Abstract #924, 223rd ECS Meeting, © 2013 The Electrochemical Society

# Low Leakage Current GaN MIS-HEMTs with $SiN_x$ Passivation and Gate Insulator using *In Situ* $N_2$ Plasma Treatment

Shih-Chien Liu, Huan-Chung Wang, and Edward Yi Chang
Department of Materials Science and Engineering,
National Chiao-Tung University, Hsinchu, 300 Taiwan.
Tel: +886-3-5712121*31536, Fax: +886-3-5745497,

Gallium nitride (GaN)-based High Electron Mobility Transistors (HEMTs) for high breakdown voltage, high power switching applications are studied in these twenty years. However, GaN HEMTs often suffer from surface state effects such as high gate leakage, current collapse, and a variety of reliability issues without passivation [1]. Different materials such as $SiN_x$, $SiO_x$, $Al_2O_3$, and $HfO_2$ were widely used as the gate dielectric and/or passivation on AlGaN/GaN metal-insulator-semiconductor HEMTs (MIS-HEMTs) [2]. However, the Ga−O and Al−O bonds would easily form between oxide-base dielectric and AlGaN/GaN interface. The deep interface states could induce the current collapse severely under high gate or high drain voltage. Plasma-enhanced chemical vapor deposition (PECVD)-grown $SiN_x$ have been proved as an effective material to reduce the surface states and efficiently suppress current collapse in AlGaN/GaN HEMTs. However, the increasing of surface leakage current from gate to drain and the isolation etching area have been observed after $SiN_x$ passivation [3], [4]. In this study, the effective *in situ* $N_2$ plasma treatment before $SiN_x$ deposition was demonstrated. The lower leakage current and higher drain current were achieved. 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 was use Ni/Au metal. The gate-to-drain spacing, gate-to-source spacing, and gate length are 15, 3, and 2 μm, respectively. The samples were treated by PECVD *in situ* $N_2$ plasma (100 Watt) for 3 min. The 20 nm $SiN_x$ was deposited by PECVD as the gate dielectric and passivation. Five samples were separated after mesa and ohmic contact. The surface conditions before $SiN_x$ deposition were prepared: sample A with $N_2$ plasma, sample B with HF ($HF:H_2O = 1:10$) clean (1 min) and $N_2$ plasma, sample C with HF clean, sample D without treatment, sample E is conventional HEMT sample without $SiN_x$ gate dielectric. Fig. 1 shows the $I_D$-$V_D$ characteristics. The drain current curves ($V_G = 0$ V) and the on-resistance with $N_2$ plasma treatment were obviously better than the other samples. Fig. 2 shows the $I_G$-$V_G$ characteristics. The gate leakage current curves of sample A and B have more than 1000 times lower than the other samples. Fig. 3 shows the isolation leakage current curves. There was no leakage current increasing after $SiN_x$ deposition with $N_2$ plasma treatment. Fig. 4 shows the OFF-state breakdown voltage characteristics. The drain leakage current is effectively suppressed by $N_2$ plasma treatment. Under $V_D = 200$ V, the leakage current is extremely low in this study. All the output characteristics measured earlier reveal an important issue that the surface conditions of AlGaN/GaN HEMTs before $SiN_x$ deposition would severely affect devices performance. The *in situ* $N_2$ plasma treatment could be an effective technique for $SiN_x$ deposition on AlGaN/GaN HEMTs.

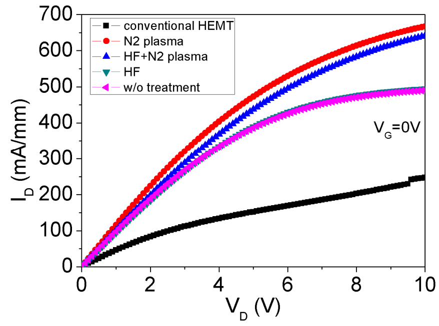

Fig. 1. $I_D$-$V_D$ characteristics comparison

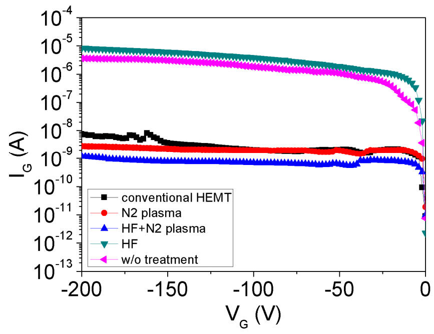

Fig. 2. $I_G$-$V_G$ characteristics comparison

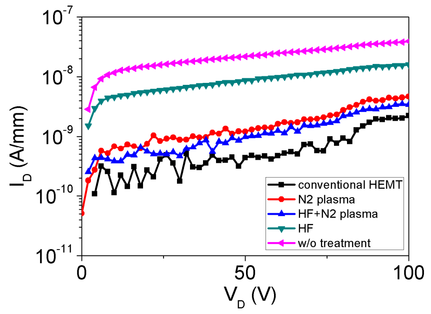

Fig. 3. Isolation (gap = 20 μm and width = 76 μm) leakage current comparison

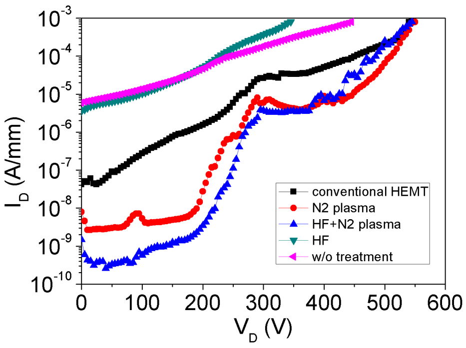

Fig. 4. OFF-state breakdown voltage characteristics comparison

## Reference

[1] R. Vetury, N. Q. Zhang, S. Keller, and U. K. Mishra, IEEE Trans. Electron Devices, vol. 48, no. 3, pp. 560-566, Mar. 2001.
[2] X. Hu, A. Koudymov, G. Simin, J. Yang, M. A. Khan, A. Tarakji, M. S. Shur, and R. Gaska, Appl. Phys. Lett., vol. 79, no. 17, pp. 2832-2834, Oct. 2001.
[3] X. Xin, J. Shi, L. Liu, J. Edwards, K. Swaminathan, M. Pabisz, M. Murphy, L. F. Eastman, and M. Pophristic, IEEE Electron Device Letters, vol. 30, no. 10, pp. 1027-1029, Oct. 2009.
[4] Z. H. Liu, G. I. Ng, H. Zhou, S. Arulkumaran, and Y. K. T. Maung, Appl. Phys. Lett., vol. 98, 113506, Mar. 2011.