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AlGaN/GaN heterostructure MIS-HEMTs with Si_3N_4 gate insulator

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1. Introduction

AlGaN/GaN HEMTs receive much attention for high-frequency and high-power applications. In order to fully develop the potential of the device, it is important to solve the problems such as a large gate leakage current [1,2] and drain current collapse [3], which limit the RF performance of the device. Even though MOSFETs [4,5] and MISFETs [1] approaches are promising, there are still some problems to be solve. In this report, we fabricated AlGaN/GaN heterostructure MIS-HEMTs and obtained good results.

2. Experiments

Figure 1 shows schematic cross section of the fabricated AlGaN/GaN MIS-HEMTs. Si_3N_4 gate insulator (10 nm) was deposited by ECR sputtering after the ohmic contact formation. 1.5-µm-long Shottky gate was formed by Ni/Au (10/200 nm) evaporation and the subsequent lift-off process. Si_3N_4 serves simultaneously as a gate insulator and a surface passivation film. Reference device without Si_3N_4 gate insulator was also fabricated.

Figure 2 and 3 show I_D-V_{DS} characteristics of the fabricated AlGaN/GaN HEMTs with and without Si_3N_4 gate insulator, respectively. Both devices show good pinch-off and saturation characteristics. This suggests that the interface between Si_3N_4 and AlGaN is satisfactory good. The maximum transconductance g_{mmax} of both devices were 90 mS/mm and 140 mS/mm, respectively. The smaller g_{mmax} of the MIS-HEMTs is probably due to the decrease in gate-channel capacitance by inserting Si_3N_4 insulator. Threshold voltage shift of the MIS-HEMTs from –2 V to –5 V is due to a voltage drop at the Si_3N_4 gate insulator.

Figure 4 shows the I_G-V_{GS} characteristics of the device with and without Si_3N_4 gate insulator. Si_3N_4 gate insulator could reduce the gate leakage current by about three orders magnitude below that measured for the devices without Si_3N_4 gate insulator. By this decrease in the gate leakage current, the negative drain current at small V_{DS} observed for the device without Si_3N_4 gate insulator (Fig.3) was suppressed even at a large gate voltage of 3 V, as shown in Fig.2.

Figure 5 shows noise power spectral density of the HEMTs with and without Si_3N_4 gate insulator at frequencies below 1 MHz. While 1/f noise is observed for the MIS-HEMTs, the bulge which reflects the existence of deep level is superimposed on 1/f noise in the low-frequency regime for devices without Si_3N_4 insulator, as shown by an arrow. Moreover, the magnitude of the noise power spectral density of the device without Si_3N_4 insulator was larger than that of MIS-HEMTs due to the increase of the noise at frequencies below 1 KHz originating from the deep level. Sharp peaks around 100 KHz are external noise.

Figure 6 shows the effect of the negative gate bias stress. Drain current was measured after a stress of V_{GS}=-5 V for 10 s at V_{DS}=10 V. Even though a large current decrease, so-called current collapse, was observed in the device without Si_3N_4 gate insulator, it was not observed in the MIS-HEMTs, as shown in Fig.6. These results suggest that Si_3N_4 film is effective in passivating the device surface and suppress the current collapse.

3.Summary

In summary, it has been demonstrated that the gate leakage current, low-frequency noise and current collapse are suppressed in the AlGaN/GaN MIS-HEMTs using Si_3N_4 film as a gate insulator.

References

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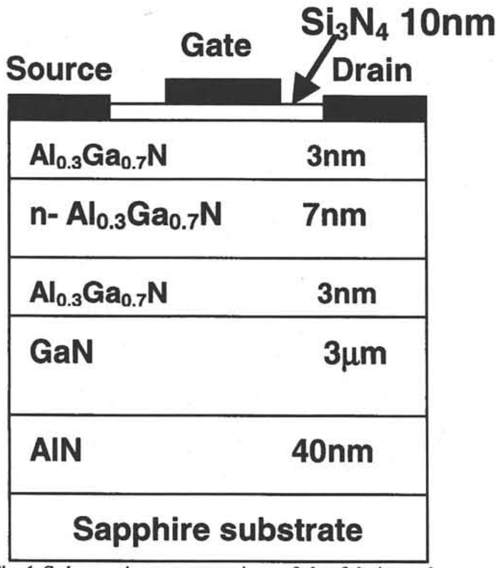

Fig.1 Schematic cross section of the fabricated AlGaN/GaN MIS-HEMTs.

