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(54) SCHOTTKY STRUCTURE IN GAAS SEMICONDUCTOR DEVICE

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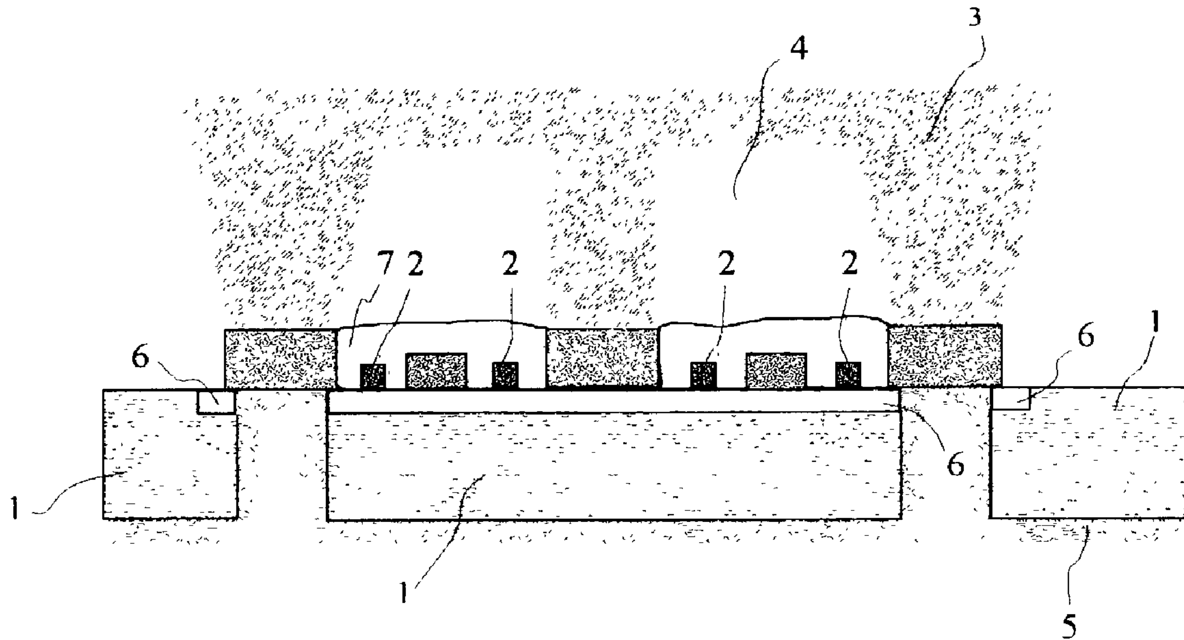
(57) **ABSTRACT**

The present invention provides a Schottky Structure in gallium arsenide (GaAs) semiconductor device, which comprises a gallium arsenide (GaAs) semiconductor substrate, a titanium (Ti) layer on a surface of said gallium arsenide (GaAs) semiconductor substrate to form Schottky contact, a diffusion barrier layer on a surface of said titanium (Ti) layer to block metal diffusion, and a first copper layer on a surface of said diffusion barrier layer.



