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, Al-GaN/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, Al2O3, and SiO2 have been reported using different deposition methods [3-5]. In this study, we employed SiO2 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 SiO2 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 epilayer structure consisted of a 4 nm undoped-GaN capping layer, a 20 nm undoped-Al0.2Ga0.8N barrier, a 1 nm AlN spacer, a 1.7 µm undoped-GaN buffer, and undoped-GaN/AlGaN/AIN transition layers on a N-type Si (111) substrate. The gate overhang length ($L_{ov}$) of the recessed MOSHFET was varied from 1 to 5 µm.

The device process began with mesa isolation using a low damage Cl2/BCl3 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 SiO2 layer was deposited at 250 °C by ICPCVD. The optimized deposition conditions were SiH4/O2/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 SiO2 layer underneath the contact regions was etched away using a Cl2 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.

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 SiO2. 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.
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References

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

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.