fourth partial region, and a fifth partial region. A direction from the first partial region to the first electrode is along a second direction crossing the first direction. A direction from the second partial region to the second electrode is along the second direction. A direction from the third partial region to the third electrode is along the second direction. The fourth partial region is between the first partial region and the third partial region in the first direction. The fifth partial region is between the third partial region and the second partial region in the first direction. The second semiconductor region includes  $\text{Al}_{x2}\text{Ga}_{1-x2}\text{N}$  ( $x1 < x2 \leq 1$ ). The second semiconductor region includes a first semiconductor portion and a second semiconductor portion. A direction from the fourth partial region to the first semiconductor portion is along the second direction. A direction from the fifth partial region to the second semiconductor portion is along the second direction. The first member includes a first region and a second region. The second semiconductor portion is between the fifth partial region and the first region in the second direction. At least a part of the second region is between at least a part of the first region and the first electrode region in the first direction. The at least a part of the second region is between the second semiconductor portion and the second electrode region in the second direction. The second region includes at least one first element selected from the group consisting of Ti, Al, Ga, Ni, Nb, Mo, Ta, Hf, V, and Au. The first region does not include the first element, or a concentration of the first element in the first region is lower than a concentration of the first element in the second region.

- (19) Various embodiments are described below with reference to the accompanying drawings.
- (20) The drawings are schematic and conceptual; and the relationships between the thickness and width of portions, the proportions of sizes among portions, etc., are not necessarily the same as the actual values. The dimensions and proportions may be illustrated differently among drawings, even for identical portions.
- (21) In the specification and drawings, components similar to those described previously or illustrated in an antecedent drawing are marked with like reference numerals, and a detailed description is omitted as appropriate.

#### First Embodiment

- (22) FIG. **1** is a schematic cross-sectional view illustrating a semiconductor device according to a first embodiment.
- (23) As shown in FIG. **1**, a semiconductor device **110** according to the first embodiment includes a first electrode **51**, a second electrode **52**, a third electrode **53**, a first semiconductor region **10**, a second semiconductor region **20**, and a first member **40**.
- (24) A direction from the first electrode **51** to the second electrode **52** is along a first direction D**1**.

The first direction **D1** is defined as an X-axis direction. One direction perpendicular to the X-axis direction is defined as a Z-axis direction. A direction perpendicular to the X-axis direction and the Z-axis direction is defined as a Y-axis direction.

(25) The second electrode **52** includes a first electrode region **52a** and a second electrode region **52b**.

(26) A position of the third electrode **53** in the first direction **D1** is between a position of the first electrode **51** in the first direction **D1** and a position of the second electrode **52** in the first direction **D1**. For example, the third electrode **53** is between the first electrode **51** and the second electrode **52** in the first direction **D1**.

(27) The first semiconductor region **10** includes  $\text{Al.sub.x1Ga.sub.1-x1N}$  ( $0 \leq x1 < 1$ ). In one example, a composition ratio  $x1$  is not less than 0 and not more than 0.1. The first semiconductor region **10** is, for example, a GaN layer.

(28) The first semiconductor region **10** includes a first partial region **11**, a second partial region **12**, a third partial region **13**, a fourth partial region **14**, and a fifth partial region **15**. A direction from the first partial region **11** to the first electrode **51** is along the second direction **D2**. The second direction **D2** crosses the first direction **D1**. The second direction **D2** is, for example, the Z-axis direction.

(29) A direction from the second partial region **12** to the second electrode **52** is along the second direction **D2**. A direction from the second partial region **12** to at least a part of the second electrode **52** is along the second direction **D2**. A direction from the third partial region **13** to the third electrode **53** is along the second direction **D2**. The fourth partial region **14** is between the first partial region **11** and the third partial region **13** in the first direction **D1**. The fifth partial region **15** is between the third partial region **13** and the second partial region **12** in the first direction **D1**.

(30) The first partial region **11** is, for example, a region that overlaps the first electrode **51** in the Z-axis direction. The second partial region **12** is, for example, a region that overlaps the second electrode **52** in the Z-axis direction. The third partial region **13** is, for example, a region that overlaps the third electrode **53** in the Z-axis direction.

(31) The second semiconductor region **20** includes  $\text{Al.sub.x2Ga.sub.1-x2N}$  ( $x1 < x2 \leq 1$ ). In one example, a composition ratio  $x2$  is not less than 0.05 and not more than 0.35. The second semiconductor region **20** is, for example, an AlGaIn layer.

(32) The second semiconductor region **20** includes a first semiconductor portion **21** and a second semiconductor portion **22**.

(33) A direction from the fourth partial region **14** to the first semiconductor portion **21** is along the second direction **D2**. A direction from the fifth partial region **15** to the second semiconductor portion **22** is along the second direction **D2**.

(34) For example, the first electrode **51** is electrically connected with the first semiconductor portion **21**. The second electrode **52** is electrically connected with the second semiconductor portion **22**.

(35) A current flowing between the first electrode **51** and the second electrode **52** can be controlled by a potential of the third electrode **53**. The potential of the third electrode **53** may be, for example, a potential based on a potential of the first electrode **51**. For example, a distance between the first electrode **51** and the third electrode **53** is shorter than a distance between the second electrode **52** and the third electrode **53**. The first electrode **51** functions as, for example, a source electrode. The second electrode **52** functions as, for example, a drain electrode. The third electrode **53** functions as, for example, a gate electrode. The semiconductor device **110** is, for example, a transistor.

(36) The first semiconductor region **10** and the second semiconductor region **20** are included in a semiconductor member **10M**. The first semiconductor region **10** includes a portion facing the second semiconductor region **20**. A carrier region **10c** is formed in the facing portion. The carrier region **10c** is, for example, a two-dimensional electron gas. The semiconductor device **110** is, for example, a HEMT (high electron mobility transistor).

(37) In the second electrode **52**, the first electrode region **52a** is in contact with, for example, the second semiconductor portion **22**. The second electrode region **52b** projects toward the third electrode **53** with reference to the first electrode region **52a**. The second electrode region **52b** is a protruding portion or an eaves portion.