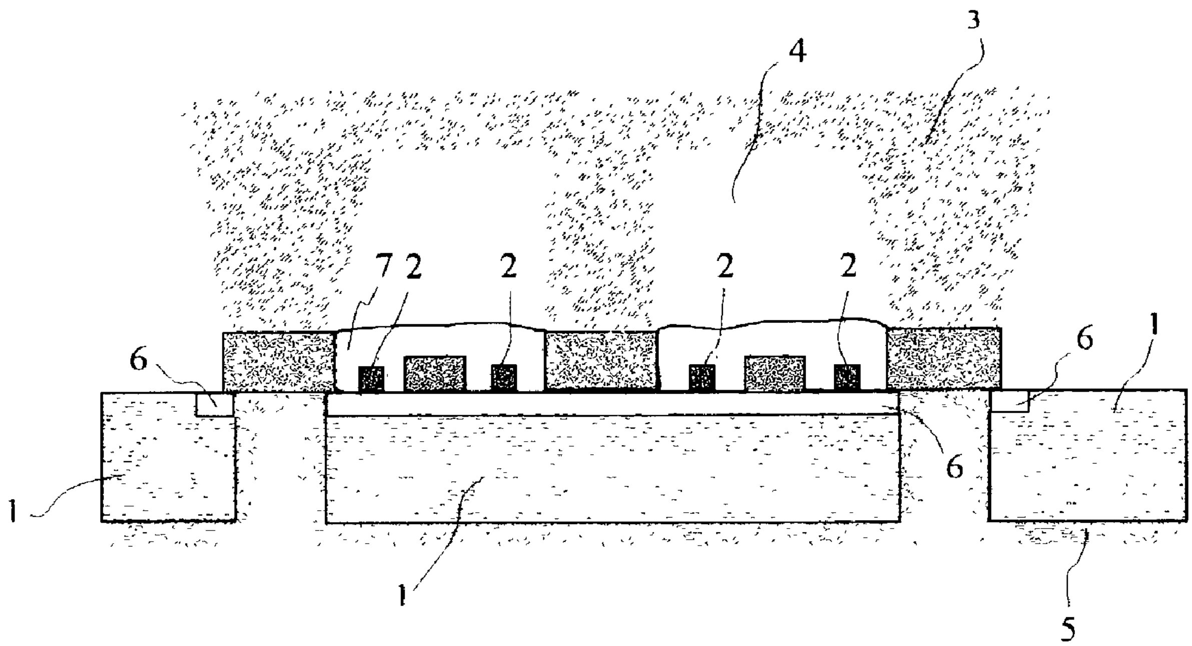


FIG. 1

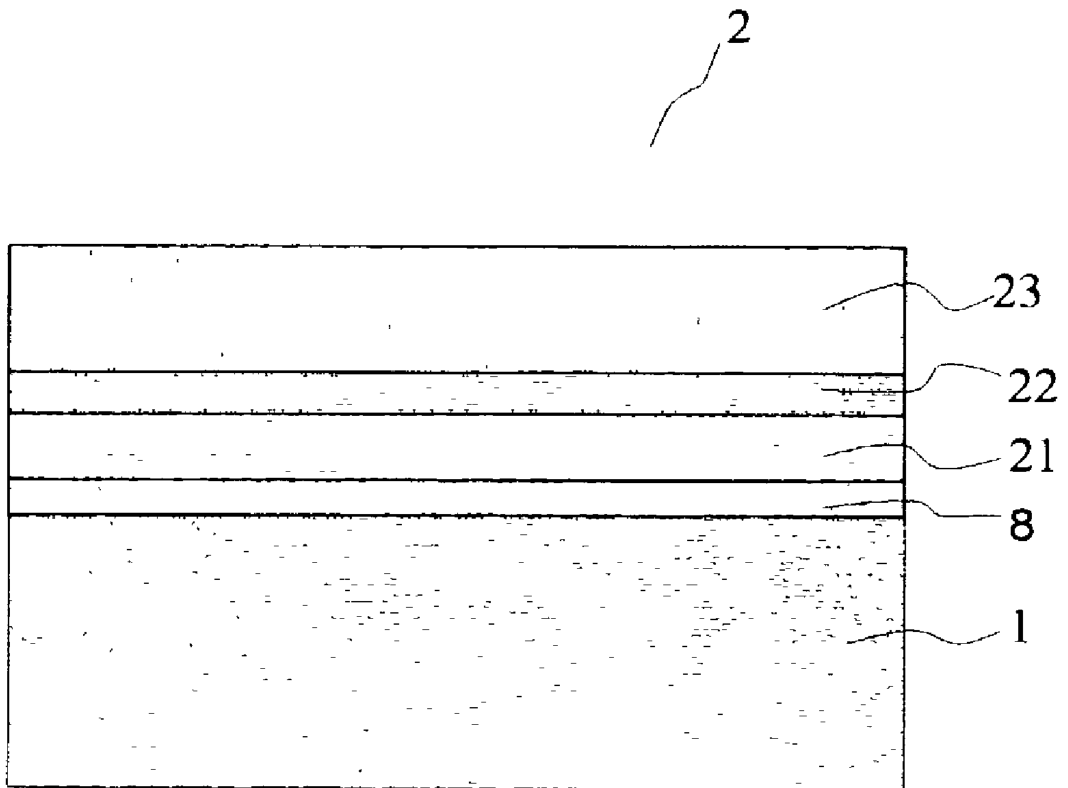


