Gallium Nitride High Electron Mobility Transistors on Native Substrates

Fabrication, Characterization and Modelling

<u>Abstract:</u>

The advantages of GaN HEMTs grown on native GaN over GaN/Si or GaN/Sapphire substrates are investigated and correlated with epitaxial material quality. TEM plan-view and cross sectional analyses of GaN/GaN reveal dislocation densities below 1×10^{6} cm^{-2}, which is at least 3 orders of magnitude lower than that of GaN/Si or GaN/Sapphire. In the case of GaN/Si, the dislocations do not only originate from the substrate/nucleation layer interface, but also the strain relief and isolation buffer stacks are main contributors to the dislocation density. GaN/GaN HEMTs show superior electrical and thermal performance and feature 3 orders of magnitude lower off-state leakage. The current collapse (also referred to as current dispersion or Ron- increase) after stress bias is less than 15 % compared to 50 % in the case of GaN/Si. In addition, GaN/GaN HEMTs show only a 2 % drop of the on-state current due to self-heating in DC operation compared to 13 % and 16 % for GaN/Si and GaN/Sapphire, respectively. The GaN/Si thermal performance becomes comparable to that of GaN/GaN only after substrate removal. Therefore, GaN/GaN provides high on-state current, low off-state leakage current, minimal current collapse, and enhanced thermal power dissipation capability at the same time, which can directly be correlated to the absence of the high dislocation density. The hardware results are complemented with simulation results based on a compact, physics-based GaN HEMT model which is implemented in Verilog-A format.

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