Extended Abstracts of the 2012 International Conference on Solid State Devices and Materials, Kyoto, 2012, pp212-213

Influence of *in situ* N_2 Plasma Pretreatment on the SiN Prepassivation of AlGaN/GaN HEMT

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1. Introduction

AlGaN/GaN heterostructures have very superior material properties such as high breakdown field and high saturation current. Especially, AlGaN/GaN HEMTs have received much attention for next-generation high-frequency and high-power devices, particularly at high temperature and voltage operation [1]. Although significant progresses have been made in the past few years, additional efforts are needed in regard to current collapse effects and reliability issues [2]. To reduce current collapse, proper surface passivation is needed in AlGaN/GaN HEMTs [3]. Moreover, N_2 plasma pretreatment has been recently reported to supperssion current collapse prior to the SiN passivation [3]-[5].

In this study, we tried to use SiN prepassivation for additional effects; preventing nitrogen desorption at the GaN surface during high temperature ohmic alloy and early protection of surface open to the process flow. Furthermore, this work focuses on the *in situ* N_2 plasma treatment just prior to the SiN prepassivation to further mitigate current collapse.

2. Experimental Procedure

AlGaN/GaN heterostructure with 3 nm GaN capping layer and 17.5 nm AlGaN barrier (26 % Al) on a GaN buffer layer grown by metal-organic chemical vapor deposition (MOCVD) on Si substrate was used. The cleaning of samples was done by acetone, methanol and IPA. To remove the native oxide, all the samples were treated in diluted HF solution for 10 min after SPM cleaning. For the prepassivation processing, the SiN was deposited at 350 °C in a inductively coupled plasma CVD (ICP-CVD) using SiH_4 and N_2 as precursors. Refractive index (R.I) was 2. In this experiment, lowest N_2 plasma power (140 W) was used for reducing surface damage. Sample B and C were exposed to an *in situ* N_2 plasma prior to the SiN prepassivation for 1 min and 5 min, respectively. Sample A was used as reference without *in situ* plasma pretreatment before the prepassivation. Electrical isolation was performed by forming the mesa structure with an inductively coupled plasma (ICP) etching system with BCl_3/Cl_2 mixture. Ohmic contacts were made by Si/Ti/Al/Mo/Au (5/20/80/35/40 nm) and Schottky gates were fabricated by Ni/Au (40/360 nm). The device has a gate length L_g of 2 μm and L_{ds} = 8 μm, L_{gd} = 3 μm.

3. Results and Discussion

The DC characteristics of AlGaN/GaN HEMT with SiN prepassivation using the N_2 plasma pretreatment for 1 and 5 min and without plasma treatment are shown in Fig. 1 and 2. By N_2 plasma pretreatment, drain current and transconductance is increasing about 16 % and 9 %, respectively. Moreover, the slight negative shift of the threshold voltage from -1.6 to -2 V is showed in Fig. 2. However, not significant difference in DC characteristics was found for 1 and 5 min.

