Technology and performance of AlGaN/GaN HEMTs fabricated on 2-inch epitaxy for microwave power applications

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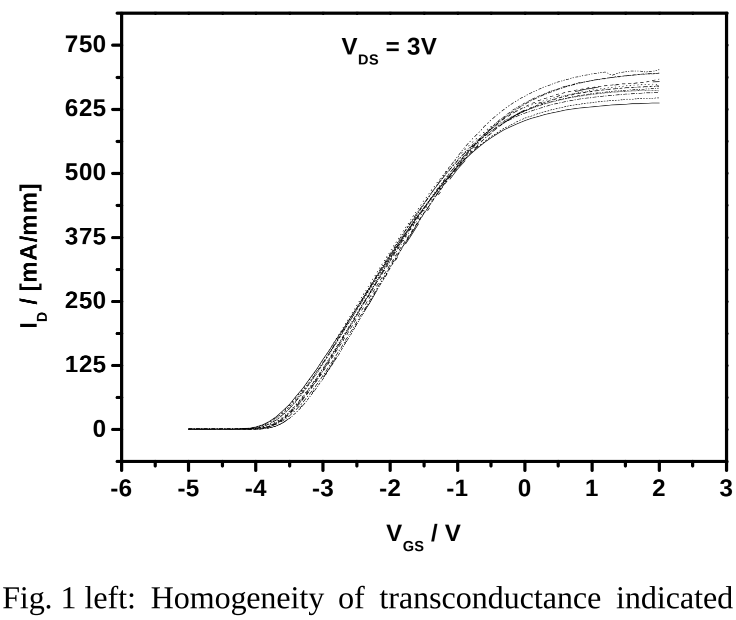
We report on the technology as well as current voltage characterisation, radio frequency small signal and microwave power performance of AlGaN/GaN based high electron mobility transistors.

The $Al_{0.25}Ga_{0.75}N$ /GaN HFET structures were grown by MOCVD on sapphire 2”-wafers. The layer design is as follows: 2.7µm GaN buffer layer, 50nm Si-doped GaN channel layer, 3nm $Al_{0.25}Ga_{0.75}N$ spacer, 15nm Si-doped $Al_{0.25}Ga_{0.75}N$ supply layer, 10nm $Al_{0.25}Ga_{0.75}N$ barrier layer and a 2nm thick GaN cap layer. Alternatively, channel doping was omitted on some samples.

Device fabrication was accomplished using 0.5µm stepper lithography from a Nikon NSR-2005i10C stepper on 2-inch wafers. The process consists of 6 masks to allow the manufacture of air bridges that are required for the fabrication of Power-HEMTs.

Source and drain ohmic contacts use a metallization consisting of Ti/Al/Ti/Au/WSiN (10/50/25/30/120 nm) with improved edge and surface morphology. Due to the properties of the WSiN sputter deposition process the Ti/Al/Ti/Au-layers, which are deposited by e-beam evaporation, are totally embedded. While standard ohmic source and drain contacts without WSiN are very rough after rapid thermal annealing at 850°C, both the surface and the contours of the metallization employed here were still smooth and well defined after



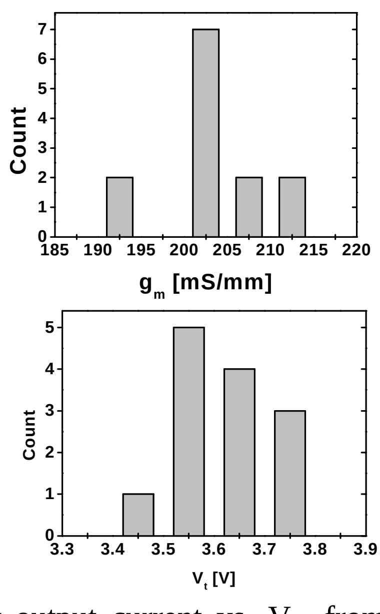


Fig. 1 left: Homogeneity of transconductance indicated by output current vs. V_{gs} from test-HEMTs distributed over the 2-inch wafer. Right: Histogram of maximum trans-conductance and pinch off voltage calculated from the figures on the left.

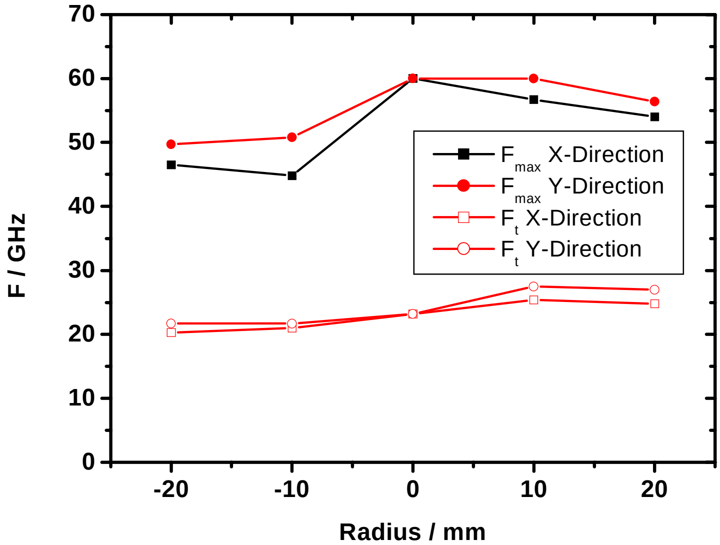


Fig. 2: Radial distribution of Ft and Fmax on a 2-inch wafer.

annealing. The contact resistance was determined to be 0.6 Ωmm by TLM measurements. We found the ohmic contact covered by WSiN to be stable in electrical performance and morphology for temperatures of 400°C up to 120 hours [1,2].

The electrical isolation of the devices is performed by mesa-etching with a RIE chlorine process. Gate contacts are made from a Pt/Au metallization and a gate length of 0.5µm is used at this stage. Electrolytic gold air bridges (3.5 µm thick) connect the transistor fingers to form microwave power cells.

Test devices are distributed equally over the 2-inch wafer. They indicate the quality and homogeneity of epitaxy and device processing. The transconductance of 2-finger HEMTs from the different stepper exposure fields are shown in figure 1. It is clearly seen that the pinch-off and transconductance vary by a small amount, only. The standard deviations from the figures of the HEMTs in fig.1 are calculated to be 2.4% for the pinch-off voltage and 2.8% for saturation current. The average maximum transconductance is 203 mS/mm at –2.5V and in the range of Vgs =–2.0 to –3.0 Volts the transconductance varies by only ±2.5% .

From small signal RF measurements the current gain cut off frequency F_t and the maximum frequency of oscillation Fmax were determined also to check the homogeneity and uniformity of the wafers. For DC values V_{ds} = 9Volts and V_{gs} = -2.5V the cut off frequency ranges from 21 to 27 GHz, depending on position. For the same DC parameters the fmax values range from 45 to 56 GHz. The distribution for the cut off frequency f_t over the wafer area is presented in fig.2. A systematic shift of frequency ft is observed over the wafer and a similar shift for f_{max} is observed in the same areas.

S-parameters of the microwave power transistors were measured up to 50 GHz. From the measurements the circuit elements of the HFET equivalent model are extracted. On wafer load pull measurements at 2 GHz are performed and will be presented.

References:
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