(38) As shown in FIG. 1, the first electrode **51** may include a third electrode region **51c** and a fourth electrode region **51d**. The third electrode region **51c** is in contact with, for example, the first semiconductor portion **21**. The fourth electrode region **51d** projects toward the third electrode **53** with reference to the third electrode region **51c**. The fourth electrode region **51d** is a protruding portion or an eaves portion. By providing these protruding portions, it is easy to obtain a stable electrode shape. For example, the margin in the manufacturing process is expanded, and a practical semiconductor device can be obtained.

(39) As shown in FIG. 1, the semiconductor device **110** may include a base body **18s** and a buffer layer **18b**. The base body **18s** may include, for example, a silicon substrate or a sapphire substrate. The buffer layer **18b** is between the base body **18s** and the semiconductor member **10M**. The buffer layer **18b** is provided on the base body **18s**. The first semiconductor region **10** is provided on the buffer layer **18b**. The second semiconductor region **20** is provided on the first semiconductor region **10**. The first to third electrodes **51** to **53** are provided on the second semiconductor region **20**.

(40) The first member **40** includes a first region **41** and a second region **42**. The second semiconductor portion **22** is between the fifth partial region **15** and the first region **41** in the second direction **D2**. At least a part of the second region **42** is between at least a part of the first region **41** and the first electrode region **52a** in the first direction **D1**. At least a part of the second region **42** is between the second semiconductor portion **22** and the second electrode region **52b** in the second direction **D2**.

(41) The first semiconductor portion **21** is between the fourth partial region **14** and a part of the first region **41**. For example, the first semiconductor portion **21** is protected by a part of the first region **41**. It is easy to obtain more stable characteristics. In this example, another part of the first region **41** is between the third partial region **13** and the third electrode **53**. Another part of the first region **41** functions as a gate insulating film.

(42) In the first configuration according to the embodiment, the second region **42** includes at least one first element selected from the group consisting of Ti, Al, Ga, Ni, Nb, Mo, Ta, Hf, V and Au. On the other hand, the first region **41** does not include the first element. Alternatively, a concentration of the first element in the first region **41** is lower than a concentration of the first element in the second region **42**. As will be described later, the second configuration or the third configuration may be applied. Stable characteristics can be obtained in the semiconductor device having the first configuration as described above.

(43) For example, in the semiconductor device **110**, if the second electrode **52** is provided with the second electrode region **52b** (protruding portion), the on-resistance may increase. For example, current collapse occurs. It is considered that this is due to the presence of a trap in an insulating film between the second electrode region **52b** and the semiconductor member **10M**. It is considered that the on-resistance increases due to the charge trapped in the trap in the insulating film.

(44) In the embodiment, the above-mentioned first element is introduced into the second region **42** located below the second electrode region **52b**. It is considered that introduction of the first element substantially eliminates the traps in the second region **42**. As a result, the increase in on-resistance is suppressed.

(45) Hereinafter, examples of experimental results relating to semiconductor devices will be described. First, a method for manufacturing an experimental sample will be described.

(46) FIGS. 2A to 2C are schematic cross-sectional views illustrating a method for manufacturing the semiconductor device according to the first embodiment.

(47) In these figures, the base body **18s** and the buffer layer **18b** are omitted. As shown in FIG. 2A, the second semiconductor region **20** is provided on the first semiconductor region **10**. A first

member film **40f**, which is the first member **40**, is provided on the second semiconductor region **20**. The first member film **40f** is, for example, a silicon nitride film. In this example, the third electrode **53** is provided on the first member film **40f**.

(48) As shown in FIG. 2B, a part of the first member film **40f** is removed. The first electrode **51** and the second electrode **52** are formed in the removed region. In this example, the first electrode **51** and the second electrode **52** include the first element. Then, heat treatment is performed at a high temperature.

(49) As a result, as shown in FIG. 2C, a part of the first element included in the second electrode **52** moves (diffuses) into the first member film **40f**. As a result, the second region **42** including the first element is formed. In this example, a part of the first element included in the first electrode **51** moves (diffuses) into the first member film **40f**. As a result, a region **42r** including the first element is also formed in the vicinity of the first electrode **51**. In this example, the first element is Al.

(50) A first sample SP1 is formed by the above method. On the other hand, a second sample is formed in the same manner. In the second sample, a temperature of the above heat treatment is lower than a temperature in the first sample SP1. In the second sample, the second region **42** does not include the first element.

(51) FIG. 3 is a graph illustrating characteristics of the semiconductor device.

(52) FIG. 3 illustrates an on-resistance during a stress test in the first sample SP1 and the second sample SP2. In the stress test, a measurement environmental temperature is 150° C. and a drain stress voltage is 900 V. The horizontal axis of FIG. 3 is a stress time  $t_{m0}$ . The vertical axis of FIG. 3 is a rate of increase  $\Delta R$  of the on-resistance. The rate of increase  $\Delta R$  is a ratio of the on-resistance at the stress time  $t_{m0}$  to the on-resistance when the stress time  $t_{m0}$  is 0 (initial state). The rate of increase  $\Delta R$  is preferably close to 1.

(53) As shown in FIG. 3, in the second sample SP2, as the stress time  $t_{m0}$  becomes longer, the rate of increase  $\Delta R$  becomes remarkably large. On the other hand, in the first sample SP1, the increase of the rate of increase  $\Delta R$  is suppressed even if the stress time  $t_{m0}$  becomes long. By providing the second region **42** including the first element in this way, stable characteristics can be obtained.

(54) FIGS. 4A to 4F are analysis images of the semiconductor device according to the embodiment.