FIG. 2

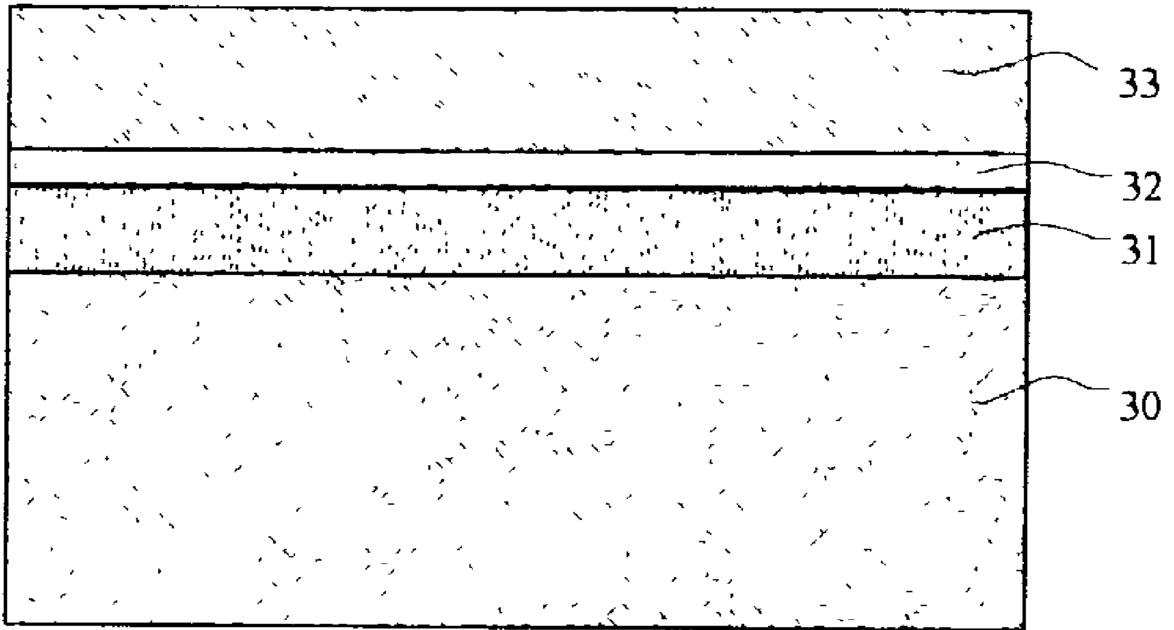


FIG. 3

(Prior Art)

