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Normally-off Recessed AlGaN/GaN MOSHFETs using ICPCVD SiO_2

B.-R. Park[1], J.-G. Lee[1], I.-H. Min[2], K.-S. Seo[2], and H.-Y. Cha[1,*]

[1] School of Electronic and Electrical Engineering, Hongik University, Seoul 121-791, Korea
* Phone: +82-2-320-3062 E-mail: hcha@hongik.ac.kr
[2] Department of Electrical Engineering, Seoul National University, Seoul 151-742, Korea

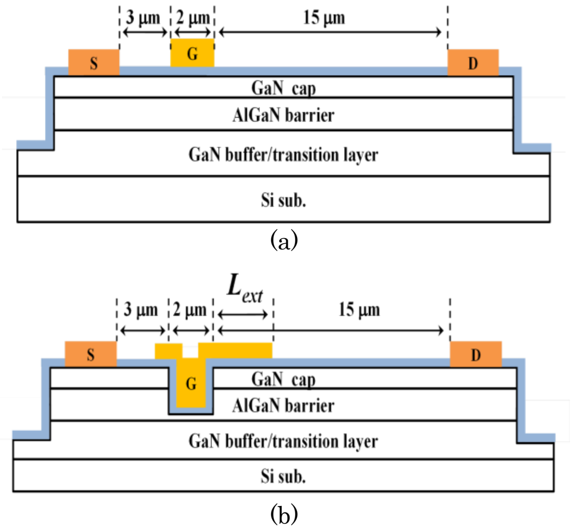
1. Introduction

GaN based FETs are a very promising candidate for next generation, high efficient power devices due to their superior material properties, such as high critical electric field and high electron mobility [1]. Thanks to their strong piezoelectric and spontaneous polarization effects, AlGaN/GaN HFETs can exhibit high current density even without intentional doping [2]. On the other hand, this intrinsic 2DEG channel makes it very difficult to implement normally-off operation. A common configuration utilized for normally-off operation is a recessed MISHFET and various gate dielectric materials including SiN_x, Al_2O_3, and SiO_2 have been reported using different deposition methods [3-5]. In this study, we employed SiO_2 for the gate dielectric layer whose deposition conditions were optimized using inductively coupled plasma chemical vapor deposition (ICPCVD) to obtain a high breakdown voltage.

2. Experiments and Discussion

AlGaN/GaN MOSHFETs were fabricated utilizing optimized SiO_2 deposition conditions for high breakdown voltage. Both normally-on and normally-off mode operations were implemented by non-recessed and recessed MOSHFET configurations. The cross-sectional schematics of non-recessed and recessed AlGaN/GaN MOSHFETs are shown in Fig. 1. The epitaxial structure consisted of a 4 nm undoped-GaN capping layer, a 20 nm undoped-$Al_{0.23}Ga_{0.77}N$ barrier, a 1 nm AlN spacer, a 1.7 µm undoped-GaN buffer, and undoped-GaN/AlGaN/AlN transition layers on an N-type Si (111) substrate. The gate overhang length (L_{ext}) of the recessed MOSHFET was varied from 1 to 5 µm.

The device process began with mesa isolation using a low damage Cl_2/BCl_3 etching method [6]. The recess was then carried out using the same recipe and the final target thickness of the recessed AlGaN barrier was 3 nm. For comparison, non-recessed normally-on MOSHFETs were also fabricated on the same wafer. After cleaning the surface, a 20 nm SiO_2 layer was deposited at 250 °C by ICPCVD. The optimized deposition conditions were $SiH_4/O_2/Ar$ (=4/7.2/60 sccm), a source RF power of 1500 W, and a pressure of 5 mTorr, which resulted in high breakdown electric field (~11 MV/cm) with good uniformity. The measured refractive index was 1.47. For the source and drain contact formation, the SiO_2 layer underneath the contact regions was etched away using a CF_4 RIE process prior to metallization. A Si/Ti/Al/Mo/Au (=5/15/60/35/50 nm) metal stack was used for the ohmic metallization and annealed by a two-step annealing process at 810 °C for 30 s and 840 °C for 30 s. A Ni/Au (=20/380 nm) was used for gate metallization.



