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AlGaN/GaN Schottky Barrier Diodes Employing TaN Schottky Contact

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1. Introduction

AlGaN/GaN Schottky barrier diodes (SBDs) have a consideralbe attention for power devices due to wide bandgap properties such as a high critical electric field and a low intrinsic carrier concentration [1]. In addition, high mobility of two-dimensional electron gas offers a low on-resistance and a fast switching speed [2].

Ni based Schottky metals have been widely used for anode of the AlGaN/GaN SBDs due to rather large work function and a good adhesion with GaN [3]. However, it is difficult to form thick Ni electrodes because of a strong internal stress of Ni [4]. Also Ni is not easily oxidized so that thick Au on the Ni is widely used [5]. Moreover, metal based Schottky contacts may be degraded during high temperature process due to inter-diffusion between metal and the AlGaN/GaN heterostructure [6].

The purpose of this paper is to report the AlGaN/GaN SBDs employing TaN Schottky contact instead of the Ni-based contact. It is well known that TaN is stable at high temperature and an inoxdizable ceramic material so that TaN is suitable material for Schottky metal in the AlGaN/GaN SBDs [7].

Also we have proposed and fabricated new structure where all electrodes are formed on only an active region in order to suppress the leakage current and increase the breakdown voltage effectively. We compare the proposed structures with the conventional structures where all electrodes are formed on the active as well as mesa wall or the etched region. It should be noted that the surface leakage current through the etched region due to the generated traps during the etching process.

We achieved the high breakdown voltage of 1820 V at the sample with TaN Schottky contact without any overlap region between the etched region and electrodes. The leakage current was decreased from 1.55 mA/mm to 1.12 μA/mm by TaN Schottky contact. We tested all samples at 250 ^{o}C and the extracted Schottky barrier height (SBH) by using current-voltage characteristics.

2. Device structure and fabrication

The cross-sectional view and top view of the proposed device are shown in Fig. 1. The AlGaN/GaN heterostructure was grown on Si (111) substrate. The structure comprises the following specific la yers; a 3.9 μm-thick C-doped GaN buffer layer, a 100 nm-thick i-GaN, a 20 nm-thick i-$Al_{0.23}Ga_{0.77}N$ barrier layer, and a 3 nm-thick i-GaN cap layer. Mesa isolation using Cl_2 and BCl_3 based ICP-RIE was performed in order to define an active region. Ohmic metals of Ti/Al/Ni/Au (20/80/20/100 nm) for cathode were formed by e-gun evaporation. We annealed the ohmic metals at 880 ^{o}C for 40 sec under N_2 ambient for ohmic contact formation. Prior to Schottky contact formation, we dipped the samples into the 30:1 BOE for 30 sec in order to remove the native oxide. 240 nm-thick TaN for anode was deposited by rf sputtering and lift-off. The process sputtering power, temperature, and gas flow were 50 W, room temperature, and Ar of 15 sccm respectively. The AlGaN/GaN SBD with Ni/Au Schottky contact was also fabricated for comparison purpose.

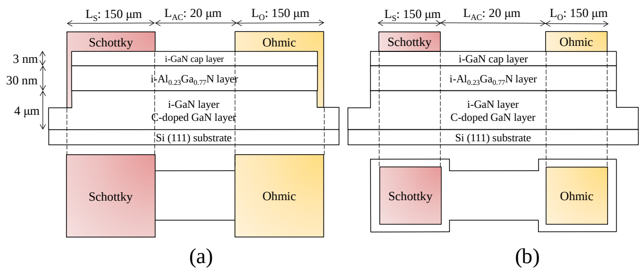

Fig. 1. Device structure of the AlGaN/GaN SBD (a) with mesa wall/electrodes overlap region **(structure 1)** (b) without the overlap region **(structure 2)**

3. Experimental Results

Fig. 2 shows the current-voltage characteristics for all devices. The leakage current of the Ni/Au Schottky based device is decreased from 1.55 mA/mm to 984 μA/mm at anode-cathode voltage of -100 V by using structure 2, Also, that of the TaN Schottky based device is decreased from 2.62 μA/mm to 1.12 μA/mm as well.

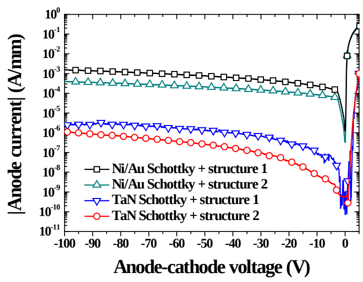

Fig. 2. Current-voltage characteristics for all devices at room temperature

It indicates that the interface between electrodes and the etched GaN surface is important leakage path which should be suppressed for high breakdown voltage.