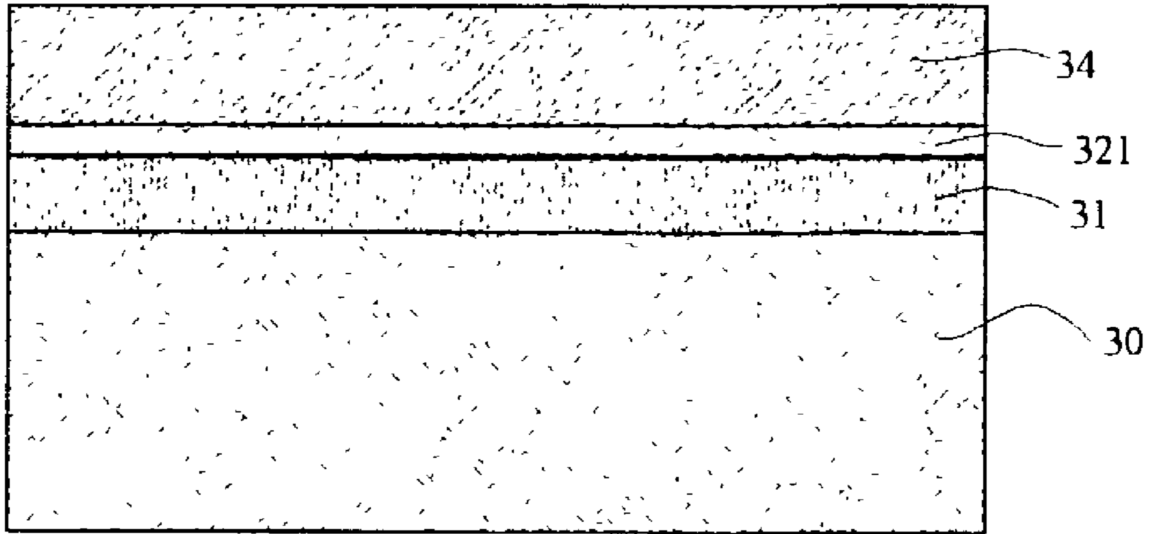


FIG. 4

SCHOTTKY STRUCTURE IN GAAS SEMICONDUCTOR DEVICE

REFERENCE CITED

[0001] [1] U.S. Pat. No. 5,049,954.

[0002] [2] U.S. Pat. No. 5,695,810.

[0003] [3] U.S. Pat. No. 6,288,449.

BACKGROUND OF THE INVENTION

[0004] 1. Field of the Invention

[0005] The present invention relates to a Schottky Structure in gallium arsenide (GaAs) semiconductor device, particularly to a lower electric resistance and superior heat conductivity with Schottky Structure. Therefore, this invention can be employed a easy connective manufacturing process with other manufacturing process for gallium arsenide (GaAs) device.

[0006] 2. Prior Arts

[0007] In General, the Ti/Pt/Au Schottky contact on n-GaAs is the most widely used Schottky structure in the fabrication of metal semiconductor field effect transistors (MESFET), high electron mobility transistors (HEMT) and Schottky diodes. In the Ti/Pt/Au structure, Titanium (Ti) layer provides good Schottky Contract, platinum (Pt) layer acts as a diffusion barrier, and Gold (Au) layer provides high electrical conductivity. Lately, new Schottky structures (Ti/W/Cu, Ti/Co/Cu, Ti/Mo/Cu) with copper and refractory diffusion barrier metal for GaAs semiconductor has become an important device in the field of copper process. A platinum (Pt) layer **32** was replaced with diffusion barrier layer of the refractory material wolfram (W), cobalt (Co), tantalum (Ta) and molybdenum (Mo) due to their superior electrical conductivity, lower resistivity and anti-diffusion capability. Gold (Au) layer was replaced with first copper layer due to their lower electric resistance and superior heat conductivity. Thus, it may increase electrical characteristics and it also may do copper process directly.

[0008] Kizahi Shimada et al., U.S. Pat. No. 5,049,954, GaAs field effect semiconductor device having Schottky gate structure, which discloses Ti film on a surface of gallium arsenide (GaAs) substrate, and a refractory electrode film on a surface of the Ti film including refractory metals, carbides, and nitrides. But, the present invention provides a first copper layer on a surface of diffusion barrier layer to form Schottky Structure. Thus, it can obtain a fact of commercial value of the Schottky Structure, which is more useful.

[0009] Valerg M. Dubin et al., U.S. Pat. No. 5,695,810, Use of cobalt tungsten phosphide as a barrier material for copper metallization, which discloses a CoWP barrier material to prevent copper diffusion. But, the present invention provides a diffusion barrier layer on a surface of said titanium (Ti) layer to block metal diffusion. Thus, it can obtain another face of commercial value of Schottky Structure in a greater area.

[0010] Siddhartha Bhowmik et al., U.S. Pat. No. 6,288,449, Barrier for copper metallization, which discloses a diffusion barrier layer with multiple layers Ta/TaN/TiN for copper metallization. But, the present invention provides a diffusion barrier layer with single layer for copper process. Thus, it can be very useful for Schottky Structure.