(55) FIGS. 4A to 4C correspond to the first sample SP1. FIGS. 4D to 4F correspond to the second sample SP2. In these samples, the second electrode region **52b** of the second electrode **52** includes Al. In these samples, an insulating member **48** (see FIG. 10), which will be described later, is provided. FIGS. 4A and 4D correspond to a transmission electron microscope (TEM) image. FIGS. 4B and 4E are EDX images related to Al. In FIGS. 4B and 4E, a concentration of Al is high in the bright region. FIGS. 4C and 4F are EDX images related to nitrogen. In FIGS. 4C and 4F, a concentration of nitrogen is high in the bright region.

(56) As shown in FIGS. 4A and 4D, there is the second region **42** below the second electrode region **52b** of the second electrode **52**. FIGS. 4A to 4F show a position of an interface IF1 between the second region **42** and the second electrode region **52b**.

(57) As shown in FIG. 4B, in the first sample SP1, the second region **42** includes the first element (Al). As shown in FIG. 4E, in the second sample SP2, the second region **42** does not include the first element (Al).

(58) FIGS. 5A and 5B are optical micrograph images of the semiconductor device according to the embodiment.

(59) As shown in FIG. 5A, in the first sample SP1, the second region **42** including the first element is observed. The second region **42** includes a portion not covered by the second electrode **52**. As shown in FIG. 5B, in the second sample SP2, the second region **42** including the first element is not observed.

(60) As described above, it is considered that the increase of the on-resistance is suppressed by including the first element in the second region **42** between the second electrode region **52b** and the second semiconductor portion **22** as illustrated in FIG. 3.

(61) FIG. 6 is a graph illustrating characteristics of the semiconductor device according to the embodiment.

(62) FIG. 6 illustrates a leakage current density  $IL1$  in a first film sample SF1 corresponding to the first sample SP1 and a second film sample SF2 corresponding to the second sample SP2. The first film sample SF1 is a silicon nitride film including a first element (Al). The second film sample SF2 is a silicon nitride film that does not substantially include the first element. The horizontal axis of FIG. 6 is a voltage  $V1$  applied to these film samples. The vertical axis is the leakage current density  $IL1$  flowing through these film samples.

(63) As shown in FIG. 6, the leakage current density  $IL1$  is low in the second film sample SF2. On the other hand, in the first film sample SF1, the leakage current density  $IL1$  is high. In the first film sample SF1, it is considered that the leakage current density  $IL1$  is high and the voltage applied between the second electrode region 52b and the semiconductor member 10M is substantially lowered. For example, it is considered that the second electrode region 52b is substantially in ohmic contact with the second semiconductor portion 22 via the second region 42. As a result, as illustrated in FIG. 3, it is considered that the increase in on-resistance is suppressed.

(64) As described above, the second electrode 52 may include the first element. The first element included in the second region 42 may be introduced from the second electrode 52. For example, the first region 41 and the second region 42 may include at least one second element selected from the group consisting of nitrogen and oxygen, and silicon. The first region 41 includes, for example, silicon nitride that is substantially free of the first element. The second region 42 is, for example, silicon nitride including the first element.

(65) In the first configuration, the concentration of the first element in the second region 42 is, for example, not less than 5 atm %. As a result, the increase in on-resistance can be effectively suppressed.

(66) In the first configuration, the concentration of the first element in the first region 41 is, for example, not more than 0.5 atm %. Thereby, for example, a gate leak current can be suppressed.

(67) As shown in FIG. 1, the second region 42 includes a first end portion 42e and a second end portion 42f. These ends correspond to the two ends in the first direction D1. The second end portion 42f is between the first end portion 42e and the first electrode region 52a in the first direction D1. The second end portion 42f faces the first electrode region 52a. A position of the first end portion 42e in the first direction D1 is between the position of the third electrode 53 in the first direction D1 and a position of the second electrode region 52b in the first direction D1. The first end portion 42e projects toward the third electrode 53 with reference to the end of the second electrode region 52b in the first direction D1. As a result, the increase in on-resistance can be suppressed more stably.

(68) As shown in FIG. 1, a length of the second region 42 along the first direction D1 is defined as a length L1. The length L1 corresponds to a distance between the first end portion 42e and the second end portion 42f. The length L1 is preferably, for example, not more than 2  $\mu\text{m}$ . Even if there are variations in the manufacturing process, the increase in on-resistance can be stably suppressed.

(69) As shown in FIG. 1, the second region 42 includes a portion that overlaps the second electrode region 52b in the second direction D2. A length of the overlapping portion along the first direction D1 is defined as a length L2. The length L2 corresponds to, for example, an amount of protrusion of the second electrode region 52b. In the embodiment, the length L2 is preferably not more than 0.8  $\mu\text{m}$ . When the length L2 is not excessively long, for example, a distance between the third electrode 53 and the second electrode 52 can be maintained long. For example, a high breakdown voltage can be maintained. Current collapse can be suppressed.

(70) In the embodiment, the second region 42 may be formed by a method different from the method described with respect to FIGS. 2A and 2C. Hereinafter, an example of another method for forming the second region 42 will be described.

(71) FIGS. 7A to 7E are schematic cross-sectional views illustrating a method for manufacturing



the semiconductor device according to the first embodiment.

(72) In these figures, the base body **18s** and the buffer layer **18b** are omitted. As shown in FIG. 7A, the second semiconductor region **20** is provided on the first semiconductor region **10**. The first member film **40f**, which is the first member **40**, is provided on the second semiconductor region **20**. The first member film **40f** is, for example, a silicon nitride film. In this example, the third electrode **53** is provided on the first member film **40f**.

(73) As shown in FIG. 7B, a mask member **40M** is formed on the first member film **40f**. The mask member **40M** has an opening **40o**. An element **ii** is introduced into a part of the first member film **40f** through the opening **40o**. The element **ii** includes the first element. The introduction of the element **ii** is performed, for example, by ion implantation. The region into which the element **ii** is not introduced is the first region **41**. The region into which the element **ii** is introduced is the second region **42**.

(74) As shown in FIG. 7C, after the mask member **40M** is removed, a part of the first region **41** is removed to form an opening **51o**. A part of the second region **42** is removed to form an opening **52o**.

