ECS Transactions, 53 (2) 61-63 (2013)
10.1149/05302.0061ecst ©The Electrochemical Society

Low Leakage Current GaN MIS-HEMT with SiN_x Gate Insulator using N_2 Plasma Treatment

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In this work, an effective N_2 plasma treatment for suppressing leakage current in GaN MIS-HEMT has been demonstrated. We observed an important issue of leakage current from the SiN_x/GaN interface. To investigate the leakage current mechanisms, we measured the leakage current from all the possible paths in the device structure, such as gate, mesa isolation, and drain leakage. The current−voltage measurement results reveal a severe leakage path at the SiN_x/GaN interface after SiN_x deposited on the GaN surface without N_2 plasma treatment. By using N_2 plasma treatment, we succeed in suppressing the leakage current and effectively improve breakdown voltage. A significant performance improvement of GaN MIS-HEMT with very low leakage current has been achieved through the N_2 plasma treatment.

Introduction

Gallium nitride (GaN)-based High Electron Mobility Transistor (HEMT) with high breakdown voltage for high power switching applications are studied extensively in recent year. However, GaN HEMTs often suffer from surface state effects such as high gate leakage, current collapse, and a variety of reliability issues (1). Different materials such as SiN_x (2), SiO_x (3), and Al_2O_3 (4) were widely used as the gate dielectric and/or passivation layer on AlGaN/GaN metal-insulator-semiconductor HEMTs (MIS-HEMTs). However, the Ga−O and Al−O bonds would easily form between oxide-based dielectric and AlGaN/GaN interface. The deep interface states could induce the current collapse severely under high gate or high drain voltages. Plasma-enhanced chemical vapor deposition (PECVD)-grown SiN_x has been proved as an effective material to reduce the surface states and can efficiently suppress current collapse in AlGaN/GaN HEMTs. However, the increase of surface leakage current from gate to drain and from the isolation etching area have been observed after SiN_x deposition (5), (6). In this work, the GaN MIS-HEMTs with very low leakage current by N_2 plasma treatment are demonstrated.

Devices Fabrication

The AlGaN/GaN heterostructure is grown by commercial metal-organic chemical vapor deposition (MOCVD) on silicon substrate. The mesa isolation was etched by inductively coupled plasma (ICP). Ohmic contacts were formed by an alloyed Ti/Al/Ni/Au metal stack. The gate metal was Ni/Au. For the high-power devices design in this study, the gate-to-drain spacing, the gate-to-source spacing, and the gate length are 15, 3, and 2 μm, respectively. The samples were treated by PECVD N_2 plasma. The 20 nm SiN_x was deposited by PECVD as the gate dielectric. Three samples were separated after mesa and ohmic contact were formed. The surface conditions before SiN_x deposition were prepared: sample A with N_2 plasma treatment, sample B without treatment, sample C is conventional HEMT sample without SiN_x gate dielectric for comparing the leakage current induced by SiN_x deposition.

Results and Discussion

To investigate the leakage phenomenon, we measured the leakage current from any possible path in the structure, such as Schottky gate, isolation, and drain leakage current. Fig. 1 shows the GaN HEMTs I_G−V_G characteristics. In this work, the Schottky gate leakage current of sample A is about three orders lower than sample B. It shows the gate leakage current of sample B increases easily when the gate bias voltages was applied. Fig. 2 shows the leakage current from mesa isolation region. The obvious increase of leakage current is observed after SiN_x deposition. It indicates the SiN_x thin film deposition will result in the increase leakage current from the mesa isolation region. This unwanted leakage current seriously affects the device performance when GaN HEMTs were operated at high bias voltage. Fig. 3 shows the OFF-state breakdown voltage characteristics. Under V_D = 200 V, the leakage current of sample B is three orders higher than sample A and the leakage current of sample A is extremely low in this study compared to the other samples. It reveals that the drain leakage current is effectively suppressed by N_2 plasma treatment. This leakage current phenomenon reveals an unfavorable GaN surface condition before SiN_x deposition which will severely affect devices performance.

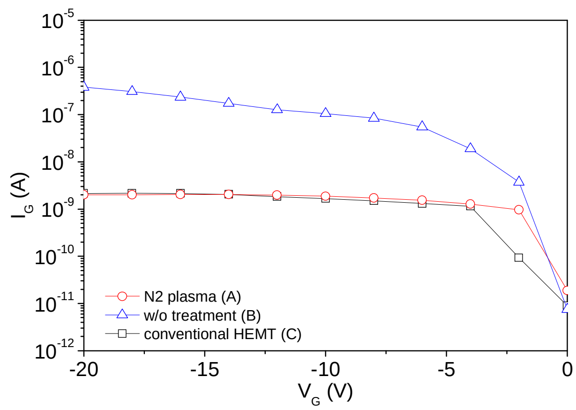

Figure 1. Schottky gate leakage current comparison.

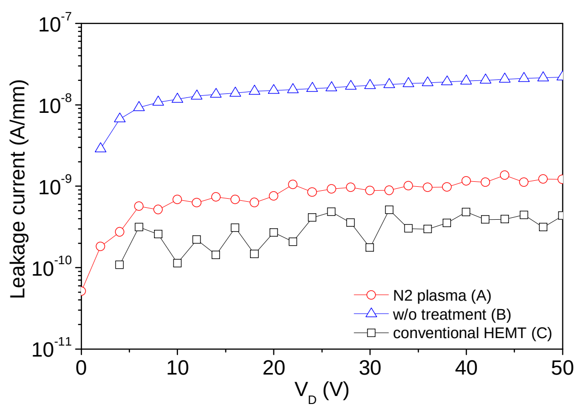

Figure 2. Leakage current measured from mesa isolation region (gap = 20 μm).

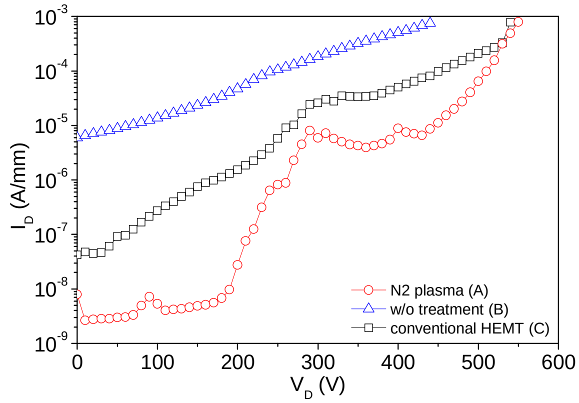

Figure 3. OFF-state drain leakage current comparison.

Conclusion

In conclusion, all the output DC characteristics comparison in this study indicate that the GaN surface condition before SiN_x deposition greatly affect the GaN HEMT performance. In this work, the GaN MIS-HEMT with very low leakage current has been demonstrated. It is shown that N_2 plasma treatment before SiN_x deposition can effectively reduce the GaN device leakage current that flow through the SiN_x/GaN interface.

Acknowledgments

The author would like to acknowledge all colleagues in this work. This work was supported in part by National Nano Device Laboratories and National Chiao Tung University Nano Facility Center.

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