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Normally-off AlGaN/GaN HEMT with Recessed Gate for High Power Applications

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1. Introduction

Owing to their excellent physical properties, such as high breakdown electric field and high electron mobility, AlGaN/GaN HEMTs are promising for high efficiency power devices[1]. To realize these high power devices, normally-off operation mode is required to achieve low power consumption and high flexibility of circuit design. To achieve the normally-off operation mode, AlGaN/GaN HEMTs with very thin AlGaN barrier layer[2] and with p-type doping layer[3] are reported. However these structures involve the increase of sheet resistance and are not compatible with high breakdown voltage and low on-state resistance (Ron).

This time, we have successfully fabricated normally-off AlGaN/GaN HEMTs with recessed gate structure without the increase of the series resistance.

2. Fabrication Process

Epitaxial layers were grown on 3inch diameter sapphire substrates by metal organic chemical vapor deposition (MOCVD). The layers were a 2.0um GaN and a 25nm undoped-$Al_{0.25}Ga_{0.75}N$. The average sheet resistance was 600Ω/sq. The 2DEG mobility was 1300cm^2/Vs at room temperature.

Following the epitaxial growth, the isolation mesa and gate recess were formed by using Cl_2-based inductively-coupled-plasma reactive ion etching (ICP-RIE). The Etching rate was 5-7nm/min for recess fabrication and etching time was varied 0 to 150sec to change the recess depth. Ohmic contacts were formed by furnace anneal of Ti/Al at 750ºC for 100sec. The ohmic contact resistance was typically 0.5mΩ.mm measured by a transfer length method. After SiO_2 deposition, Ni/Au schottky gates were fabricated by e-beam evaporated deposition.

3. Schottky Characteristics

Fig.1 shows the carrier distributions from C-V measurement of schottky diode with different etching time for recess formation. It was observed that the concentration of 2DEG decreased as the thickness of AlGaN became thinner and etching rate was almost constant. The relationship between etching time and schottky characteristics is shown in Fig.2. As etching time became longer, tunnel current through thin AlGaN layer increased in the voltage range of 0 to –2V, but the reverse saturation current decreased in the voltage range of less than –2V. We think this is due to that the damaged layer at the vicinity of surface formed during temperature descending after epitaxial growth was removed by recess etching.

4. HEMTs Characteristics

The structure of HEMTs was as follows. The spacing of source-drain was 11.0μm. The length and width of gate were 1.5μm and 100μm respectively.

The Ids-Vgs characteristics with different recess etching time were plotted in Fig.3. The threshold voltage (Vth) moves toword the positive direction with increasing etching time, and Vth and transconductance (Gm) of HEMTs with 150sec recess etching were 0.3V and 130mS/mm, respectively. From the relation of AlGaN thickness and Vth, it is estimated that the thickness of AlGaN should be less than 10nm to achieve normally-off operation. The Ids-Vds characteristics of normally-off HEMTs measured by a curve tracer (Tektronix:370A) are shown in Fig.4. The Ron estimated from active area was 2.0mΩ.cm^2 and drain current was only 65μA/mm at Vgs=0V and Vds=400V. The results show our normally-off AlGaN/GaN HEMTs have very good pinch–off characteristics and are promising for high power applications requiring high breakdown voltage and low Ron characteristics.

5. Conclusion

Normally-off AlGaN/GaN HEMTs with recessed gate structure have been successfully fabricated. The Vth and the Ron were 0.3V and 2.0mΩ.cm^2, respectively. The device shows a good pinch-off characteristic such as drain current was only 65μA/mm even at high Vds of 400V. The Ron shows the lowest value for normally-off AlGaN/GaN HEMTs to our best knowledge. The results promise that normally-off AlGaN/GaN HEMTs with recessed gate structure are most suitable for high performance power application.

References

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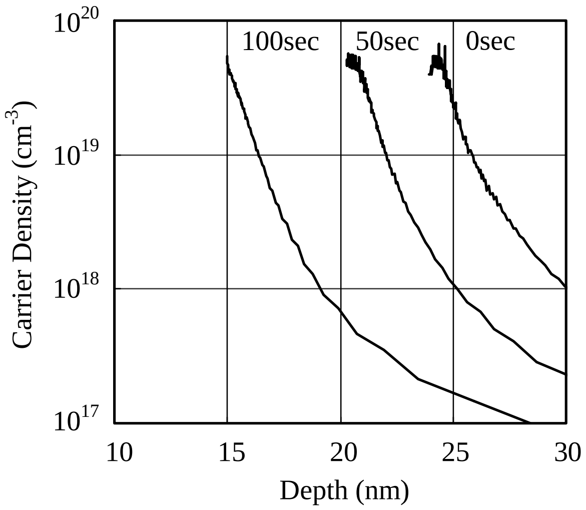

Fig.1. Carrier density distributions for various recess etching times.

