Extended Abstracts of the 2013 International Conference on Solid State Devices and Materials, Fukuoka, 2013, pp144-145

Analysis of Forward Characteristics in AlGan/GaN SBD with Schottky Contact Lying on Mesa Edge

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Abstract

AlGaN/GaN SBD employing the structure with covering mesa edge by Schottky metal has been proposed and fabricated. Novel properties such as turn-on voltage shift and diode idealization were found. The corresponding turn-on voltage shift is about -0.15 V. We believe that mesa edge contact helps a SBD on AlGaN/GaN to be idealized.

1. Introduction

The Schottky barrier characteristics of AlGaN/GaN have a significant influence on the device performance [1]. In spite of the importance of Schottky barrier height to device design, there have been few reports that mentioned mesa edge effects [2]. Here, we report the results of our investigation on the analysis of Direct Current (DC) behavior of Schottky contacts lying on mesa edge in AlGaN/GaN Schottky Barrier Diode (SBD).

2. Device Structure and Fabrication

The epi structure for this study consisted of a thin GaN cap layer (2 nm) and 20 nm AlGaN with 25% Al mole fraction on top of a 4 μm GaN layer grown on Si (111) substrate. First, the sample was cleaned by SPM (H_2SO_4:H_2O_2=4:1) followed by buffered HF (1:6, 3 min) to remove organic residue and native oxide. To form a Schottky contact on mesa edge, a part of area under Schottky metal was etched by low damage chlorine-based inductively coupled plasma etcher. This etching process was performed together with ordinary isolation process with 200 nm depth. Ti/Al/Ni/Au (30/100/30/100 nm) were deposited on AlGaN, followed by annealing in a N_2 ambient at 900°C for 30s to form ohmic contacts. The Schottky contact was achieved by Ni/Au (30/350 nm) metal stack. The metals were annealed at 350°C for 5 min for thermal stabilization and post gate annealing process [3]. Additional fabrication such as passivation was not performed for accurate experiment.

The schematic structure of proposed SBD is shown in Fig. 1. A small circular area under Schottky metals was etched to evaluate Schottky contact on mesa edge. The distance between Anode and cathode is 10 μm. The detailed information of four different types of fabricated SBD is listed in Table 1. Type-C has the same effective area of Schottky contacts as that of Type-C but diameter is doubled. The one thing we should notify is that the Schottky metal of Type-A and C lies on mesa edge but Type-B and D does not.

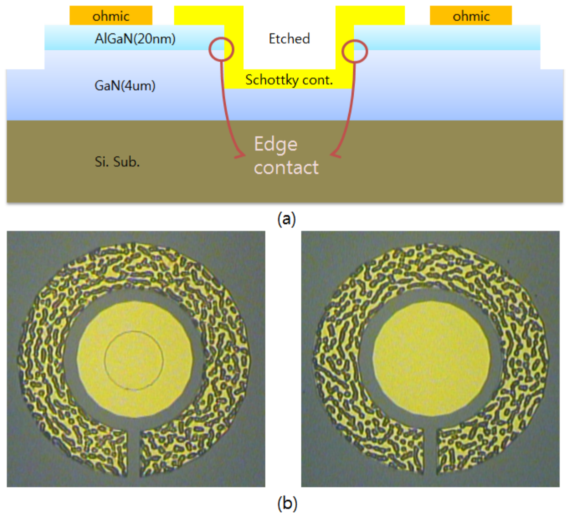


Fig. 1 The proposed SBD structure (a) Cross-sectional view (b) Top view, Type-A (Proposed, left) Type-B (Reference, right)

Table I Structure of SBDs

Type	Schottky diameter (um)	Etched diameter (um)	Effective Area of Schottky Contacts (mm²)	Length of mesa edge contacts (um)
Type-A	200	100	0.0235	314
Type-B	200	0	0.0314	0
Type-C	400	346	0.0316	1086
Type-D	400	0	0.125	0

3. Experimental Results

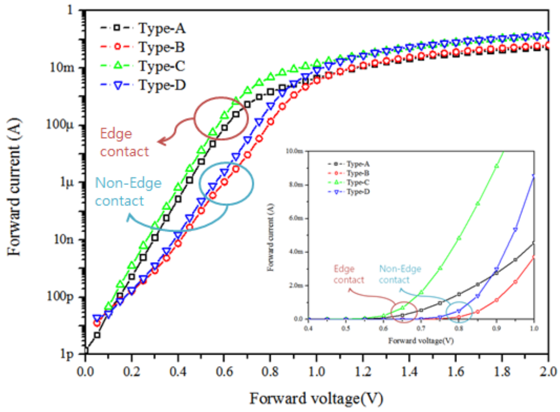
Figure 2 shows forward characteristics of fabricated devices. As focusing on the thermionic region, it seems that edge contact causes an about -0.15 V shift in turn-on voltage compared to non-edge contacts devices. The detailed forward bias characteristics were studied to determine the ideality factor and barrier height of diode. The diode equation for V> 3kT/q is known to be