(75) As shown in FIG. 7D, a conductive portion **51m** to be the first electrode **51** is formed on the opening **51o** and the first region **41**. A conductive portion **52m** to be the second electrode **52** is formed on the opening **52o** and the second region **42**.

(76) As shown in FIG. 7E, the first electrode **51** is obtained from the conductive portion **51m** by performing the heat treatment. The second electrode **52** is obtained from the conductive portion **52m**. The second region **42** including the first element can also be formed by such a method.

(77) In the embodiment, the first member **40** may have the following second configuration. In the second configuration, the first region **41** includes at least one second element selected from the group consisting of nitrogen and oxygen, and silicon. The second region **42** includes silicon, and a concentration of silicon in the second region is higher than a concentration of silicon in the first region **41**. In the second configuration, the first region **41** includes, for example, at least one selected from the group consisting of silicon nitride, silicon oxide and silicon oxynitride. In the second configuration, the second region **42** includes, for example, polysilicon.

(78) In the second configuration, the second region **42** is less likely to include a trap than the first region **41**. For example, an electrical resistance of the second region **42** is lower than an electrical resistance of the first region **41**. For example, a voltage applied to the second region **42** between the second electrode region **52b** and the second semiconductor portion **22** is low. Even in the second configuration including such a second region **42**, the increase in on-resistance can be suppressed.

(79) In the embodiment, the first member **40** may have the following third configuration. In the third configuration, the first region **41** includes at least one second element selected from the group consisting of nitrogen and oxygen, and silicon. In the third configuration, the first region **41** includes, for example, at least one selected from the group consisting of silicon nitride, silicon oxide and silicon oxynitride. The second region **42** includes  $\text{Al}_{z1}\text{Ga}_{1-z1}\text{N}$  ( $0 \leq z1 \leq 1$ ). The second region **42** includes, for example, GaN, AlGa<sub>N</sub> or AlN. The second region **42** may include polycrystals. By including polycrystals in the second region **42**, for example, the resistance can be lowered and the trap can be substantially reduced. The increase in on-resistance can be suppressed. In the third configuration, the second region **42** may include at least one of the third element or the fourth element. The third element includes at least one selected from the group consisting of Si, Ge, and Sn. The fourth element includes at least one selected from the group consisting of Mg and Zn. The third element is, for example, an n-type impurity. The fourth element is, for example, a p-type impurity.

(80) In the third configuration, the second region **42** is less likely to include a trap than the first region **41**. For example, the electrical resistance of the second region **42** is lower than the electrical resistance of the first region **41**. For example, the voltage applied to the second region **42** between the second electrode region **52b** and the second semiconductor portion **22** is low. Even in the third

configuration including the second region **42**, the increase in on-resistance can be suppressed.

(81) In the example of the semiconductor device according to the embodiment described below, the first member **40** may have any of the above-mentioned first to third configurations.

(82) FIG. **8** is a schematic cross-sectional view illustrating a semiconductor device according to the first embodiment.

(83) As shown in FIG. **8**, in a semiconductor device **111** according to the embodiment, a part of the first region **41** is above the second region **42**. Except for this, the configuration of the semiconductor device **111** may be the same as the configuration of the semiconductor device **110**.

(84) In the semiconductor device **111**, a part of the second region **42** is between the second semiconductor portion **22** and a part of the first region **41**. For example, the second region **42** is protected by the first region **41**. It is easy to obtain more stable characteristics.

(85) FIGS. **9A** to **9E** are schematic cross-sectional views illustrating a method for manufacturing the semiconductor device according to the first embodiment.

(86) In these figures, the base body **18s** and the buffer layer **18b** are omitted. As shown in FIG. **9A**, the second semiconductor region **20** is provided on the first semiconductor region **10**. A second region film **42F**, which is the second region **42**, is provided on the second semiconductor region **20**. For example, the material of the second region **42** according to the first to third configurations described above is applied to the second region film **42F**. In one example, the second region film **42F** is a silicon film (second configuration). In another example, the second region film **42F** is a GaN film, an AlGaIn film, or an AlN film (third configuration). In another example, the second region film **42F** is a silicon nitride film (first configuration) including a first element.

(87) As shown in FIG. **9B**, the first region film **41F**, which is the first region **41**, is formed on the second semiconductor region **20** and the second region film **42F**. The first region film **41F** is, for example, a silicon nitride film.

(88) As shown in FIG. **9C**, a part of the first region film **41F** is removed to form the opening **51o**. A part of the second region film **42F** is removed to form the opening **52o**. As a result, the first region **41** and the second region **42** are formed.

(89) As shown in FIG. **9D**, the conductive portion **51m** to be the first electrode **51** is formed on the opening **51o** and the first region **41**. The conductive portion **52m** to be the second electrode **52** is formed on the opening **52o** and the second region **42**.

(90) As shown in FIG. **9E**, the first electrode **51** is obtained from the conductive portion **51m** by performing the heat treatment. The second electrode **52** is obtained from the conductive portion **52m**. Also by such a method, the first member **40** including any one of the first to third configurations can be formed. As a result, the semiconductor device **111** is obtained.

(91) FIG. **10** is a schematic cross-sectional view illustrating a semiconductor device according to the first embodiment.

(92) As shown in FIG. **10**, a semiconductor device **112** according to the embodiment includes the insulating member **48**. Except for this, the configuration of the semiconductor device **112** may be the same as the configuration of the semiconductor device **110**.

(93) In the semiconductor device **112**, the first region **41** is between the second semiconductor portion **22** and the insulating member **48** in the second direction **D2**. For example, the insulating member **48** protects the first region **41**. It is easy to obtain more stable characteristics. The insulating member **48** includes, for example, at least one selected from the group consisting of oxygen and nitrogen, and silicon. The insulating member **48** includes, for example, silicon oxide. The insulating member **48** includes, for example, silicon nitride.

(94) In the semiconductor device **112**, the second region **42** is between at least a part of the insulating member **48** and the first electrode region **52a** in the first direction **D1**.

(95) FIG. **11** is a schematic cross-sectional view illustrating a semiconductor device according to the first embodiment.