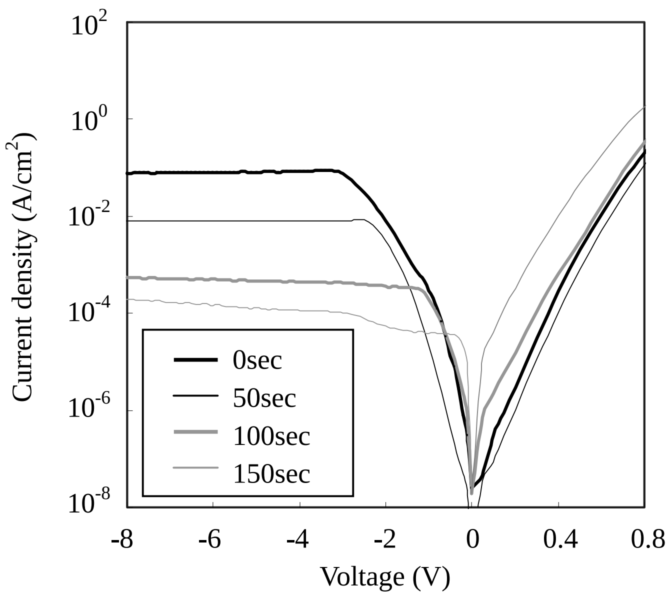

Fig.2. Measured I-V characteristics of 100μm diameter C-V test structures with different recess etching time.

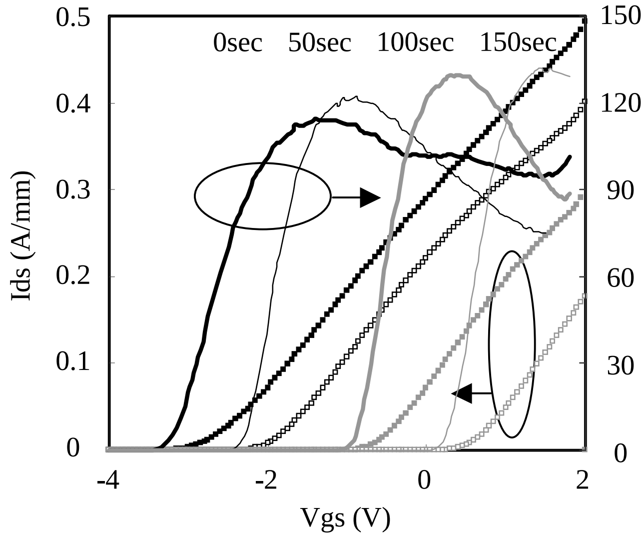

Fig.3. Ids-Vgs and Gm-Vgs characteristics of HEMTs with different recess etching time.

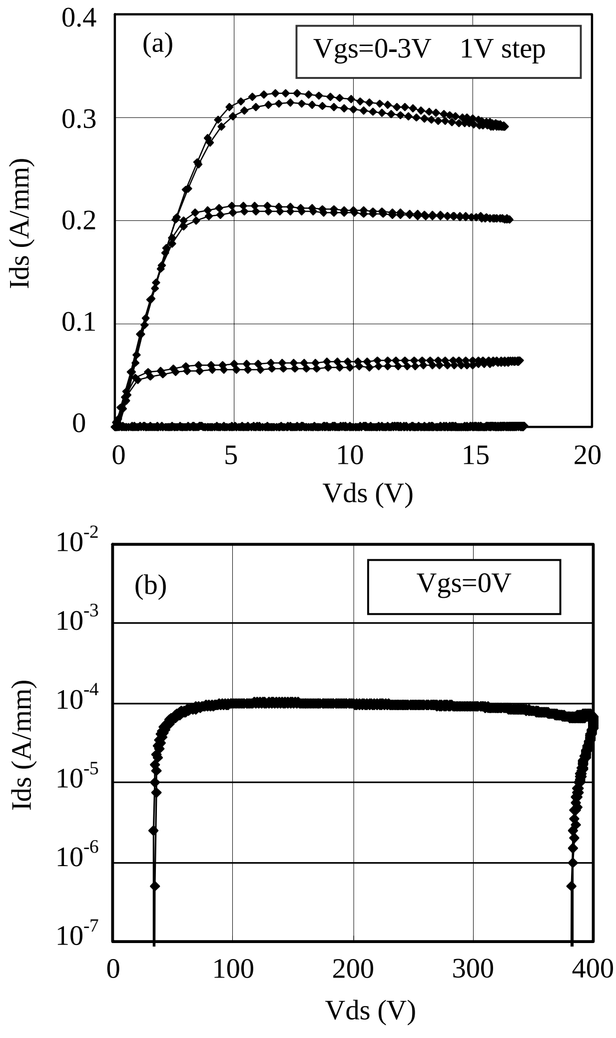

Fig.4. (a) Ids-Vds characteristics and (b) pinch off characteristics of normally-off AlGaN/GaN HEMTs.