Geometry and Short Channel Effects of Enhancement-Mode n-Channel GaN MOSFETs on p and n^- GaN/Sapphire Substrates

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Previously, we have explored and optimized GaN MOS capacitors with deposited SiO_2 as gate oxide achieving a mid-bandgap interface-state density around 10^{10} /cm^2-eV [1]. Further we have reported the preliminary results of long-channel enhancement-mode n-channel MOSFETs on p and n^- GaN/sapphire substrates with maximum field-effect mobility of 167 cm^2/V-s and breakdown voltage to almost 1 kV [2]. In this paper, we report on the first characterization of the geometry and short channel effects of these n-channel GaN MOSFETs.

A schematic cross-sectional view of our lateral, non-self-aligned, n+ poly-Si gate, implanted GaN MOSFETs is shown in Fig. 1. We have designed and fabricated both linear and circular (self-enclosed) devices (Fig. 2), with 0.6 μm field oxide for linear device isolation. The off-state leakage current and the subthreshold slope of these two types of MOSFETs with a channel length of 80 μm are shown in Fig. 3. When compared to circular MOSFETs, 2 to 4 orders of magnitude higher in off-state leakage current (1.1 μA/mm vs. 26 nA/mm and 550 nA/mm vs. < 60 pA/mm) can be seen for linear MOSFETs, on p and n^- GaN respectively. In addition, we observe that GaN MOSFETs on p GaN exhibit higher leakage current than those on n^- GaN and we attribute this excessive leakage to epi-layer defects. On the other hand, the subthreshold slopes are quite similar. Fig. 4 shows the output I-V characteristics of linear GaN MOSFETs with channel length of 2 μm and channel width of 20 μm. Short channel effects, such as non-saturating drain current and saturating transconductance, can be seen for both p and n^- GaN epilayer MOSFETs. The maximum measured transconductance is up to 30 mS/mm for MOSFETs on n^- GaN and 20 mS/mm for those on p GaN. It is worth pointing out that all of these short channel effects resemble strongly those observed for Si MOSFETs on bulk and SOI substrates with similar channel lengths but at 5X higher lateral channel electric field.

In summary, we have compared the performance of lateral GaN MOSFETs with linear and circular geometries and studied their short channel behaviors and found that they are similar to those previously reported for Si MOSFETs.

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1. W. Huang, T. Khan, and T.P. Chow, *International Conf. Silicon Carbide and Related Materials*, 2005.
2. W. Huang, T. Khan, and T. P. Chow, to be presented, *International Symposium on Power Semiconductor Devices and Power ICs*, June 2006.

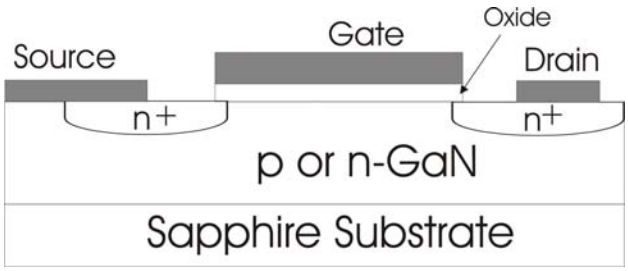


Fig. 1 A schematic cross-sectional view of ion-implanted n-channel GaN MOSFET

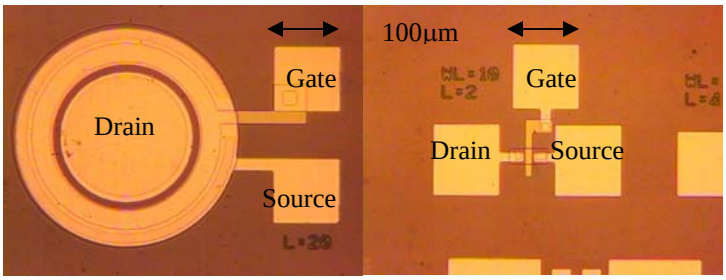
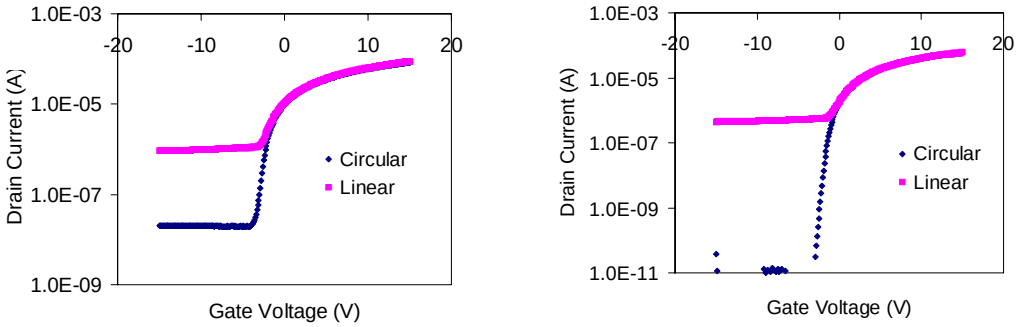
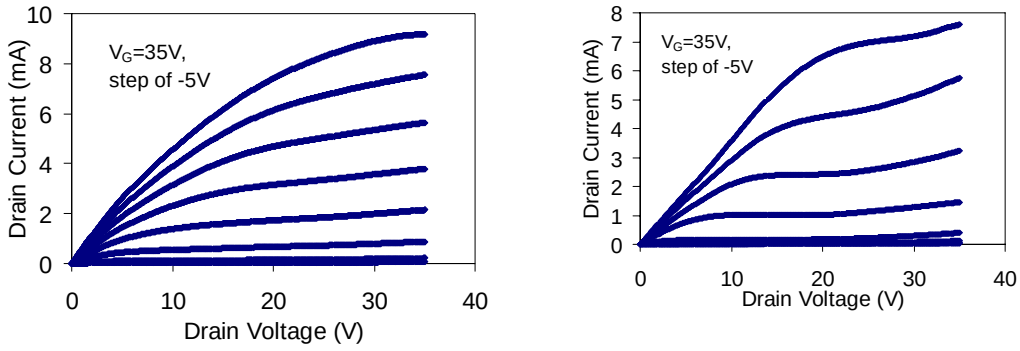


Fig. 2 Photographs of circular and linear MOSFETs



a) p GaN/Sapphire substrate b) n⁻ GaN/Sapphire substrate

Fig. 3 Transfer I-V characteristics of linear GaN MOSFETs with channel length 80 μm and channel width 800 μm



a) p GaN/Sapphire substrate b) n⁻ GaN/Sapphire substrate

Fig. 4 Drain I-V characteristics of linear GaN MOSFETs with channel length 2 μm and channel width 20 μm