(96) As shown in FIG. **11**, a semiconductor device **113** according to the embodiment also includes

the insulating member **48**. The configuration of the insulating member **48** and the second region **42** in the semiconductor device **113** is different from the configuration in the semiconductor device **112**. Except for this, the configuration of the semiconductor device **113** may be the same as the configuration of the semiconductor device **112**.

(97) In the semiconductor device **113**, the first region **41** is between the second semiconductor portion **22** and the insulating member **48** in the second direction **D2**. A part of the insulating member **48** is between a part of the first region **41** and a part of the second region **42** in the second direction **D2**.

(98) FIG. **12** is a schematic cross-sectional view illustrating a semiconductor device according to the first embodiment.

(99) As shown in FIG. **12**, a semiconductor device **114** according to the embodiment also includes the insulating member **48**. The configuration of the insulating member **48** and the second region **42** in the semiconductor device **114** is different from the configuration in the semiconductor device **112**. Except for this, the configuration of the semiconductor device **114** may be the same as the configuration of the semiconductor device **112**.

(100) In the semiconductor device **114**, a part of the insulating member **48** is between the second region **42** and the second electrode region **52b** in the second direction **D2**.

(101) With respect to the above-mentioned semiconductor devices **112** to **114**, any one of the above-mentioned first to third configurations may be applied to the first member **40**. Stable characteristics can be obtained.

(102) FIG. **13** is a schematic cross-sectional view illustrating a semiconductor device according to the first embodiment.

(103) As shown in FIG. **13**, in a semiconductor device **120** according to the embodiment, the first region **41** includes a stacked film. Except for this, the configuration of the semiconductor device **120** may be the same as the configuration of the semiconductor device **110**, for example.

(104) In the semiconductor device **120**, the first region **41** includes the first to third compound films **41a** to **41c**. The first compound film **41a** includes silicon and oxygen. The second compound film **41b** includes  $\text{Al}_{0.5}\text{Ga}_{0.5}\text{N}$  ( $0 < y \leq 1$ ). The third compound film **41c** includes silicon and nitrogen. The first compound film **41a** is, for example, a silicon oxide film. The second compound film **41b** is, for example, an AlN film. The third compound film **41c** is, for example, a silicon nitride film. The second compound film **41b** is between the second semiconductor portion **22** and the first compound film **41a**. The third compound film **41c** is between the second semiconductor portion **22** and the second compound film **41b**. Such a stacked structure may be applied to an insulating film provided between the first electrode **51** and the third electrode **53**.

(105) As shown in FIG. **13**, in the semiconductor device **120**, at least a part (part **53p**) of the third electrode **53** is between the first semiconductor portion **21** and the second semiconductor portion **22** in the first direction **D1**. The third electrode **53** is, for example, a recess type gate electrode. With such a configuration, for example, a high threshold voltage can be obtained. For example, a normal off operation is performed.

(106) The first member **40** further includes a third region **43**, a fourth region **44**, and a fifth region **45**. The third region **43** is between the third partial region **13** and at least a part (part **53p**) of the third electrode **53** in the second direction **D2**. The fourth region **44** is between the first semiconductor portion **21** and at least a part (part **53p**) of the third electrode **53** in the first direction **D1**. The fifth region **45** is between at least a part (part **53p**) of the third electrode **53** and the second semiconductor portion **22** in the first direction **D1**.

(107) The third region **43**, the fourth region **44**, and the fifth region **45** function as, for example, the gate insulating film. The third region **43**, the fourth region **44**, and the fifth region **45** may include a stacked film.

(108) For example, the first member **40** includes a first compound film **41a** including silicon and oxygen, a second compound film **41b** including  $\text{Al}_{0.5}\text{Ga}_{0.5}\text{N}$  ( $0 < y \leq 1$ ), and a third

compound film **41c** including silicon and nitrogen.

(109) The first compound film **41a** is between the third partial region **13** and at least a part (partial **53p**) of the third electrode **53** in the third region **43**. The first compound film **41a** is between the first semiconductor portion **21** and at least a part (part **53p**) of the third electrode **53** in the fourth region **44**. The first compound film **41a** is between at least a part (part **53p**) of the third electrode **53** and the second semiconductor portion **22** in the fifth region **45**.

(110) The second compound film **41b** is between the third partial region **13** and the first compound film **41a** in the third region **43**. The second compound film **41b** is between the first semiconductor portion **21** and the first compound film **41a** in the fourth region **44**. The second compound film **41b** is between the first compound film **41a** and the second semiconductor portion **22** in the fifth region **45**. The second compound film **41b** is between the second semiconductor portion **22** and the first compound film **41a** in the first region **41**.

(111) For example, the second compound film **41b** is in contact with the third partial region **13** in the third region **43**. For example, the second compound film **41b** is in contact with the first semiconductor portion **21** in the fourth region **44**. For example, the second compound film **41b** is in contact with the second semiconductor portion **22** in the fifth region **45**.

(112) The third compound film **41c** is between the second semiconductor portion **22** and the second compound film **41b** in the first region **41**. For example, the third compound film **41c** is not provided in the third region **43**, the fourth region **44**, and the fifth region **45**. By not providing the third compound film **41c** in the third region **43**, the fourth region **44**, and the fifth region **45**, for example, the fluctuation of the threshold voltage can be reduced.

(113) By providing the second compound film **41b** in the third region **43**, the fourth region **44**, and the fifth region **45**, the electron mobility can be increased. The on-resistance of the device can be reduced.

(114) By providing the first compound film **41a** in the third region **43**, the fourth region **44**, and the fifth region **45**, it is easy to obtain a stable threshold voltage. A leakage current can be reduced.

(115) The second semiconductor portion **22** is protected by providing the third compound film **41c** in the first region **41**. More stable characteristics can be obtained. Current collapse can be suppressed. The first semiconductor portion **21** is protected by providing the third compound film **41c** in the region between the first electrode **51** and the third electrode **53**. More stable characteristics can be obtained.

