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Suppression of the leakage current of a Ni/Au Schottky Barrier Diode fabricated on AlGaN/GaN hetero-structure by oxidation

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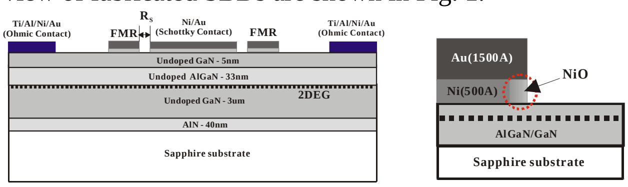
1. Introduction

Recently, wide band-gap materials, such as GaN and SiC, have attracted a considerable attention for power electronic application system. GaN has a superior material property compared with other materials so that the GaN power devices became remarkable as a device for future high power electronic systems. GaN Schottky barrier diodes (SBDs) have shown good characteristics due to its wide band-gap property and large breakdown field strength (>3MV/cm) [1]. Various lateral and vertical GaN SBDs have been reported and the high breakdown voltage and the low on-resistance of the GaN SBDs have been main issues [2-6]. Several metals, such as Pt, Ir and Pd, for the Schottky contact have been employed to improve the forward and the reverse characteristics of the GaN SBDs [4]. In order to increase the breakdown voltage, edge termination methods have been also employed, such as a planar floating guarding ring by p+ implantation, field plate and floating metal ring (FMR). It has been reported that the FMR is simple and a reliable method among several edge terminations because a FMR does not require any additional process [5].

The purpose of our work is to report a lateral GaN Schottky barrier diode which increases the breakdown voltage and decreases the leakage current by an oxidation of a Ni Schottky contact. And we have also employed multi floating metal rings (FMRs) as an edge termination method in order to increase the breakdown voltage and decrease leakage current. It is well known that FMR effectively also reduces an electric field concentration of main Schottky junction due to expanding of depletion layer along the FMR [7]. The leakage current was decreased considerably and the breakdown voltage was increased due to the oxidation of Ni Schottky contact. The large breakdown voltage of 750V was measured when the three FMRs were employed.

2. Experiments

We have used an AlGaN/GaN hetero-structure epi wafer which was grown on sapphire substrates by MOCVD method. Sheet charge concentration of 7.8×10^{12} /cm^2 and electron mobility of 1530 cm^2/Vs are measured from the hall measurement, respectively. Prior to ohmic metal deposition after patterning, the samples have been dipped in HCl:DI(1:1) solution for 1min 30s in order to remove a native oxide and the ohmic metals were deposited in a sequence by e-gun evaporator. We have used multi metals (Ti/Al/Ni/Au=20nm/80nm/20nm/100nm) for ohmic contact and the ohmic contacts were annealed in 850^{o}C by using RTA for 30s under a flowing N_2 ambient. Schottky contacts (Ni/Au=50m/150nm) were defined by a lift-off technique. We then have oxidized the as-deposited Ni/Au samples at 500^{o}C in the furnace under the O_2 ambient. Cross sectional view of fabricated SBDs are shown in Fig. 1.



a) b)

Fig. 1. a) Coss-sectional view of the proposed SBDs b) NiO formation of the gate by oxidation

3. Results and Discussions

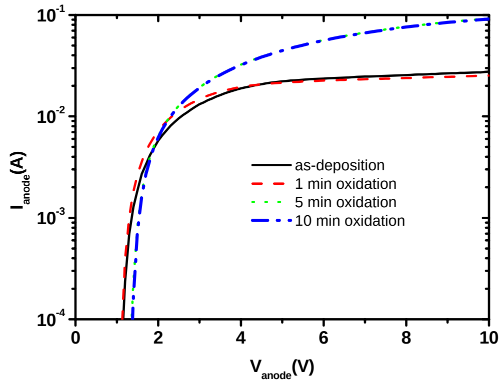


Fig. 2. Forward characteristics of the Ni Schottky contacts before and after an oxidation

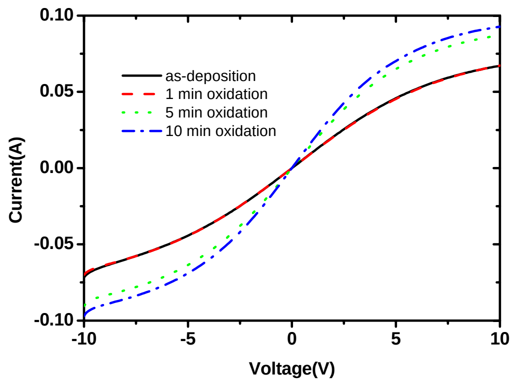


Fig. 3. Voltage-current characteristics between two ohmic contact pads (distance = 8μm)

