RF-sputtered HfO_2 Gate Insulator in High-Performance AlGaN/GaN MOS-HEMTs

Ogyun Seok[1], Woojin Ahn[1], Min-Woo Ha[2] and Min-Koo Han[1]

[1]Department of Electrical Engineering and Computer Science, Seoul National University, Seoul, Korea

[2]Compound Semiconductor Devices Research Center, Korea Electronics Technology Institute, Seongnam, Korea

1. Introduction

Recently, high-performance AlGaN/GaN MOS-HEMTs using various gate insulator materials such as SiO_2 and Al_2O_3 have been demonstrated [1-2]. We have already reported RF-sputtered HfO_2 as gate insulator for AlGaN/GaN MOS-HEMTs. We achieved a high breakdown voltage of 1526 V and a low interface trap density of 1.37×10^{12} cm^{-2} [3]. RF-sputtered HfO_2 has merits of its high-*k* characteristics and high-breakdown field as well as low cost, a high throughput, and a low temperature process.

However, AlGaN/GaN MOS-HEMTs have significant hysteresis problems. The hysteresis should be investigated for V_{TH} stability during the device switching. It is well known that characterization of oxide/AlGaN interface in AlGaN/GaN MOS-HEMTs is difficult because AlGaN/GaN MOS-HEMTs have interfaces: oxide/GaN cap, GaN/AlGaN, and AlGaN/GaN [4].

The purpose of this paper is to investigate C-V characteristics at various measuring conditions in order to verify the hysteresis mechanism in the AlGaN/GaN MOS-HEMTs,

2. Devices Structure and Fabrication

The cross-sectional view of the fabricated AlGaN/GaN MOS-HEMT is shown in Fig. 1. The mesa isolation was performed by Cl_2-based inductively coupled plasma-reactive ion etching. Ohmic contacts for source and drain, Ti/Al/Ni/Au (20/80/20/100 nm), were deposited using an e-gun evaporator and annealed at 880 ^{o}C for 40 s under N_2 ambient. After the ohmic contact formation, we dipped the samples 30:1 in order to remove native oxide. The 15 nm-thick HfO_2 gate insulator was deposited by RF-sputtering at room temperature. The sputtering power, pressure, and Ar flow were 50 W, 3 mTorr, and 15 sccm, respectively. Finally, gate, Ni/Au (50/150 nm), was formed by e-gun evaporation and lift-off process.

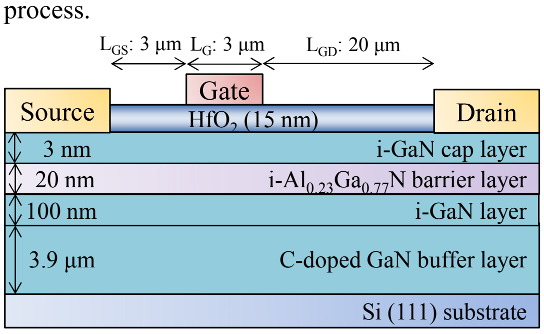

Fig. 1. Cross-sectional view of the fabricated AlGaN/GaN MOS-HEMT with RF-sputtered HfO_2

3. Experimental Results

The capacitacne-voltage characteristics at 1 MHz is shown in Fig. 2. The curve with sweeping ragnge from -10 to -0.5 V has a small hysteresis of 100 mV near threshold voltage. However, the curve with sweeping range from -10 to 5 V has a large hysteresis of 1.1 V correspoing which results from acceptor-like traps at the HfO_2/GaN interface. The electrons are accumulated at AlGaN barrier layer and capacitance increases with steep slope when gate bias is higher than 2.5 V.

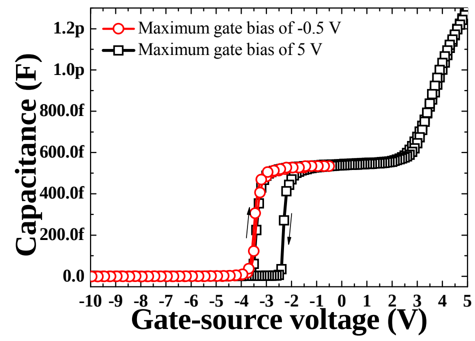

Fig. 2. Measured capacitance-voltage characteristics at 1 MHz

Fig. 3 shows the capacitance-voltage characteristics with measuring frequency of 1, 10, 100 kHz, and 1 MHz. At all frequency conditions, nearly indentical hystesis at the negative gate bias is observed. However, the lower frequency, the high-capacitance value and the large hysteresis are measured at the positive gate bias. This high-capacitance values are originated from the electron capturing at the oxide/GaN interface [5]. Our reauslts indicate that the electron capturing at oxide/GaN interface states is a slow process which responds to the lower frequency than 1 MHz. The most electrons which are captured interface states are emitted at the reverse sweep so that AlGaN/GaN MOS-HEMT with RF-sputtered HfO_2 has stable V_{TH} characteristics at the various operating frequency

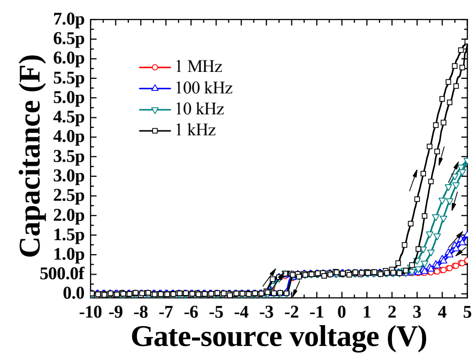

Fig. 3. Measured characteristics at frequency of 1, 10, 100 kHz, and 1 MHz with maximum gate bias of 5 V

4. Conclusion

The hysteresis in the AlGaN/GaN MOS-HEMTs employing RF-sputtered HfO_2 gate insualtor was investigated by various capacitance-voltage measurments. The electrons capturing process responds to slow frequency so that the large systeresis at the positive gate bias occured. However, The hysteresis did not affect the V_{TH} variation.

References

[1] V. Adivarahan, J. Yang, A. Koudymov, G. Simin and M. A. Khan, IEEE Electron Device Lett., **26**, 2005, 535

[2] M. Kanamura, T. Ohki, T. Kikkawa, K. Imanishi, T. Imada, A. Yamada and N. Hara, IEEE Electron Device Lett., **31**, 2010, 189

[3] O. Seok, W. Ahn, M. -K. Han and M. –W. Ha, Semicon. Sci, Technol. (under revision)

[4] C. Mizue, Y. Hori, M. Miczek and T. Hashizume, Jpn. J. Appl. Phys., **50**, 2011, 021001

[5] S. Huang, S. Yang, J. Roberts and K. J. Chen, Jpn. J. Appl. Phys., **50**, 2011, 110202