(116) FIG. **14** is a schematic cross-sectional view illustrating a semiconductor device according to the first embodiment.

(117) As shown in FIG. **14**, the insulating member **48** is provided in a semiconductor device **121** according to the embodiment. Except for this, the configuration of the semiconductor device **121** may be the same as the configuration of the semiconductor device **120**, for example. In the semiconductor device **121**, a part of the second region **42** is between the insulating member **48** and the first electrode region **52a** in the second direction D2.

(118) FIG. **15** is a schematic cross-sectional view illustrating a semiconductor device according to the first embodiment.

(119) As shown in FIG. **15**, in a semiconductor device **122** according to the embodiment, the configurations of the insulating member **48** and the second region **42** are different from the configurations of the semiconductor device **121**. Except for this, the configuration of the semiconductor device **122** may be the same as the configuration of the semiconductor device **121**, for example. In the semiconductor device **122**, a part of the insulating member **48** is between a part of the second region **42** and the second electrode region **52b** in the second direction D2.

(120) FIG. **16** is a schematic cross-sectional view illustrating a semiconductor device according to the first embodiment.

(121) As shown in FIG. **16**, in a semiconductor device **123** according to the embodiment, the configurations of the insulating member **48** and the second region **42** are different from the

configurations of the semiconductor device **121**. Except for this, the configuration of the semiconductor device **123** may be the same as the configuration of the semiconductor device **121**, for example. In the semiconductor device **123**, a part of the insulating member **48** is between a part of the first region **41** and a part of the second region **42** in the second direction **D2**.

## Second Embodiment

(122) FIG. **17** is a schematic plan view illustrating a semiconductor device according to a second embodiment.

(123) As shown in FIG. **17**, a semiconductor device **130** according to the embodiment includes multiple second electrodes **52**. Each of the multiple second electrodes **52** includes the first electrode region **52a** and the second electrode region **52b** (see FIG. **1** and the like). In this example, multiple first electrodes **51** and multiple third electrodes **53** are provided. These electrodes extend along the third direction **D3**. The third direction **D3** crosses a plane including the first direction **D1** and the second direction **D2**. The third direction **D3** is, for example, the Y-axis direction. These electrodes are aligned along the first direction **D1**.

(124) A position of the first electrode **51** (one of the multiple first electrodes **51**) in the first direction **D1** is between a position of one of the multiple second electrodes **52** in the first direction **D1** and a position of another one of the multiple second electrodes **52** in the first direction **D1**. A position of the third electrode **53** (one of the multiple third electrodes **53**) in the first direction **D1** is between a position of the first electrode **51** in the first direction **D1** and a position of another one of the multiple second electrodes **52** in the first direction **D1**.

(125) At least a part of the first to third electrodes **51** to **53** passes through an element region **10A** (for example, the active region). A peripheral region **10P** is provided around the element region **10A**. An electrode pad region is provided in the peripheral region **10P**. The multiple first electrodes **51** are electrically connected with a first electrode pad **51P**. The multiple second electrodes **52** are electrically connected with a second electrode pad **52P**. The multiple third electrodes **53** are electrically connected with a third electrode pad **53P**.

(126) As shown in FIG. **17**, the second region **42** includes a region that does not overlap the second electrode **52** in the second direction **D2**. In the semiconductor device **130**, any one of the first to third configurations is applied. By providing the second region **42**, for example, the increase in on-resistance is suppressed. It is possible to provide a semiconductor device capable of obtaining stable characteristics.

(127) For example, a material of the first electrode **51** may be the same as a material of the second electrode **52**. For example, the first electrode **51** may include at least one first element selected from the group consisting of Ti, Al, Ga, Ni, Nb, Mo, Ta, Hf, V and Au.

(128) The third electrode **53** includes, for example, at least one selected from the group consisting of TiN, WN, Ni, Au, Pt and Ti. The third electrode **53** may include, for example, conductive silicon or polysilicon.

(129) Information on length and thickness can be obtained by electron microscope observation or the like. Information on composition of the material can be obtained by SIMS (Secondary Ion Mass Spectrometry) or EDX (Energy dispersive X-ray spectroscopy).

(130) According to the embodiment, it is possible to provide a semiconductor device capable of obtaining stable characteristics.

(131) Hereinabove, exemplary embodiments of the invention are described with reference to specific examples. However, the embodiments of the invention are not limited to these specific examples. For example, one skilled in the art may similarly practice the invention by appropriately selecting specific configurations of components included in semiconductor devices such as semiconductor members, semiconductor regions, electrodes, members, insulating members, etc., from known art. Such practice is included in the scope of the invention to the extent that similar effects thereto are obtained.

(132) Further, any two or more components of the specific examples may be combined within the

extent of technical feasibility and are included in the scope of the invention to the extent that the purport of the invention is included.

(133) Moreover, all semiconductor devices practicable by an appropriate design modification by one skilled in the art based on the semiconductor devices described above as embodiments of the invention also are within the scope of the invention to the extent that the spirit of the invention is included.

(134) Various other variations and modifications can be conceived by those skilled in the art within the spirit of the invention, and it is understood that such variations and modifications are also encompassed within the scope of the invention.

(135) While certain embodiments have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions. Indeed, the novel embodiments described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the embodiments described herein may be made without departing from the spirit of the inventions. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the invention.