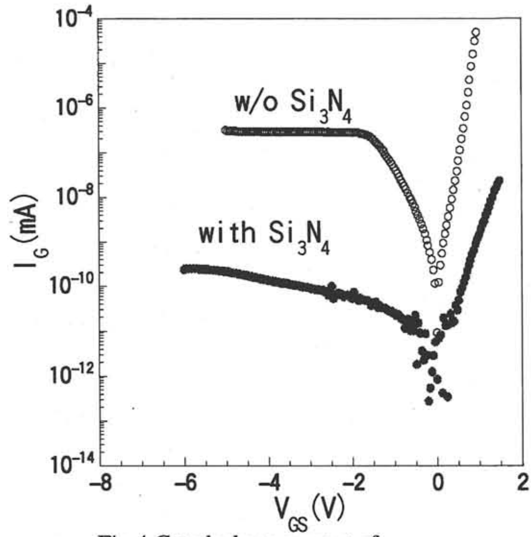

Fig.4 Gate leakage current of AlGaN/GaN HEMTs with and w/o Si_3N_4.

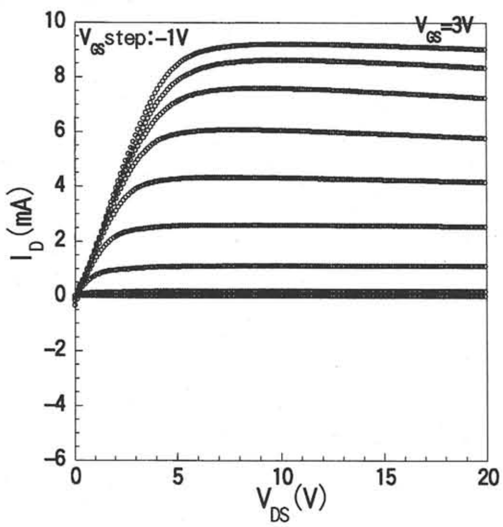

Fig.2 I_D-V_{DS} characteristics of GaN MIS-HEMTs. V_{GS}=+3～-5V. Gate width is 20 μ m.

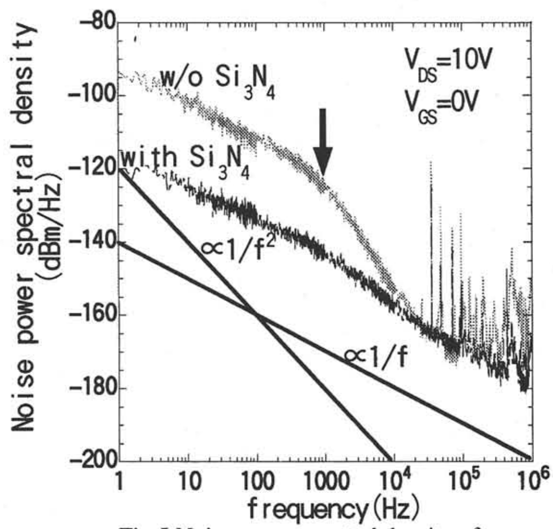

Fig.5 Noise power spectral density of AlGaN/GaN HEMTs with and without Si_3N_4.

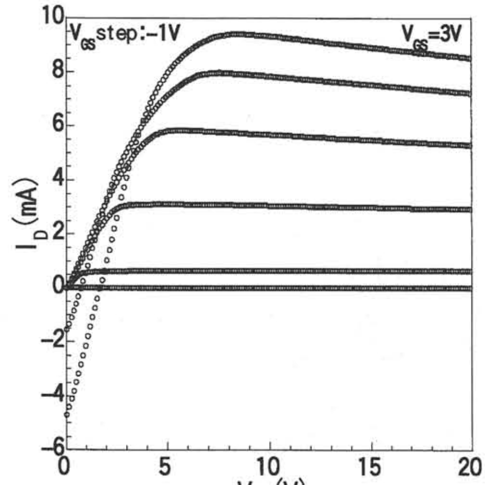

Fig.3 I_D-V_{DS} characteristics of GaN HEMTs without Si_3N_4 gate insulator. V_{GS}=+3～-2V. Gate width is 20 μ m.

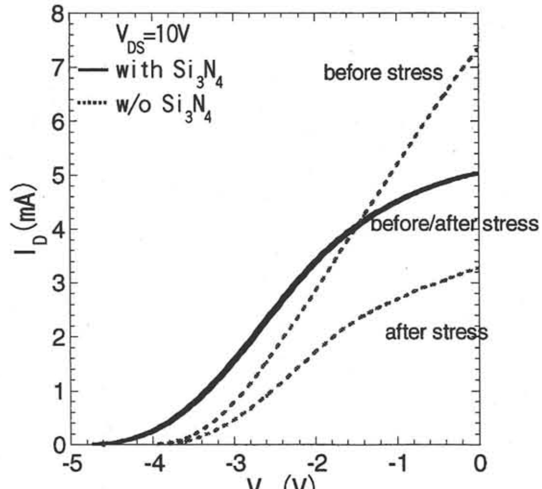

Fig.6 I_D-V_{GS} characteristics measured after the gate bias stress of V_G=-5 V for 10 s.