$$I = I_o[\exp(\frac{qV}{nkT})] \qquad (1)$$

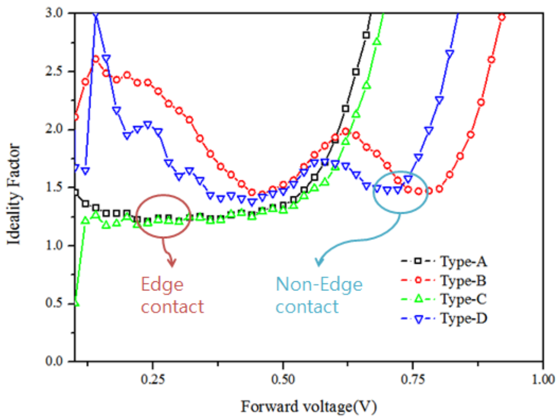
$$I_o = AA^{*}T^{2}\exp(\frac{-q\Phi_B}{kT}) \qquad (2)$$

where I_0 is the saturation current, n is the ideality factor, V is the forward bias voltage, T is the absolute temperature, q is the electron charge, k is the Boltzmann constant, Φ_B is the Schottky barrier height, A is the effective diode area, and A* is the effective Richardson constant for GaN, assumed to be 26.4 A cm^{-2} K^{-2}.

Defining saturation current (I_0) as the y-intercept of the linear extrapolation of the forward current at the linear region of current in log scaled I-V curve, I_0 is simply converted to barrier height, 0.86, 1.02, 0.85 and 0.99 eV using effective area of Schottky contact each. This causes -0.15 V shift in turn-on voltage shown in Fig 2 (a) inset. Assuming that the effect of series resistance can be neglected, the calculated values of ideality factor listed from Type-A to D were 1.23, 1.45, 1.2 and 1.4, respectively. It should also be noted that a bump in non- edge contact sample at around 0.6 V in Fig. 2(b) disappeared in edge contact sample. The edge contact seems to help to broaden the exponential region that makes a SBD idealized.



(a)



(b)

Fig. 2 Forward Characteristics of (a) Log scale I-V, Linear scale I-V (Inset) (b) Ideality factor

Fig. 3 represents reverse leakage current. It should be mentioned that the reverse leakage current has a strong tendency to proportion to effective area of Schottky contact. This indicates one of advantage of Schottky-region etched SBDs for low reverse current.

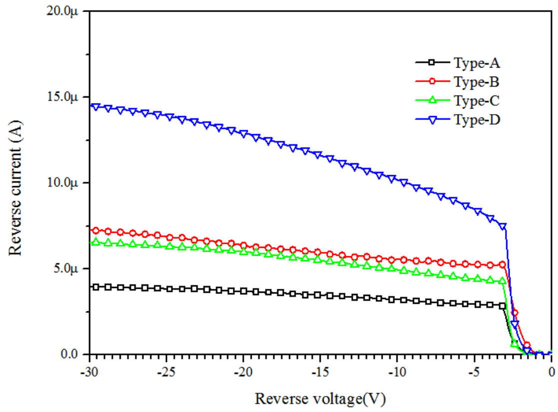


Fig. 3 Reverse Characteristics

As shown in Fig 4, we also confirm that regardless of the shape of SBD and where to Schottky contact on mesa edge, the results described above are obviously appeared in the same way. We are still studying on the exact mechanism of these phenomena. But we believe that mesa edge contact helps SBD on AlGaN/GaN to have a lower barrier height [4] and to follow ideal diode properties.

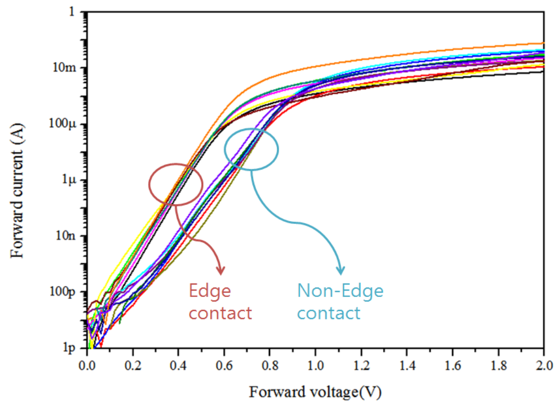


Fig. 4 Difference of Forward Characteristics between edge contact and non-edge contact

3. Conclusion

In this study, we investigated the behavior of SBD with Schottky contacts lying on mesa edge. By covering mesa edge with Schottky metals, widening forward exponential region was realized, which makes SBD more idealized. It also leads to about -0.15 V shift in turn-on voltage. These results suggest the potential of our proposed Schottky-region etched AlGaN/GaN SBD for high power applications.

Acknowledgements

This work was supported by the "Energy Efficient Power Semiconductor Technology for Next Generation Data Center" IT R&D project (No. 10038766) of Korea.

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