## Claims

1. A semiconductor device, comprising: a first electrode; a second electrode, a direction from the first electrode to the second electrode being along a first direction, and the second electrode including a first electrode region and a second electrode region; a third electrode, a position in the first direction of the third electrode being between a position in the first direction of the first electrode and a position in the first direction of the second electrode; a first semiconductor region including  $\text{Al}_{x1}\text{Ga}_{1-x1}\text{N}$  ( $0 \leq x1 < 1$ ), the first semiconductor region including a first partial region, a second partial region, a third partial region, a fourth partial region, and a fifth partial region, a direction from the first partial region to the first electrode being along a second direction crossing the first direction, a direction from the second partial region to the second electrode being along the second direction, a direction from the third partial region to the third electrode being along the second direction, the fourth partial region being between the first partial region and the third partial region in the first direction, and the fifth partial region being between the third partial region and the second partial region in the first direction; a second semiconductor region including  $\text{Al}_{x2}\text{Ga}_{1-x2}\text{N}$  ( $x1 < x2 \leq 1$ ), the second semiconductor region including a first semiconductor portion and a second semiconductor portion, a direction from the fourth partial region to the first semiconductor portion being along the second direction, and a direction from the fifth partial region to the second semiconductor portion being along the second direction; and a first member, the first member including a first region and a second region, the second semiconductor portion being between the fifth partial region and the first region in the second direction, at least a part of the second region being between at least a part of the first region and the first electrode region in the first direction, the at least a part of the second region being between the second semiconductor portion and the second electrode region in the second direction, the second region including at least one first element selected from the group consisting of Ti, Al, Ga, Ni, Nb, Mo, Ta, Hf, V, and Au, the first region not including the first element, or a concentration of the first element in the first region being lower than a concentration of the first element in the second region, wherein the first region includes a first compound film including silicon and oxygen, a second compound film including  $\text{Al}_{y2}\text{Ga}_{1-y2}\text{N}$  ( $0 < y2 \leq 1$ ), and a third compound film including silicon and nitrogen, the second compound film is between the second semiconductor portion and the first compound film, and the third compound film is between the second semiconductor portion and the second compound film.

2. The device according to claim 1, wherein the second electrode includes the first element.

3. The device according to claim 1, wherein the first region and the second region include silicon and at least one second element selected from the group consisting of nitrogen and oxygen.
4. The device according to claim 1, wherein a concentration of the first element in the second region is not less than 5 atm %.
5. The device according to claim 1, wherein a concentration of the first element in the first region is not more than 0.5 atm %.
6. The device according to claim 1, wherein the second region includes a first end portion and a second end portion, the second end portion is between the first end portion and the first electrode region in the first direction, and a position in the first direction of the first end portion is between a position in the first direction of the third electrode and a position in the first direction of the second electrode region.
7. The device according to claim 1, wherein a part of the second region is between the second semiconductor portion and a part of the first region.
8. The device according to claim 1, further comprising: an insulating member, the first region being between the second semiconductor portion and the insulating member in the second direction.
9. The device according to claim 8, wherein the second region is between at least a part of the insulating member and the first electrode region in the first direction.
10. The device according to claim 1, further comprising: an insulating member, the first region being between the second semiconductor portion and the insulating member in the second direction, and a part of the insulating member being between a part of the first region and a part of the second region in the second direction.
11. The device according to claim 8, wherein a part of the insulating member is between the second region and the second electrode region in the second direction.
12. The device according to claim 8, wherein the insulating member includes silicon and at least one selected from the group consisting of oxygen and nitrogen.
13. A semiconductor device, comprising: a first electrode; a second electrode, a direction from the first electrode to the second electrode being along a first direction, and the second electrode including a first electrode region and a second electrode region; a third electrode, a position in the first direction of the third electrode being between a position in the first direction of the first electrode and a position in the first direction of the second electrode; a first semiconductor region including  $\text{Al}_{x1}\text{Ga}_{1-x1}\text{N}$  ( $0 \leq x1 < 1$ ), the first semiconductor region including a first partial region, a second partial region, a third partial region, a fourth partial region, and a fifth partial region, a direction from the first partial region to the first electrode being along a second direction crossing the first direction, a direction from the second partial region to the second electrode being along the second direction, a direction from the third partial region to the third electrode being along the second direction, the fourth partial region being between the first partial region and the third partial region in the first direction, and the fifth partial region being between the third partial region and the second partial region in the first direction; a second semiconductor region including  $\text{Al}_{x2}\text{Ga}_{1-x2}\text{N}$  ( $x1 < x2 \leq 1$ ), the second semiconductor region including a first semiconductor portion and a second semiconductor portion, a direction from the fourth partial region to the first semiconductor portion being along the second direction, and a direction from the fifth partial region to the second semiconductor portion being along the second direction; and a first member, the first member including a first region and a second region, the second semiconductor portion being between the fifth partial region and the first region in the second direction, at least a part of the second region being between at least a part of the first region and the first electrode region in the first direction, the at least a part of the second region being between the second semiconductor portion and the second electrode region in the second direction, the first region including silicon and at least one second element selected from the group consisting of nitrogen and oxygen, the second region including silicon, and a concentration of silicon in the second region being higher than a concentration of silicon in the first region, wherein the first region includes a

first compound film including silicon and oxygen, a second compound film including  $\text{Al.sub.y2Ga.sub.1-y2N}$  ( $0 < y2 \leq 1$ ), and a third compound film including silicon and nitrogen, the second compound film is between the second semiconductor portion and the first compound film, and the third compound film is between the second semiconductor portion and the second compound film.

14. The device according to claim 13, wherein the second region includes polysilicon.

15. A semiconductor device, comprising: a first electrode; a second electrode, a direction from the first electrode to the second electrode being along a first direction, the second electrode including a first electrode region and a second electrode region; a third electrode, a position in the first direction of the third electrode being between a position in the first direction of the first electrode and a position in the first direction of the second electrode; a first semiconductor region including  $\text{Al.sub.x1Ga.sub.1-x1N}$  ( $0 \leq x1 < 1$ ), the first semiconductor region including a first partial region, a second partial region, a third partial region, a fourth partial region, and a fifth partial region, a direction from the first partial region to the first electrode being along a second direction crossing the first direction, a direction from the second partial region to the second electrode being along the second direction, a direction from the third partial region to the third electrode being along the second direction, the fourth partial region being between the first partial region and the third partial region in the first direction, the fifth partial region being between the third partial region and the second partial region in the first direction; a second semiconductor region including  $\text{Al.sub.x2Ga.sub.1-x2N}$  ( $x1 < x2 \leq 1$ ), the second semiconductor region including a first semiconductor portion and a second semiconductor portion, a direction from the fourth partial region to the first semiconductor portion being along the second direction, a direction from the fifth partial region to the second semiconductor portion being along the second direction; and a first member, the first member including a first region and a second region, the second semiconductor portion being between the fifth partial region and the first region in the second direction, at least a part of the second region being between at least a part of the first region and the first electrode region in the first direction, the at least a part of the second region being between the second semiconductor portion and the second electrode region in the second direction, the first region including silicon and at least one second element selected from the group consisting of nitrogen and oxygen, the second region including  $\text{Al.sub.z1Ga.sub.1-z1N}$  ( $0 \leq z1 \leq 1$ ), wherein the first region includes a first compound film including silicon and oxygen, a second compound film including  $\text{Al.sub.y2Ga.sub.1-y2N}$  ( $0 < y2 \leq 1$ ), and a third compound film including silicon and nitrogen, the second compound film is between the second semiconductor portion and the first compound film, and the third compound film is between the second semiconductor portion and the second compound film.