(a)

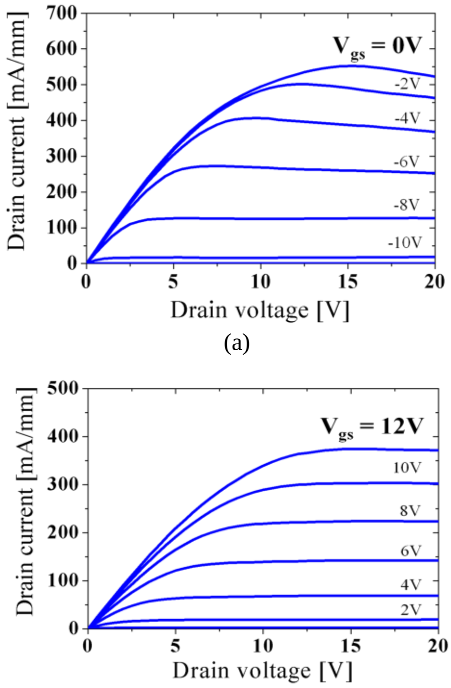
(b)

Fig. 1 Cross-sectional schematic of (a) non-recessed and (b) recessed AlGaN/GaN MOSHFETs.

The current-voltage characteristics of non-recessed and recessed devices are compared in Figs. 2(a) and 2(b). The maximum current densities of the non-recessed and recessed devices were 550 and 375 mA/mm, respectively. The breakdown characteristics were measured with the gate voltage of -15 and 0 V for non-recessed and recessed devices, respectively. The measured breakdown voltages as a function of the gate overhang length are plotted in Fig. 3(a). The breakdown voltage monotonically decreases with increasing the gate overhang length, suggesting that the high electric field at the recessed corner is sufficiently suppressed even with a short overhang length. A breakdown voltage of 820 V was achieved with the gate overhang length of 1 µm (see Fig. 3(b)). For comparison, non-recessed device exhibited the breakdown voltage of 780 V.

3. Conclusions

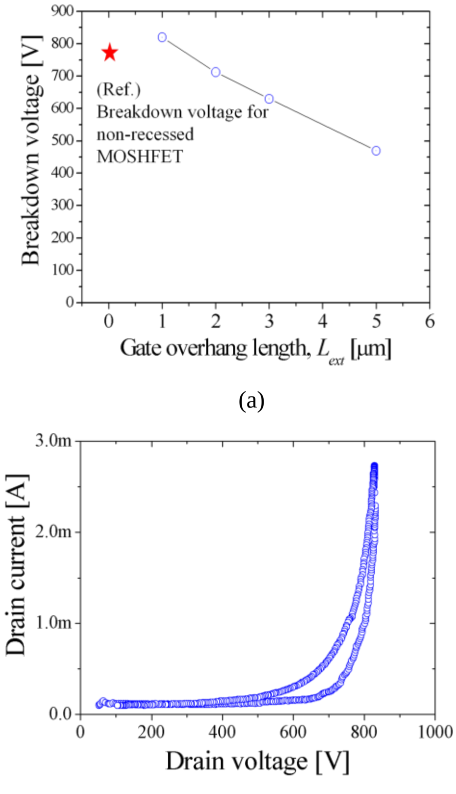
High performance normally-off AlGaN/GaN MOSHFETs were successfully fabricated using ICPCVD SiO_2. A breakdown voltage of 820 V and a maximum current density of 375 mA/mm were achieved for the gate-to-drain distance of 15 µm.



(a)

(b)

Fig. 2 Current-voltage characteristics of (a) non-recessed and (b) recessed MOSHFETs.



(a)

(b)

Fig.3 (a) Breakdown voltage characteristics of recessed MOSHFETs as a function of gate overhang length. (b) Breakdown characteristics of a recessed MOSHFET with a gate overhang length of 1 μm

Acknowledgements

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