Large periphery AlGaN/GaN Metal-Oxide-Semiconductor Heterostructure Field Effect Transistors on SiC Substrates

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The development of new generations of GaN/AlGaN microwave power electronics requires Field-Effect Transistors (FETs) with low gate leakage and superior pinch-off characteristics, specifically at elevated temperatures. These properties directly impact the devices drain breakdown voltage, rf- performance, and noise figure. In the past, several groups have attempted to achieve gate leakage suppression and superior pinch-off characteristics using the Metal-Insulator FET (MISFETs) or Metal-Oxide FETs (MOSFETs) device approach. However, the performance level of all these insulated gate devices was well below that of the state-of-the-art AlGaN/GaN HFETs. We now report on a novel AlGaN/GaN Metal-Oxide-Semiconductor Heterostructure Field Effect Transistors (MOS-HFET) on SiC substrate. Our MOS-HFET design combines the advantages of the MOS structure suppressing the gate leakage current and AlGaN/GaN interface providing high-density 2D electron gas (2DEG) channel.

We demonstrate that the dc- and microwave performance of the MOS-HFETs is superior to that of conventional AlGaN/GaN HFETs fabricated on the same GaN-AlGaN HEMT wafer with $n_s=1x10^{13}$ cm^{-2} and mobility of 1200 cm^2/V-sec. This points to the high quality of SiO_2/AlGaN heterointerface. For devices with a source - drain separation of 5 μm and a gate length of 2 μm the maximum device current close to 1.3 A/mm was measured at a positive gate bias of +9 V. Further, the devices completely pinched off around -9 V. The MOS-HFETs could also operate at positive gate biases higher than +10 V and the gate leakage current was more than six orders of magnitude smaller than that for the conventional AlGaN/GaN HFETs (Please see Figure 1 and 2). The MOS-HFETs exhibited stable operation at elevated temperatures up to 300 °C with excellent pinch-off characteristics. A pinch-off current as low as 0.15 nA/mm at room temperature and 38 μA/mm at 250 °C was measured at a gate voltage V_g = -15 V and at a drain bias of 10 V. Even at 300 °C the pinch-off current remains 10 mA/mm, which is about 100 times less than the maximum saturation current. Up to 300 °C no degradation was observed in the maximum saturation current.

For the devices of our study with a gate length of 2 μm, we also measured the current gain as a function of frequency. The cutoff frequency (f_t) values of 8.2 GHz and 5.9 GHz were measured for the MOS-HFET and the HFET, respectively. Note this value of the ($f_t \cdot L_g$) product of 16.4 GHz-micron for MOS-HFET also compares very favorably with the highest reported values of state-of-the-art AlGaN/GaN HFETs. We also compared the maximum output RF power for both MOS-HFET and HFET devices. Under identical bias conditions, 30 V drain bias and -1.5 V gate bias, the maximum power of about 2 W/mm was measured for both device types. Our data thus clearly indicates that the MOS-HFET device approach preserves the high frequency performance.

We have also demonstrated a large periphery MOSHFET device for the first time. The saturation current, transconductance and the maximum rf-output power scale linearly with gate width upto 1mm. (see Figures 3 and 4). Even for the large periphery devices the gate leakage currents were 4-6 orders below those for HFETs. The f_t values also did not vary with the device periphery. This shows an excellent potential for using the MOSHFET device approach for high power microwave applications.

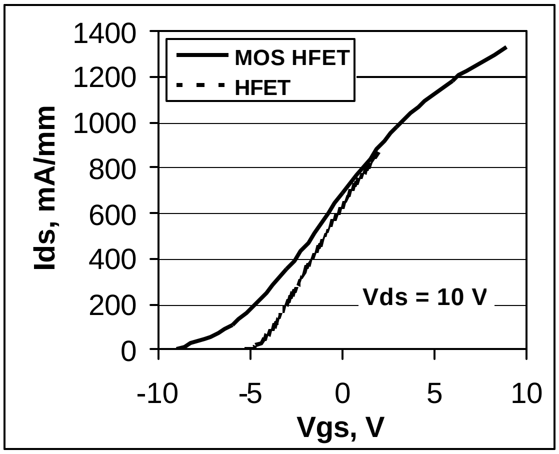

Figure 1. The saturation-current for the MOS-HFET and base-line HFET devices. Drain to source voltage is 10 V. The gate length is 2 µm; the drain to source opening is 5 µm

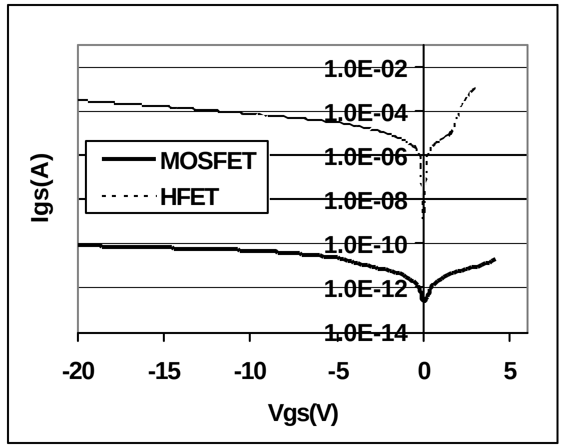

Figure 2. Gate leakage current for the MOS-HFET and the base-line HFET

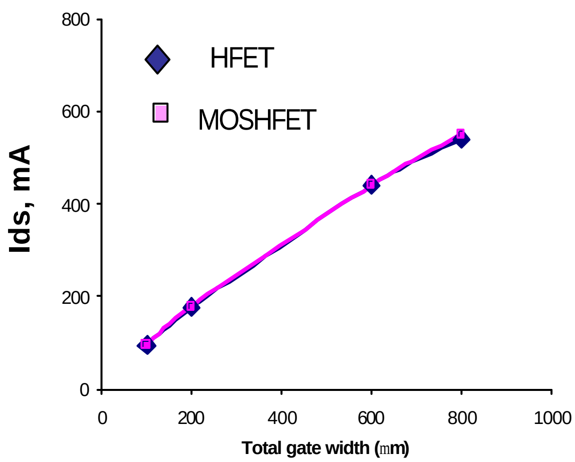

Figure 3. MOSHFET and HFET source-drain current versus gate width

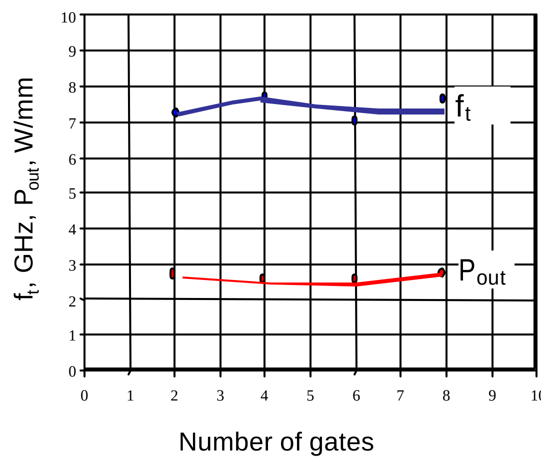

Figure 4. MOSHFET f_t and P_{out} (2GHz) versus number of gates

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