16. The device according to claim 15, wherein the second region includes polycrystal.

17. The device according to claim 15, wherein the second region includes at least one of a third element or a fourth element, the third element includes at least one selected from the group consisting of Si, Ge, and Sn, and the fourth element includes at least one selected from the group consisting of Mg and Zn.

18. A semiconductor device, comprising: a first electrode; a second electrode, a direction from the first electrode to the second electrode being along a first direction, and the second electrode including a first electrode region and a second electrode region; a third electrode, a position in the first direction of the third electrode being between a position in the first direction of the first electrode and a position in the first direction of the second electrode; a first semiconductor region including  $\text{Al.sub.x1Ga.sub.1-x1N}$  ( $0 \leq x1 < 1$ ), the first semiconductor region including a first partial region, a second partial region, a third partial region, a fourth partial region, and a fifth partial region, a direction from the first partial region to the first electrode being along a second direction crossing the first direction, a direction from the second partial region to the second electrode being along the second direction, a direction from the third partial region to the third electrode being



along the second direction, the fourth partial region being between the first partial region and the third partial region in the first direction, and the fifth partial region being between the third partial region and the second partial region in the first direction; a second semiconductor region including  $\text{Al.sub.x2Ga.sub.1-x2N}$  ( $x_1 < x_2 \leq 1$ ), the second semiconductor region including a first semiconductor portion and a second semiconductor portion, a direction from the fourth partial region to the first semiconductor portion being along the second direction, and a direction from the fifth partial region to the second semiconductor portion being along the second direction; and a first member, the first member including a first region and a second region, the second semiconductor portion being between the fifth partial region and the first region in the second direction, at least a part of the second region being between at least a part of the first region and the first electrode region in the first direction, the at least a part of the second region being between the second semiconductor portion and the second electrode region in the second direction, the second region including at least one first element selected from the group consisting of Ti, Al, Ga, Ni, Nb, Mo, Ta, Hf, V, and Au, the first region not including the first element, or a concentration of the first element in the first region being lower than a concentration of the first element in the second region, wherein at least a part of the third electrode is between the first semiconductor portion and the second semiconductor portion in the first direction, the first member further includes a third region, a fourth region and a fifth region, the third region is between the third partial region and the at least a part of the third electrode in the first direction, and the fifth region is between the at least a part of the third electrode and the second semiconductor portion, the first member includes a first compound film including silicon and oxygen, a second compound film including  $\text{Al.sub.y2Ga.sub.1-y2N}$  ( $0 < y_2 \leq 1$ ), and a third compound film including silicon and nitrogen, the first compound film is between the third partial region and the at least a part of the third electrode in the third region, is between the first semiconductor portion and the at least a part of the third electrode in the fourth region, and is between the at least a part of the third electrode and the second semiconductor portion in the fifth region, the second compound film is between the third partial region and the first compound film in the third region, is between the first semiconductor portion and the first compound film in the fourth region, is between the first compound film and the second semiconductor portion in the fifth region, and is between the second semiconductor portion and the first compound film in the first region, and the third compound film is between the second semiconductor portion and the second compound film in the first region.

19. A semiconductor device, comprising: a first electrode; a second electrode, a direction from the first electrode to the second electrode being along a first direction, and the second electrode including a first electrode region and a second electrode region; a third electrode, a position in the first direction of the third electrode being between a position in the first direction of the first electrode and a position in the first direction of the second electrode; a first semiconductor region including  $\text{Al.sub.x1Ga.sub.1-x1N}$  ( $0 \leq x_1 < 1$ ), the first semiconductor region including a first partial region, a second partial region, a third partial region, a fourth partial region, and a fifth partial region, a direction from the first partial region to the first electrode being along a second direction crossing the first direction, a direction from the second partial region to the second electrode being along the second direction, a direction from the third partial region to the third electrode being along the second direction, the fourth partial region being between the first partial region and the third partial region in the first direction, and the fifth partial region being between the third partial region and the second partial region in the first direction; a second semiconductor region including  $\text{Al.sub.x2Ga.sub.1-x2N}$  ( $x_1 < x_2 \leq 1$ ), the second semiconductor region including a first semiconductor portion and a second semiconductor portion, a direction from the fourth partial region to the first semiconductor portion being along the second direction, and a direction from the fifth partial region to the second semiconductor portion being along the second direction; and a first member, the first member including a first region and a second region, the second semiconductor portion being between the fifth partial region and the first region in the second direction, at least a

part of the second region being between at least a part of the first region and the first electrode region in the first direction, the at least a part of the second region being between the second semiconductor portion and the second electrode region in the second direction, the second region including at least one first element selected from the group consisting of Ti, Al, Ga, Ni, Nb, Mo, Ta, Hf, V, and Au, the first region not including the first element, or a concentration of the first element in the first region being lower than a concentration of the first element in the second region, wherein the first region and the second region include silicon and at least one second element selected from the group consisting of nitrogen and oxygen, and a concentration of the first element in the second region is not less than 5 atm %.

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