Improved current collapse in AlGaN/GaN HEMTs by O_2 plasma treatment

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Introduction

AlGaN/GaN HEMTs are attractive for use in next-generation, low-loss, high-voltage, and high-temperature power applications. To achieve high-efficiency operation in power AlGaN/GaN HEMTs, current collapse must be minimized since it gives rise to a significant increase in dynamic on resistance (R_{on}) under high drain voltage operation. O_2 plasma treatment is widely used in AlGaN/GaN HEMT processing and is known to give various effects on the device performance. Hong et al. reported that the gate leakage current was reduced by applying an O_2 plasma treatment on the access region of AlGaN/GaN HEMTs [1]. Meyer et al. reported that O_2 plasma pre-treatments resulted in improved pulsed I-V characteristics with degraded gate-leakage and gate-breakdown characteristics [2]. In this work, we use O_2 plasma as a pre-treatment before SiN passivation and observe dramatic improvements in the current collapse with no significant changes in gate-leakage and gate-breakdown characteristics.

Experiments

Fig.1 shows the cross section of the fabricated AlGaN/GaN HEMT on a SiC substrate. The structure consists of a 500 nm undoped GaN channel layer and a 25 nm undoped AlGaN barrier layer. The Al composition in AlGaN was 20 %. Using standard device fabrication processes, including BCl_3/Cl_2-based mesa isolation, ohmic metallization by Ti/Al/Mo/Au (annealed at 880 °C), and Schottky gate metallization by Ni/Au, AlGaN/GaN HEMTs were fabricated with a nominal gate length of 3 μm, a gate-to-drain spacing of 10 μm and a gate width of 100 μm. O_2 plasma treatments were conducted on the AlGaN surface with a plasma power of 300 W and a treatment time of 6 min. After the plasma treatment, SiN was deposited as a passivation layer with a thickness of 160 nm. The device exhibited a maximum drain current of 0.55 A/mm with a threshold voltage of -2.8 V and an off-state breakdown voltage of 1000 V.

Results

Fig.2 compares two terminal gate leakage current characteristics with and without O_2 plasma treatment. It was found that gate leakage characteristics were hardly affected by O_2 plasma treatments. Fig.3 shows drain I-V characteristics measured by Tektronix curve tracer for devices with and without O_2 plasma treatment. Measurements were made with a fixed gate voltage of 0 V, while changing the drain bias voltage up to 50V. The plasma-treated device exhibited much improved drain current dispersion. More detailed time response of drain current is shown in Fig.4, where the on-state duration time and the off-state duration time are 1 μs and 10 ms, respectively. An off-state drain voltage of 100 V was used with a load resistance of 10 kΩ. A quick response with a time constant of less than 1μs is observed for the device with O_2 plasma treatment. Fig.5 shows the normalized dynamic R_{on} (NDR) as a function of the off-state drain voltage. The NDR is defined as the ratio of measured dynamic R_{on} and its static value. The NDR is increased with increasing the off-state drain voltage. However, much lower NDR by more than orders of magnitude was obtained for the device with O_2 plasma treatment than that without plasma treatment.

Summary

Table I summarizes measured device characteristics. Note that O_2 plasma treatments resulted in improved current collapse without degrading DC drain characteristics, including low gate leakage characteristics with a high breakdown voltage of around 1000 V. The dynamic R_{on} was decreased from 4600 Ωmm (without O_2 plasma) to 80 Ωmm (with O_2 plasma), indicating 98 % improvement in the current collapse characteristics.

[1] S. K. Hong et al., Electronics Lett., vol. 44, pp.1091-1092, 2008.
[2] D. J. Meyer et al., CS MANTECH Conference, 13.4, April 14-17, Chicago, USA, 2008.

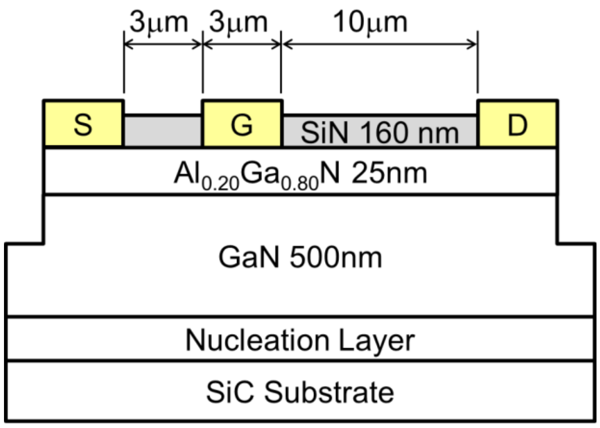

Fig. 1 Cross sectional view of fabricated AlGaN/GaN HEMT.