However, the on-current of the TaN Schottky based devices at anode-cathode voltage of 5 V is degraded by 2 orders compared with the Ni/Au Schottky based devices due to a considerable resistance of TaN film. The SBH was extracted by the current-voltage characteristics as shown in Table. 1. We obtained SBH of 0.7 eV by using TaN Schottky contact and structure 2 without any passivation layer.

Fig. 3 shows the measured breakdown voltage. The breakdown voltage was defined at the leakage current of 1 mA/mm. The breakdown voltage of the Ni/Au Schottky based device is increased from 350 V to 438 V by adopting structure 2. That of the TaN Schottky based device is increased from 1408 V to 1820 V as well. The TaN Schottky blocks the leakage current and sustains the high reverse voltage effectively.

Table. 1. Extracted SBH by current-voltage characteristics and breakdown voltage

	SBH (ϕ_{BN})	Breakdown voltage
Ni/Au Schottky + structure 1	0.45 eV	350 V
Ni/Au Schottky + structure 2	0.49 eV	438 V
TaN Schottky + structure 1	0.65 eV	1408 V
TaN Schottky + structure 2	0.70 eV	1820 V

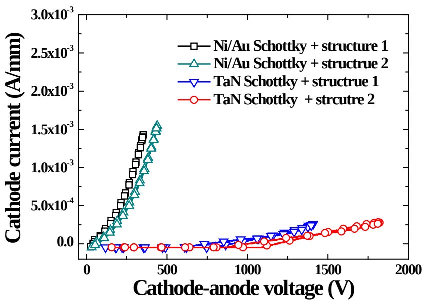

Fig. 3. Measured breakdown voltage for all devices

We measured the current-voltage characteristics of all devices at high temperature of 250 ^{o}C to test the thermal stability of TaN and Ni/Au Schottky contact.

The leakage current and on-current at 250 ^{o}C are degraded compared with the values at room temperature. The Ni/Au Schottky based devices with structure 1 and 2 exhibit large leakage currents of 6.97 and 6.98 mA/mm at V_{AC}= -100 V and 250 ^{o}C. The on-current of the Ni/Au Schottky based device with structure 1 is decreased from 300 to 68.7 mA/mm and the value with structure 2 is decreased 300 to 67.9 mA/mm. The on/off ratio of the Ni/Au based devices at 250 ^{o}C is about 10.

In the SBD with TaN Schottky contact and structure 2, the low leakage current of 5.41 μA/mm is obtained. The on/off ratio is about 130 at 250 ^{o}C. The on-currents of the TaN Schottky based devices are not significantly altered. TaN Schottky contact may be suitable material for anode in the AlGaN/GaN SBDs due to the stable thermal characteristics and the low leakage current.

4. Conclusion

We have proposed and fabricated the AlGaN/GaN SBDs employing TaN Schottky contact for high breakdown voltage. Ni/Au Schottky based devices were also fabricated for comparison purpose. We achieved the high breakdown voltage of 1820 V by using TaN Schottky without any passivation layer or post treatment methods while that of the conventional device was 350 V. The SBH was also increased from 0.45 eV to 0.7 eV by using TaN Schottky and the proposed devices exhibits stable electric characteristics at high temperature.

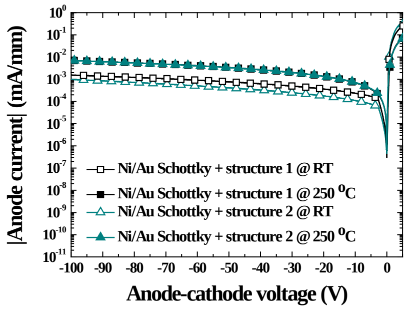

Fig. 4. Current-voltage characteristics of the Ni/Au based devices at room temperature and 250 ^{o}C

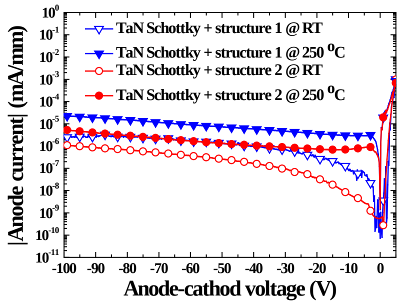

Fig. 5. Current-voltage characteristics of the TaN based devices at room temperature and 250 ^{o}C

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