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New GaN Schottky barrier diode employing a trench on AlGaN/GaN heterostructure

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Abstract

A new GaN Schottky barrier diode employing a trench structure, which is proposed and fabricated, successfully decreases a forward voltage drop without sacrificing any other electric characteristics. The trench is located in the middle of Schottky contact during a mesa etch. The Schottky metal of Pt/Mo/Ti/Au is e-gun evaporated on the 300 nm-deep trench as well as the surface of the proposed GaN Schottky barrier diode. The trench forms the vertical Au Schottky contact and lateral Pt Schottky contact due to the evaporation sequence of Schottky metal. The forward voltage drops of the proposed diode and conventional one are 0.73 V and 1.25 V respectively because the metal work function (5.15 eV) of the vertical Au Schottky contact is considerably less than that of the lateral Pt Schottky contact (5.65 eV). The proposed diode exhibits the low on-resistance of 1.58 mΩ cm^2 while the conventional one exhibits 8.20 mΩ cm^2 due to the decrease of a forward voltage drop.
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1. Introduction

GaN may be an attractive material for high power switching devices and microwave amplifiers due to its high breakdown field and high sheet carrier density [1]. It is well known that the

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breakdown voltage and forward voltage drop are very important device parameters in power semiconductors [2]. GaN Schottky barrier diode is widely used because P doping of GaN material is rather difficult due to the activation problem [3]. Also, it should be noted that the Schottky barrier diode is preferred due to the lower knee voltage of the Schottky barrier diode compared to the PN diode. Various GaN Schottky diodes employing P+ field limiting rings [4,5] or metal field plates [6,7] have been reported. Although the breakdown voltages of those devices are increased considerably, they exhibit a rather high forward voltage drop of 3–5 V at 100 A/cm^2 due to the large active area and high series resistance [4–7]. Recently, 6 A/600 V GaN Schottky barrier diode, of which electric characteristics are compared to SiC Schottky barrier diode has been reported and the GaN Schottky barrier diode exhibits the low forward voltage drop of 1.6–2.0 V at 25 °C [8].

It is important to decrease the forward voltage drop of switching diodes in order to decrease a power loss. GaN field effect Schottky barrier diode with a low forward voltage drop has been reported [9]. However, that device requires a rather complex selective epitaxial layer growth on the grooved structure. Although the forward voltage drop of that device is decreased, the fabrication process is challenging. It may also be pointed out that the device structure is not novel.

The purpose of this paper is to propose a new GaN Schottky barrier diode employing a trench structure in order to decrease the forward voltage drop without any additional fabrication process. The trench is located in the Schottky contact of the proposed GaN Schottky barrier diode. The active area of the proposed device is identical to that of conventional one. The 300 nm-deep trench is simultaneously defined during a mesa etch. The trench of the proposed device forms the vertical Schottky contact and lateral Schottky contact while the conventional device has only the lateral Schottky contact. The Au which has a relatively low metal work function (5.15 eV) forms the vertical Schottky contact while the Pt which has a high metal work function (5.65 eV) makes the lateral Schottky contact by the sequential e-gun evaporation of Schottky metal (Pt/Mo/Ti/Au). The Au vertical Schottky contact turns on at the low anode voltage and decrease a forward voltage drop of devices. The lateral Schottky contact sustains the breakdown voltage due to a high metal work function. Our experimental results show that the proposed GaN Schottky barrier diode decreases the forward voltage drop from 1.25 to 0.73 V due to the design of the vertical Au Schottky contact. The numerical simulation of the proposed GaN Schottky barrier diode is also performed to analyze the current transport.

2. Experimental

The cross-sectional view and fabricated image of the proposed GaN Schottky barrier diode employing a trench structure are shown in Fig. 1. AlGaN/GaN heterostructure was grown by metal organic chemical vapour deposition on sapphire substrate. After a mesa etch, the ohmic metal (Ti/Al/Ni/Au, 20/80/20/100 nm) of a cathode contact was formed by e-gun evaporation. The Schottky metal (Pt/Mo/Ti/Au, 5/20/20/350 nm) of an anode contact was formed on the surface as well as the trenched wall. The devices were made passive with a 300 nm-thick SiO_2 layer by using inductively coupled plasma-chemical vapour deposition at 150 °C. The distance between an anode and a cathode is 5 μm and the device width is 100 μm. The length of an anode in a full cell is 9 μm. The measured electric characteristics of the fabricated device are based on a single cell as shown in Fig. 1. The device area for estimating a current density is defined as the active area where the pad size is not considered. The active area of the proposed device is the product of width (100 μm) and the distance between cathode contacts (19 μm).

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