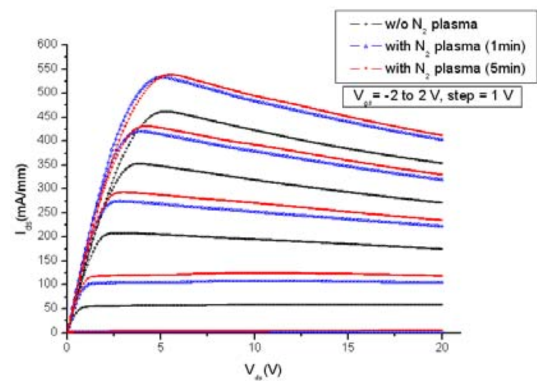

Fig. 1. Output characteristics of AlGaN/GaN HEMT

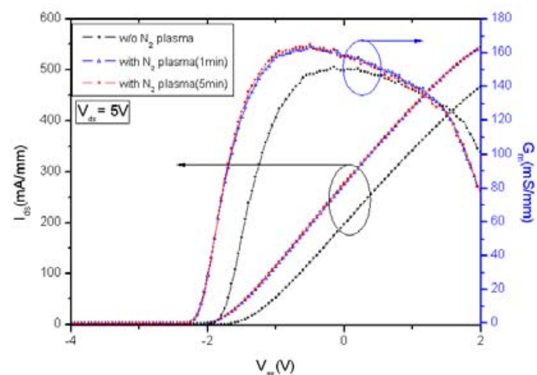

Fig. 2. Transfer characteristics of AlGaN/GaN HEM

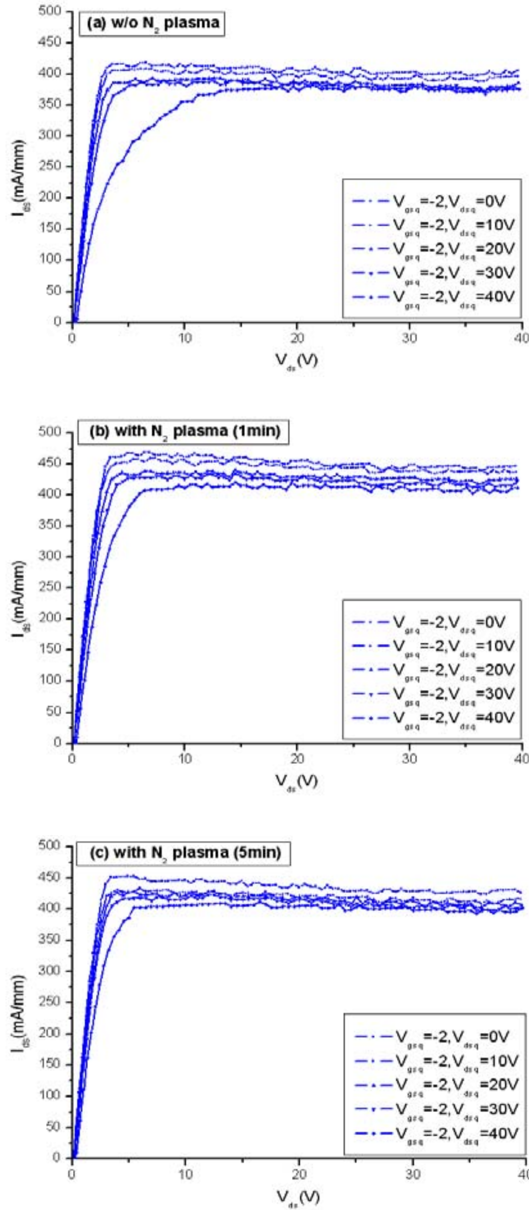

Fig. 3. Pulsed I-V characteristics of AlGaN/GaN HEMT with SiN prepassivation (W_G = 2×75 ㎛). : (a) without N_2 plasma pretreatment as a reference, with N_2 plasma pretreatment (b) during 1 min, (c) during 5 min.

Table 1. Characteristics of leakage and breakdown voltage

Samples	w/o N_2 plasma	N_2 plasma (1 min)	N_2 plasma (5 min)
Breakdown Voltage (at 1 mA/mm)	196 V	190 V	188 V

To further examine the effect of the N_2 plasma pretreatment on the charge trapping in the HEMT, pulsed I-V characteristics were measured. Fig. 3 showed that pulsed I_{ds} without drain stress was increased about 12 % by N_2 plasma pretreatment, which is in regard to the results of DC characteristics. Moreover, a notable impact of N_2 plasma treatment prior to SiN prepassivation was found to suppress current collapse. N_2 plasma treatment for 5 min was better than that for 1 min to mitigate surface trapping effect. The reason is thought that surface oxide and carbon residuals are more effectively eliminated with increasing N_2 plasma time.

Table 1 shows off-state breakdown voltage at I_{ds} = 1 mA/mm. When N_2 plasma treatment time increased off-state breakdown voltage of HEMT was hardly changed.

4. Conclusion

In summary, the beneficial influences of in situ N_2 plasma treatment just before SiN prepassivation have been investigated in the AlGaN/GaN HEMTs. From DC characteristics, drain current and transconductance was improved by N_2 plasma pretreatment. Moreover, pulsed I-V characteristics showed that N_2 plasma pretreatment was able to reduce current collapse.

These results confirm that the use of N_2 plasma also leads to the beneficial effects on AlGaN/GaN HEMT with SiN prepassivation process. Furthermore, N_2 plasma is able to further suppress current collapse which is one of the bottlenecks to improve efficiency of AlGaN/GaN HEMT at high power and frequency operation.

Acknowledgement

This work was supported by the Brain Korea 21 project, the Department of Electrical Engineering and Computer Science, Seoul National University in 2012 and by the National Research Foundation of Korea (NRF) grant funded by the Korea Government (MEST, No. 2011-0027639).

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