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Comparison of AlGaN/GaN High Electron Mobility Transistors grown by MOVPE on 3C-SiC/Si(111), Si(111) and 6H-SiC for RF applications

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In spite of their outstanding performances for microwave power applications, transistors based on GaN-on-SiC [1] suffer from the lower availability and higher cost of the substrate compared to Silicon ones permitting also to get GaN devices interesting high frequency performances [2]. However, difficulties remain to grow high crystal quality and crack-free RF compatible GaN based epilayers on Silicon. More, the growth parameters of the AlN nucleation layer of High Electron Mobility Transistor (HEMT) structures strongly influence the propagation losses due to the risk of diffusion of Al and/or Ga into the Si substrate [3-4]. It has been reported that the use of 3C-SiC intermediate layer as a template for the growth of AlGaN/GaN HEMT heterostructures on Si substrate limits the risks of cracks generation, enhances the crystal quality of the GaN film [5] and limits the degradation of Silicon substrate resistivity permitting to preserve low RF propagation losses [6]. RF performances were reported on MOCVD grown AlGaN/GaN HEMTs using an ultrathin 3C-SiC intermediate layer. A current gain cutoff frequency (f_T) of 176 GHz and a maximum oscillation frequency (f_{max}) of 70 GHz were obtained on a 80 nm-rectangular gate length device [7]. But the thickening of the 3C-SiC intermediate layer seems suitable to improve the thermal dissipation, crystal quality, RF propagation losses and device performance. In this work, GaN epilayers were grown by MOVPE on a 0.8 μm thick 3C-SiC layer on Si(111) substrate having 5 k $\Omega\cdot\text{cm}$ resistivity, and they were compared to ones grown directly on Silicon and 6H-SiC substrates. On 3C-SiC/Si, the HEMT structure exhibits a two-dimensional electron gas with a mobility higher to 2000 $\text{cm}^2/\text{V}\cdot\text{s}$ and a sheet resistance of 392 Ω . Low RF losses of 0.4 dB/mm are obtained at 40 GHz as a result of a highly resistive interface with Silicon. More, short gate transistors were fabricated using e-beam lithography. In spite of ohmic contact resistance of 0.6 $\Omega\cdot\text{mm}$, a saturated current density of 0.7 A/mm is reached at a gate bias of +1V with a transconductance peak superior to 250 mS/mm for 75 nm T-shaped gate transistors. For the first time, a device with transition frequencies f_T/f_{max} of 60/98 GHz on such thick 3C-SiC template is reported, only 10 GHz behind the device we fabricated on bulk 6H-SiC, showing the capability of this new cost effective route for high frequency power applications.

References

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Supplementary information

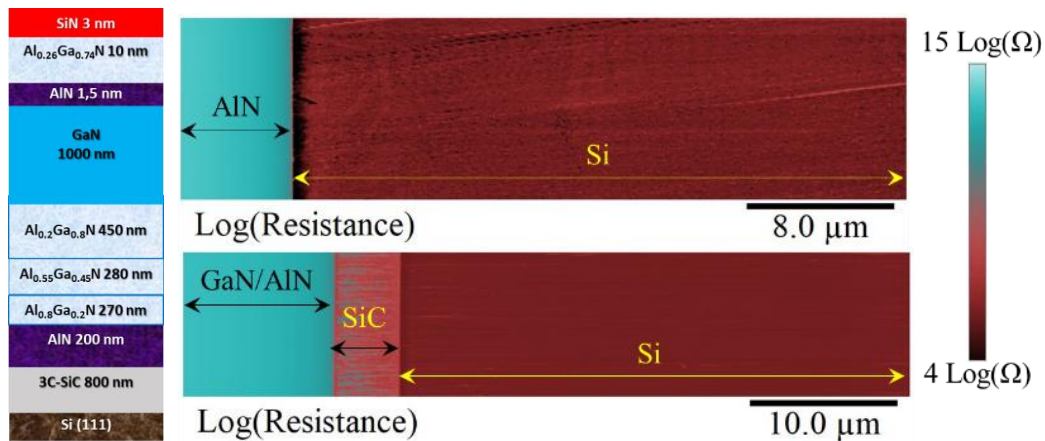


Figure 1: (left) Cross section picture of the HEMT structure grown on 3C-SiC/Si; (right) Top: scanning spreading resistance microscopy (SSRM) showing the resistivity drop at AlN/Si interface. Bottom: absence of resistivity drop at AlN/3C-SiC and 3C-SiC/Si interfaces.

Grown structure	Substrate resistivity [ohm.cm]	Losses at 40 GHz [dB/mm]
GaN on Si(111)	> 5000	1.2
GaN on 3C-SiC/Si(111)	> 5000	0.38
HEMT on 3C-SiC/Si(111)	> 5000	0.41
HEMT on 6H-SiC	semi-insulating	0.25

Table 1. Propagation losses at 40 GHz in the epi-layers grown on Si(111), 3C-SiC/Si templates and 6H-SiC substrate.

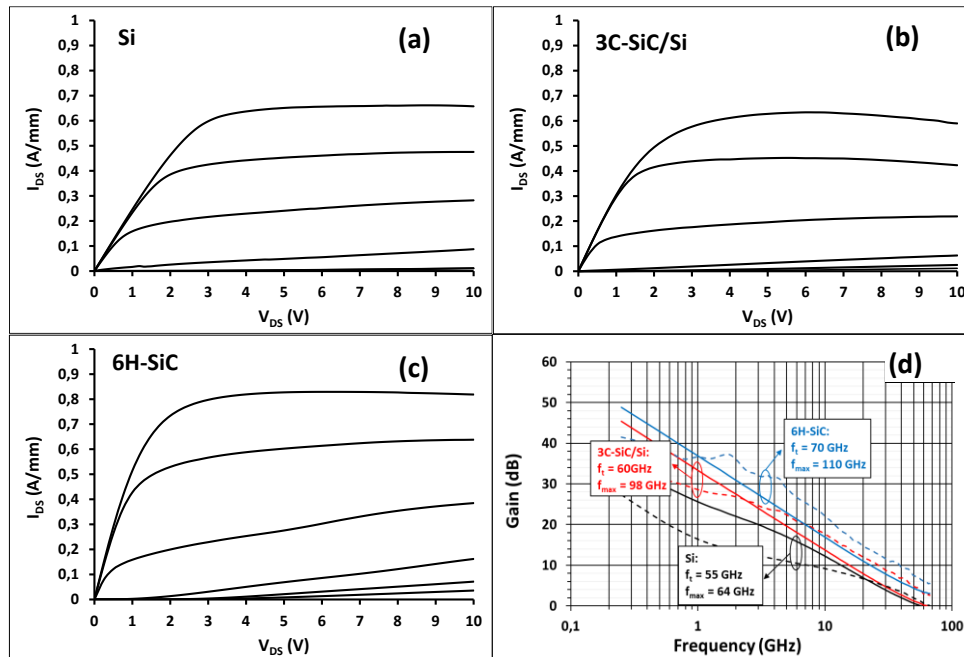


Figure 2: DC output characteristics of a 2 x 50 μm x 0,075 μm gate transistor fabricated on the AlGaN/GaN HEMT heterostructure grown on (a) Si(111), (b) 3C-SiC/Si(111) and (c) 6H-SiC (V_{GS}=0V to -5V, V_{GS} steps = -1V). (d) comparison of gains measured on the transistors.