OBJECTS OF THIS INVENTION

[0011] Therefore, the present invention provides a Schottky Structure in gallium arsenide (GaAs) semiconductor device with copper metallization.

[0012] The main object of the present invention is to provide a lower electric resistance and superior heat conductivity with Schottky Structure.

[0013] Another object of this invention is to provide a high frequency device with Schottky Structure.

[0014] The other object of this invention is to provide an easy connective manufacturing process with Cu metallization process.

SUMMERY OF THE INVENTION

[0015] The present invention provides a Schottky Structure in gallium arsenide (GaAs) semiconductor device. Please refer to **FIG. 1**, we disclose a schematic diagram of High Electron Mobility Transistors (HEMT), which comprises a semi-insulating gallium arsenide (GaAs) semiconductor substrate **1**, a Schottky structure **2**, a copper air bridge **3**, a air **4**, a copper layer **5**, a n-type gallium arsenide (n-GaAs) **6**, and a nitride **7**. The gold (Au) was replaced with copper due to their lower electric resistance and superior heat conductivity.

[0016] Furthermore, the present invention overcomes a deep acceptor problem with copper process. Thus, it can be employed to Monolithic Microwave Integrated Circuit (MMIC). The present invention provides that a new Schottky Structure has excellent characteristic and cost compare to the conventional Ti/Pt/Au structure and can be used as the Schottky Structure for gallium arsenide (GaAs) device

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] The present invention will be better understood from the following detailed description of preferred embodiments of the invention, taken in conjunction with the accompanying drawing, in which:

[0018] **FIG. 1** illustrates a schematic diagram of High Electron Mobility Transistors (HEMT);

[0019] **FIG. 2** illustrates a preferred embodiment of the present invention;

[0020] **FIG. 3** illustrates a conventional schematic diagram of a Schottky Structure in gallium arsenide (GaAs) semiconductor device; and

[0021] **FIG. 4** illustrates another preferred embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0022] The following descriptions of the preferred embodiments are provided to understand the features and the structures of the present invention.

[0023] The present invention provides a Schottky Structure in gallium arsenide (GaAs) semiconductor device. Its purpose is to provide a copper process for industry. Please

refer to **FIG. 2**, we disclose a Schottky Structure in gallium arsenide (GaAs) semiconductor device which comprises a semi-insulating gallium arsenide (GaAs) semiconductor substrate **1**, a n-type gallium arsenide (n-GaAs) **8** on a surface of said semi-insulating gallium arsenide (GaAs) semiconductor substrate **1**, a titanium (Ti) layer **21** on a surface of said n-type gallium arsenide (n-GaAs) **8** to form Schottky contact, a diffusion barrier layer **22** on a surface of said titanium (Ti) layer **21** to block metal diffusion, and a first copper layer **23** on a surface of said diffusion barrier layer **22** to form Schottky Structure. Wherein copper process on a surface of said first copper layer **23** by diffusion barrier layer to block metal diffusion.

[0024] Referring to the **FIG. 3**, we illustrate a conventional schematic diagram of a Schottky Structure in gallium arsenide (GaAs) semiconductor device which comprises a gallium arsenide (GaAs) semiconductor substrate **30**, a titanium (Ti) layer **31** on a surface of said gallium arsenide (GaAs) semiconductor substrate **30** to form Schottky contact, a platinum (Pt) layer **32** on a surface of said titanium (Ti) layer **31** to block metal diffusion, and a gold (Au) layer **33** on a surface of said platinum (Pt) layer **32** to form Schottky Structure. Gold (Au) line and Gold (Au) air bridge were replaced by copper and plating barrier layer on a surface of said aurum (Au) layer **33** to block aurum (Au) and copper diffusion when the copper process became in gallium arsenide GaAs devices.

