Comparison of side-gate modulation responses for AlGaN/GaN HEMTs on GaN substrates with and without C-doped GaN buffer layer

[1] Advanced Electron Devices Laboratory, [2] Research Center for Smart Energy Technology
Toyota Technological Institute, °Maria Emma Villamin[1], Naotaka Iwata[1, 2]
E-mail: villamin_me@toyota-ti.ac.jp

GaN HEMTs have promising potential as power transistors because of the excellent properties of GaN such as high carrier concentration, and high breakdown electric field. For optimum HEMT performance of GaN HEMT on GaN substrate, high-quality GaN substrates and buffers with high resistivities are important. However, unintentional residual impurities incorporated during growth results undoped GaN layer with low resistivity. In order to increase the resistivity, these impurities are compensated by doping the GaN with deep acceptors like carbon (C). In our previous works, we have reported that HEMT on C-doped GaN buffer showed a large modulation by side-gate (SG) measurement[1)], and showed a hysteresis feature[2)] when bi-directional dual sweep SG measurement is done. In this report, we extend the study for SG measurements on two GaN HEMT devices with C-doped GaN buffer and no-buffer device.

Figure 1 shows the schematic diagram of the devices structure (a) and the actual device (b). As seen in Fig. 1b, the SG contact surrounds the whole device, and has two inward metal branches that further surrounds the active region. Two HEMTs with identical device structure were fabricated from two separate wafers: with C-doped GaN buffer (Fig. 1a) and without buffer layer (not shown). Both HEMT wafers were grown using metal organic chemical vapor deposition on GaN substrate. The no-buffer HEMT has epitaxial layers composed of an undoped GaN layer and an AlGaN layer on top. Whereas for the with-buffer HEMT, the epitaxial layers are C-doped GaN buffer layer (300nm), followed by undoped GaN layer and an AlGaN layer. SG modulation was done by sweeping SG voltage (V_{SG}) while monitoring I_D, and at the same time the drain-to-source voltage (V_{DS}) was kept at 6 V, and the gate voltage (V_{GS}) was biased at 0 V (on state).

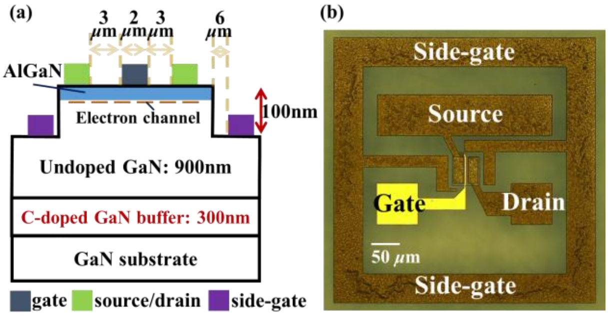

Figure 1. Schematic of GaN-on-GaN HEMT structure (a) and actual device under optical microscope (b).

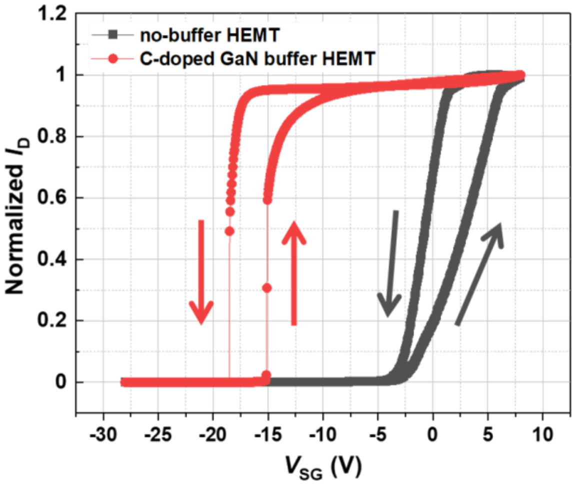

Figure 2. Normalized I_D against V_{SG} scanned from -28 V (start) to 8 V to -28 V (end), at V_{GS} = 0 and V_{DS} =6V.

On the other hand, Fig. 2 shows the normalized plot of I_D as functions of V_{SG} for the fabricated HEMTs. For the no-buffer HEMT, when V_{SG} is scanned from -28V to +8V, the I_D is zero until V_{SG} = -2V, then I_D increases as the V_{SG} reaches +8V. As the V_{SG} is swept back from +8V to -28V, the I_D value did not change until +2V, and then rapidly decreases. And I_D is zero until V_{SG} =-28V. On the other hand, for the C-doped GaN buffer HEMT, when V_{SG} is swept from -28V to +8V, the I_D is zero until V_{SG} = -15V, and then increases until V_{SG} =-10V. Then, the I_D becomes constant until V_{SG} = +8 V. As the V_{SG} is swept back from +8V to -28V, the I_D is constant until V_{SG} = -18V, and then decreases. This clearly shows that C-doped GaN buffer HEMT has hysteresis feature, which is consistent with our previously reported SG measurement of C-doped GaN buffer HEMT[2)]. Moreover, it can be seen from the data that both HEMTs show SG modulation. No-buffer HEMT exhibits SG modulation near V_{SG} = 0V whereas the C-doped GaN buffer HEMT shows SG modulation at higher V_{SG} = -15V. Based on the data shown here, it can be concluded that no-buffer HEMT is less stable to SG modulation as compared to HEMT with buffer layer.

Acknowledgement. This work was supported by MEXT “Research and development of next-generation semiconductor to realize energy-saving society” Program Grant Number JPJ005357.

References: 1.) M.E. Villamin, T. Kondo & N. Iwata, JSAP *81*st Autumn Meeting, (2020) 10p-Z04-6.
2.) M.E. Villamin, T. Kondo &N. Iwata, Ext. Abstr. Solid State Devices and Materials, 2020, D-7-06.