Current controllability and stability of multi-mesa-channel AlGaN/GaN HEMTs

T. Hashizume and K. Ohi

Research Center for Integrated Quantum Electronics (RCIQE), Hokkaido University
e-mail: hashi@rciqe.hokudai.ac.jp

We have recently developed a multi-mesa-channel (MMC) AlGaN/GaN HEMT, as shown in **Fig. 1** [1, 2]. By forming a periodic trench, the MMC HEMT has parallel mesa-shaped channels with two-dimensional electron gas (2DEG) surrounded by the gate electrode. In the present study, we report the basic DC characteristics, including threshold voltage control, subthreshold behavior, transfer characteristics and off-state breakdown properties, of such mesa-channel HEMTs.

Typical drain current-voltage (I_{DS}-V_{DS}) characteristics of conventional and MMC HEMTs measured at RT are shown in **Fig. 2**. The MMC HEMT has a mesa-top width, W_{top}, of 80 nm and a mesa/trench period of 400 within a gate-electrode width, W, of 100 μm. Thus, the effective gate width, i.e., the sum of W_{top} values, was 32 μm for the MMC structure. The MMC HEMT demonstrated good *I-V* behavior with complete pinch-off behavior. In particular, the MMC HEMT showed a shallower threshold voltage and a lower knee voltage than the conventional planar HEMT. The shallower V_{TH} dominantly arose from the lateral field effect through the mesa gate. In addition, the high impedance of each mesa channel in the MMC HEMT appears to weaken the effect of the access resistance between the drain and gate electrodes on knee voltage.

The transfer characteristics of both devices in the linear region (V_{DS} = 0.5 V) are compared in **Fig. 3**. As the mesa width decreased, a systematic shift of the threshold voltage was observed in the MMC HEMTs, probably owing to the surrounding field effect. In spite of the fact that the effective gate width of the MMC device is only 10.5 μm (about 20 % of that of the planar device), in addition, the MMC HEMT exhibited a current and a transconductance (g_m) almost equal to those of the planar device.

To investigate the gate controllability of the MMC device, we measured the subthreshold characteristics of the device. **Figure 4** shows a comparison of the drain currents for the planar and MMC HEMTs. The gate leakage currents are also plotted in Fig. 4 by broken lines. For both devices, drain current is dominated by reverse-biased gate current in the pinch-off region, as typically reported for Schottky-gate AlGaN/GaN HEMTs. Reflecting a lower gate leakage current, the drain-current ON/OFF ratio is about 10^9 for the MMC device. In addition, a small subthreshold slope of 76 mV/dec was observed in the MMC HEMT. In MMS structure, the potential modulation through the mesa edge and the undoped GaN layer becomes marked near pinch off. Thus, a combination of normal and lateral fields results in a field surrounding 2DEG, which can effectively control the depletion of 2DEG.

The MMC device also showed excellent current stability in the saturation region. **Figure 5** shows the drain *I-V* curves of the planar and MMC HEMTs with L_{GD} = 10 μm. The inset in Fig. 5 shows enlargement of drain current in the saturation region. For the planar device, the current reached its maximum and thereafter gradually decreased with increasing drain voltage. This result can be explained by the thermal effect in the channel. On the other hand, as shown in the inset of Fig. 8, the MMC device exhibits excellent current stability.

References

[1] T. Tamura, J. Kotani, S. Kasai, and T. Hashizume: Appl. Phys. Express **1** (2008) 023001.
[2] K. Ohi and T. Hashizume, Jpn. J. Appl. Phys. **48**, 081002 (2009).