[0025] The present invention provides a Schottky Structure in gallium arsenide (GaAs) semiconductor device with a copper process. **FIG. 4** illustrated another preferred embodiment of the present invention, which comprises a gallium arsenide (GaAs) semiconductor substrate **30**, a titanium (Ti) layer **31** on a surface of said gallium arsenide (GaAs) semiconductor substrate **30** to form Schottky contact, a diffusion barrier layer **321** on a surface of said titanium (Ti) layer **31** to block metal diffusion, and a first copper layer **34** on a surface of said diffusion barrier layer **321** to form Schottky Structure. Wherein copper process on a surface of said first copper layer **34** by diffusion barrier layer **321** to block metal diffusion.

[0026] Furthermore refer to **FIG. 4, a** titanium (Ti) layer **31** on a surface of said gallium arsenide (GaAs) semiconductor substrate **30** has a thickness of 30 nm to 200 nm and is deposited on a gallium arsenide (GaAs) semiconductor substrate **30** by sputtering or evaporation, a diffusion barrier layer **321** on a surface of said titanium (Ti) layer **31** has a specific thickness between 30 nm to 100 nm and is comprised of a refractory material at least one selected from a group consisting of Tungsten (W), tungsten nitride (WN), cobalt (Co), tantalum (Ta), tantalum nitride (TaN) and molybdenum (Mo), a first copper layer **34** on a surface of said diffusion barrier layer **321** has a specific thickness between 200 nm to 500 nm. Gold (Au) layer **33** was replaced with first copper layer **34** due to their lower electric resistance and superior heat conductivity. a platinum (Pt) layer **32** was replaced with diffusion barrier layer **321** of the refractory material at least one selected from a group consisting of Tungsten (W), cobalt (Co), tantalum (Ta) and molybdenum (Mo) due to their superior electrical conductivity, lower resistivity and anti-diffusion capability. Thus, it may increase electrical characteristics and it also may do copper process directly, which does not only possess a better practicality, neither only a conception based on familiarity of utilization, it is non-obviousness.

[0027] Moreover, this invention diffusion barrier layer **321** is deposited by sputtering. Further, titanium (Ti) layer and first copper layer are deposited by sputtering or evaporation, which is useful.

[0028] In summation of the foregoing section, the invention herein fully complies will all new patent application requirement and is hereby submitted to the patent bureau for review and the granting of the commensurate patent rights.

[0029] The present invention may be embodied in other specific forms without departing from the spirit of the essential attributes thereof; therefore, the illustrated embodiment should be considered in all respects as illustrative and not restrictive, reference being made to the appended claims rather than to the foregoing description to indicate the scope of the invention.

What is claimed is:

1 A Schottky Structure in GaAs semiconductor device, which comprises:

a gallium arsenide (GaAs) semiconductor substrate;

a titanium (Ti) layer, on a surface of said gallium arsenide (GaAs) semiconductor substrate to form Schottky contact;

a diffusion barrier layer, on a surface of said titanium (Ti) layer to block metal diffusion; and

a first copper layer, on a surface of said diffusion barrier layer wherein copper process on a surface of said first copper layer by diffusion barrier layer to block metal diffusion.

2 The Schottky Structure of claim 1, wherein said titanium (Ti) layer substantially has a specific thickness between 50 nm to 100 nm.

3 The Schottky Structure of claim 1, wherein said titanium (Ti) layer is deposited on a gallium arsenide (GaAs) semiconductor substrate by sputtering or evaporation.

4 The Schottky Structure of claim 1, wherein said diffusion barrier layer is comprised of a refractory material at least one selected from a group consisting of Tungsten (W), tungsten nitride (WN), cobalt (Co), tantalum (Ta), tantalum nitride (TaN) and molybdenum (Mo).

5 The Schottky Structure of claim 1, wherein said diffusion barrier layer is deposited on said titanium (Ti) layer by sputtering or evaporation.

6 The Schottky Structure of claim 1, wherein said diffusion barrier layer substantially has a specific thickness between 30 nm to 100 nm.

7 The Schottky Structure of claim 1, wherein first copper layer substantially has a specific thickness between 200 nm to 500 nm,

8 The Schottky Structure of claim 1, wherein said first copper layer is deposited on said diffusion barrier layer by sputtering or evaporation

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