Forward I-V characteristics of the fabricated GaN SBDs before and after oxidation are shown in Fig. 2. The diameter of a circular Schottky contact is 300μm without FMRs and the distance between the Schottky contact and the ohmic contact is 100μm. The change of the forward characteristics after 1min oxidation was negligible. However, the turn-on voltage was increased from 1.1V to 1.3V and the current capability at the high anode bias was increased considerably after 5 min and 10 min oxidation. The ideality factor was also improved form 1.9 to 1.5 after 10 min oxidation. An oxidation of a Ni/Au contact has been employed in order to improve the ohmic contact resistance in the p-type GaN [8-9]. The change of forward characteristics may be due to the improved surface condition from the NiO formation and the reaction between Ni and GaN. As shown in Fig. 3, the amount of current between two ohmic metal pads was also increased after 5min and 10min oxidation. This result means that the surface of an AlGaN/GaN hetero-structure has been improved after an oxidation.

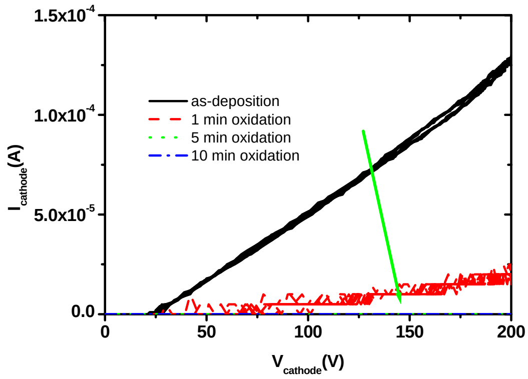


Fig. 4. Reverse characteristics of the Ni Schottky contacts before and after an oxidation

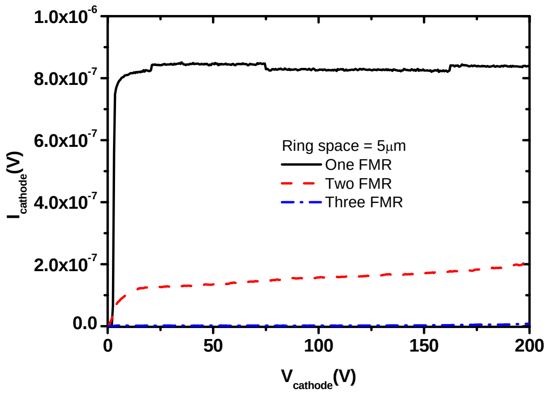


Fig. 5. Reverse leakage currents of the SBDs employing FMRs and an oxidation

We have measured the leakage current before and after oxidation at the high reverse bias of 200V. After an oxidation, the leakage current was decreased as shown in Fig. 4. It should be noted that the leakage current was considerably decreased below 1nA after 5min and 10 min oxidation.

We have also employed the FMRs in order to increase the breakdown voltage and decrease the leakage current and performed oxidation. The width of FMR is 20μm and the distance from the main junction (R_S) is 5μm. As the number of FMRs is increased, the leakage current was decreased as shown in Fig. 5 due to the low electric field concentration under the main Schottky junction. The large reverse breakdown voltage of 750V was measured when the three FMRs have been employed.

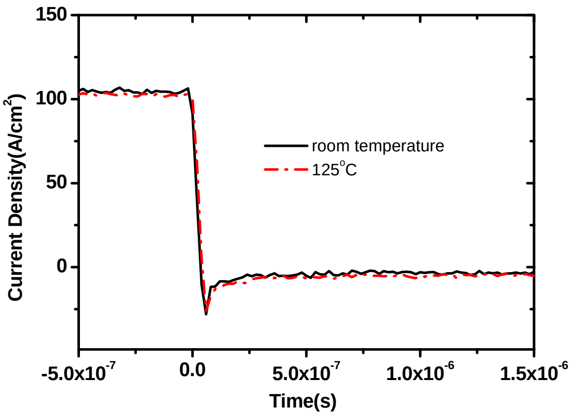


Fig. 6. Reverse recovery waveforms in the room temperature and 125°C of the proposed SBDs

We have measured the reverse recovery waveforms in the room temperature and 125°C as shown in Fig. 6. Supply voltage (V_{DD}) was 10V and the diodes were switched from forward current of 100A/cm^2. The fabricated GaN SBD shows very fast reverse recovery characteristics with high breakdown voltage in the high temperature.

4. Conclusions

We have proposed a lateral GaN Schottky barrier diode which increases the breakdown voltage and decreases the leakage current by oxidation of Ni Schottky contact. Anode current was increased and the leakage current was decreased considerably while the turn-on voltage is a little increased. When we employed the three FMRs as an edge termination, we have measured a large breakdown voltage of 750V.

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