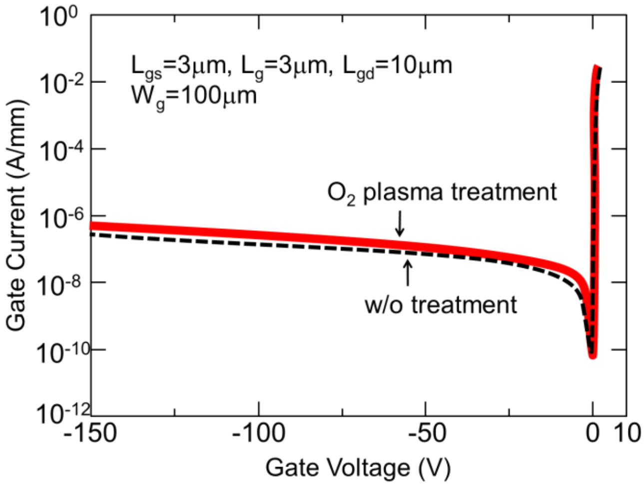

Fig. 2 Two-terminal gate current as a function of gate voltage for devices with and without O_2 plasma treatment.

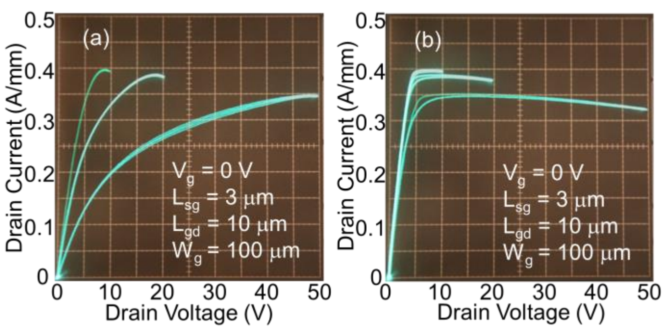

Fig. 3 Drain I-V characteristics measured at V_g = 0 V while varying drain voltage swing from 10 to 50 V for devices (a) without and (b) with O_2 plasma treatment.

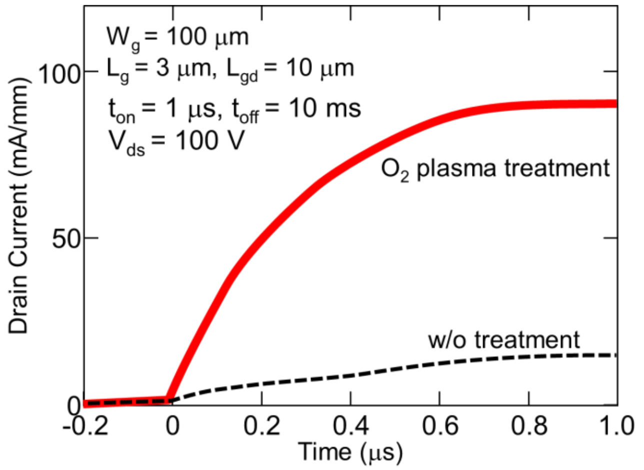

Fig. 4 Transient drain current waveform for devices with and without O_2 plasma treatment. Off-state drain bias voltage is 100 V.

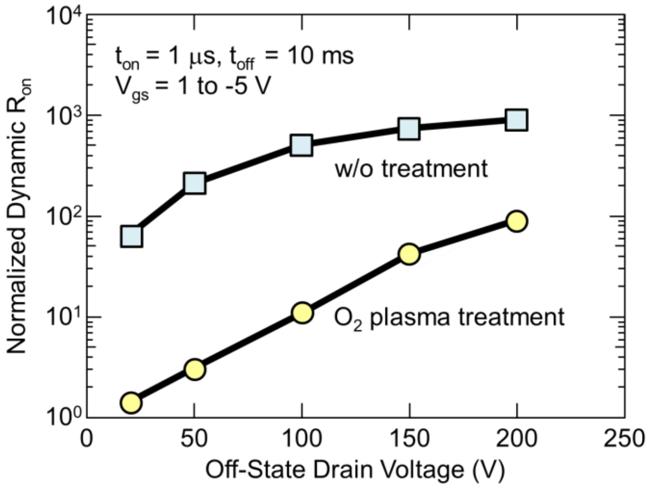

Fig. 5 Normalized dynamic R_{on} as a function of off-state drain voltage for devices with and without O_2 plasma treatment. On-state duration time is 1μs.

Table I. Summary of device performance.

	w/o Treatment	O_2 Plasma Treatment
I_{dmax} (A/mm) @V_g = 1 V	0.57	0.55
Static R_{on} (Ωmm) @V_g = 1 V	8.4	7.3
V_{th} (V)	-2.9	-2.8
Gate Leakage (A/mm) @V_g = -150 V	3×10^{-7}	5×10^{-7}
V_{BR} (V) @I_d = 100 μA/mm	980	1000
Dynamic R_{on} (Ωmm) @V_{ds_off} = 100 V	4600	80