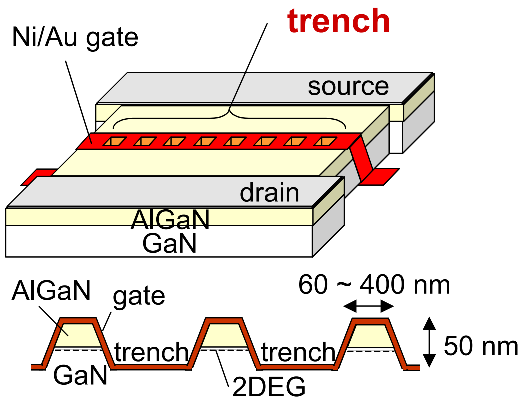

Fig. 1 Schematic illustration of MMC AlGaN/GaN HEMT.

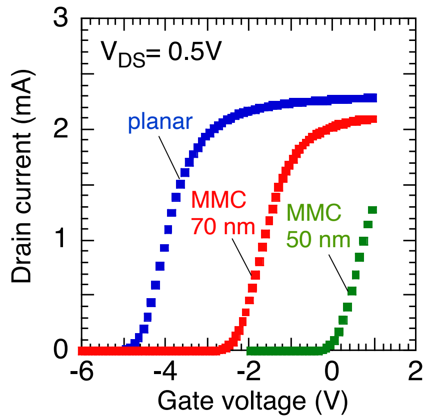

Fig. 3 Transfer characteristics in the linear region.

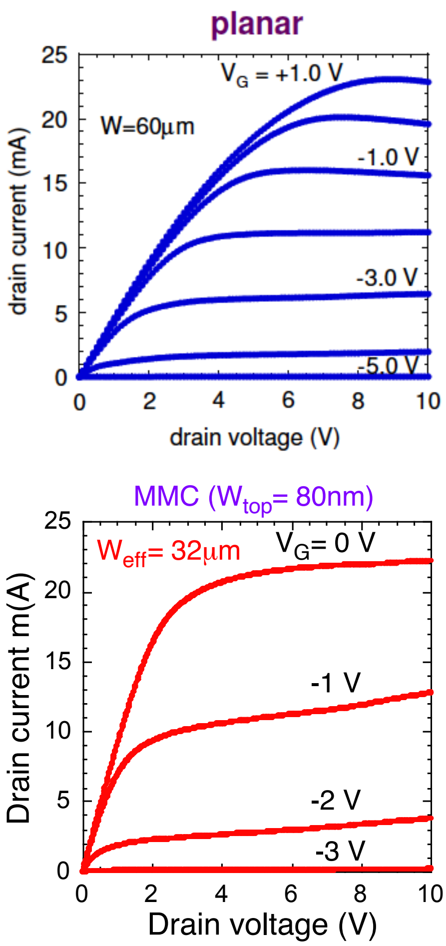

Fig. 2 Comparison of drain I-V characteristics.

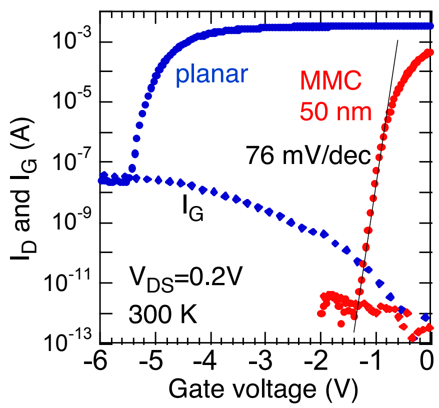

Fig. 4 Drain I-V characteristics in the subthreshold region.

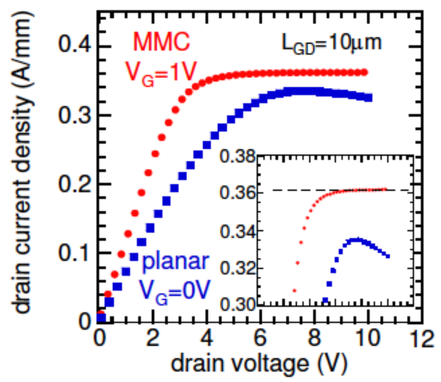

Fig. 5 Drain I-V curves of planar and MMC HEMTs. The inset indicates an enlargement of drain current in the saturation region.