# DC Characteristics of AlGaN/GaN Heterostructure Field-Effect Transistors on Free-Standing GaN Substrates

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There has been dramatic progress in recent years in development of AlGaN/GaN heterostructure field effect transistors (HFETs) for applications such as microwave power amplifiers and wireless communication systems. Most of the HFETs reported to data have been grown on sapphire or less commonly on SiC substrates. The higher thermal conductivity and improved lattice match of the SiC substrates lead to lower leakage current and fewer problems with device self-heating. Only a few reports have appeared on the characteristics of HFETs grown on bulk GaN substrates. These devices exhibited better transconductance and lower gate leakage relative to heteroepitaxial devices. In this work, we report on the dc characteristics of AlGaN/GaN HFETs fabricated on free-standing GaN templates.

The free-standing GaN substrates were ~200 µm thick and were grown by high-rate vapor phase epitaxy on c-plane sapphire substrates and removed by differential heating from a laser beam.

AlGaN/GaN HFETs were grown by metal organic chemical vapor deposition on either sapphire or free-standing GaN substrates. Figure 1 and 2 show the drain-source current ($I_{DS}$) of a function of drain-source voltage ($V_{DS}$) for both the GaN substrate HFETs (Fig.1) and those grown on sapphire (Fig. 2), respectively. The homoepitaxial HFETs show a slight lower knee voltage than the heteroepitaxial devices. When pushed to higher drain-source voltages, the GaN substrate HFETs showed less negative slope in the current-voltage characteristics as shown in Figure 3. The thermal conductivity of GaN is ~1.5 $W \cdot mm^{-1}$ compared to 0.5 $W \cdot mm^{-1}$ for sapphire. The GaN substrate HFETs show higher transconductance and a much lower degree of current collapse due to surface states on the gate-drain region than do HFETs grown on sapphire. The reduced current collapse shows that at least some of the surface states in conventional heteroepitaxial HFETs on sapphire must be associated with the higher dislocation density in this material. The results are consistent with the improved performance of GaN-based photonic devices when grown on bulk GaN.

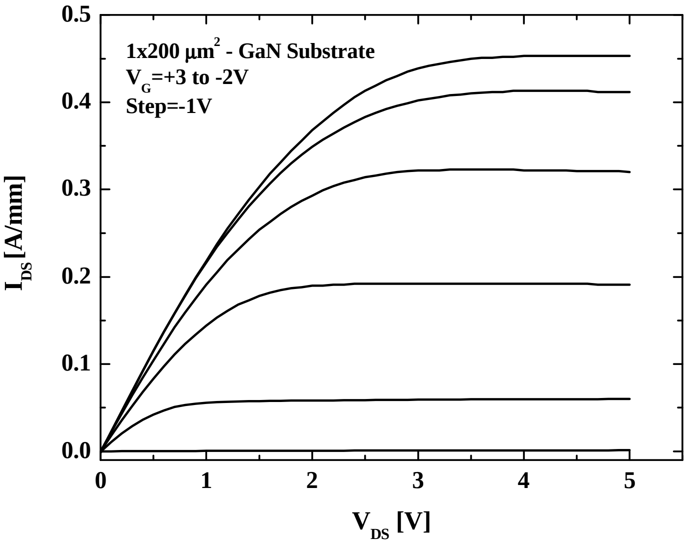

Figure 1. $I_{DS}$-$V_{DS}$ characteristics for 1x200µm$^2$ HEMTs grown on GaN substrate.

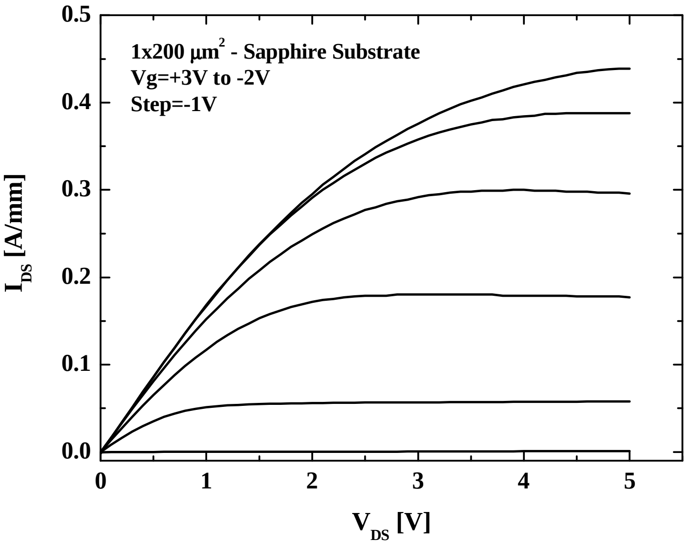

Figure 2. $I_{DS}$-$V_{DS}$ characteristics for 1x200µm$^2$ HEMTs grown on Sapphire substrate.

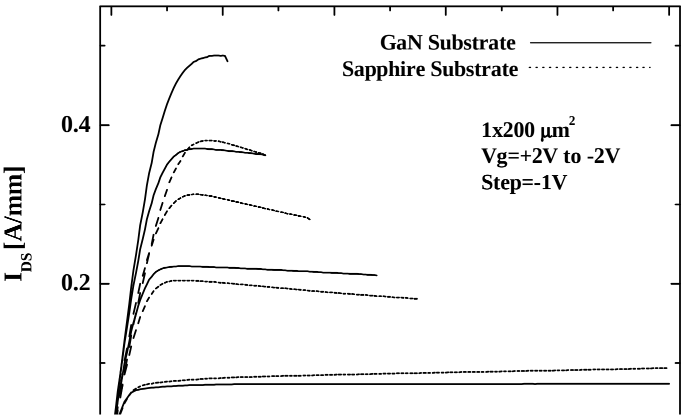

Figure 3. $I_{DS}$-$V_{DS}$ characteristics for high bias conditions, showing less self-heating for HFETs grown on GaN substrates.