A High Current Operation in a 1.6 kV GaN-based Trenched Junction Barrier Schottky (JBS) Diode

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Abstract

A gallium nitride (GaN) junction barrier Schottky (JBS) diode with trenched p-GaN region on a GaN substrate is presented. A threshold voltage of the GaN JBS diode is 0.8 V that is the same as a conventional GaN Schottky barrier diode (SBD). A specific differential on-resistance of the GaN JBS diode is 1.5 mΩ · cm² up to 4.5 V, above which it decreases with 0.9 mΩ · cm². A forward current of the GaN JBS diode at 10 V is 8.7 kA / cm² that is twice as the GaN SBD. A breakdown voltage of the GaN JBS diode is 1.6 kV that is larger than that of the GaN SBD. The breakdown voltage of the GaN JBS diode with the specific differential on-resistance of 0.9 mΩ · cm² is the highest value in the reported GaN vertical Schottky barrier diode so far.

1. Introduction

A gallium nitride (GaN) is an attractive material for high-power switching applications since GaN have a large breakdown voltage. We have reported a GaN HFET [1] and GaN diode with a specific differential on-resistance of 176 mΩ · cm² and a breakdown voltage of 9.3 kV [2] on a Si substrate with a current flow through near surface. In terms of the possibility in a high current operation, a GaN diode on a GaN substrate with the current flow in the vertical direction is desirable. Recently, the GaN diode is of interest since a high-quality GaN substrate with low dislocation density has developed [3].

As the GaN diode, a Schottky barrier diode (SBD) and a p-n junction diode (PND) were reported [4]. In general, a breakdown voltage of the GaN PND is larger than that of the GaN SBD, and a threshold voltage of the GaN PND is higher than that of the GaN SBD. In order to obtain a lower threshold voltage and higher breakdown voltage, a junction barrier Schottky (JBS) diode was reported [5]. However, there is a very few report of the GaN JBS diode because of the difficulty in the electrical activation of the ion implanted dopants in GaN.

In this study, we fabricate the GaN JBS diode on the GaN substrate with trenched p-GaN region without ion implantation.

2. Device structure and experimental procedure

Fig. 1 shows a cross sectional schematic structure of the GaN JBS diode. The surface of the GaN JBS diode is covered with p-GaN and n-GaN layer by partly removing p-GaN layer. An anode electrode is formed on the p-GaN and n-GaN layer, and a cathode electrode is formed on the GaN substrate. The area of the GaN diodes is 0.01 mm² at a forward and reverse current-voltage (I-V) measurement and 5mm² at a reverse recovery measurement. The I-V measurements and the reverse recovery measurement are performed at room temperature.

3. Results and discussion

Fig. 2 shows forward I-V characteristics of the GaN SBD, PND and JBS diode, respectively. A threshold voltage of the GaN SBD and JBS diode is 0.8 V that is smaller than that of the GaN SBD. A specific differential on-resistance of the GaN SBD is 1.1 mΩ · cm², and that of the GaN JBS diode is 1.5 mΩ · cm² up to 4.5 V, above which it decreases with 0.9 mΩ · cm². A forward current of the JBS diode at 10 V is 8.7 kA / cm², that is twice as the GaN SBD.
Fig. 3. Schematic illustrations for GaN JBS diode at (a) V_f < 5V and (b) V_f > 5V.

Fig. 4. Reverse I-V characteristics of the GaN diodes.

Fig. 5. Reverse recovery characteristics of the GaN diodes.

Fig. 6. Forward current vs. threshold voltage of the GaN diodes.

**4. Conclusions**

We have demonstrated a GaN JBS diode with trenched p-GaN region on a GaN substrate. A threshold voltage of the GaN JBS diode is 0.8 V that is the same as a conventional GaN SBD. A specific differential on-resistance of the GaN JBS diode is 1.5 mΩ · cm² up to 4.5 V, above which it decreases with 0.9 mΩ · cm². A forward current at 10 V of the GaN JBS diode is 8.7 kA/cm² which is twice as the GaN SBD. A breakdown voltage of the GaN JBS diode is 1.6 kV. A reverse recovery time in the GaN JBS diode is the same as the conventional GaN SBD.

A forward current at 9 V of the GaN JBS diode is 8.7 kA/cm² that is twice as the GaN SBD. A breakdown voltage of the GaN JBS diode with the specific differential on-resistance of 0.9 mΩ · cm² is the highest value in a reported GaN vertical Schottky barrier diode so far.

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**References**