# Trapping and Thermal Effects in III-N HEMTs

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GaN-based materials are prime candidates for high-power devices in microwave communications and radar applications. Record setting high-power, high-frequency and low-noise operations have been demonstrated for AlGaN/GaN high-electron mobility transistors (HEMTs) [1-3]. However, the power performance of these devices has been limited by trapping effects, caused by crystal imperfections, and thermal effects, due to self-heating of the device [4-7]. Accurate modeling and measurement of these effects are essential for optimization of device structure and thermal management in high-power nitride HEMTs. Measurements of the DC-IV curves as well as pulsed measurements generally reflect both of these effects. Figure 1 shows an example of these measurements on an unpassivated AlGaN/GaN HEMT grown on a sapphire substrate. Both current dispersion due to trapping effects and self-heating effects are evident in this data. As illustrated in Figure 2, the self-heating is caused by insufficient heat removal from the two-dimensional electron gas (2DEG) at high source-drain currents, while the trapping effect resulting from defects in the structure. These defects can be in the substrate, GaN buffer, AlGaN barrier, any of the interfaces, and/or on the top surface

In this work, we have used a novel method, which allows the separation of the self-heating and trapping effects, and thus permits evaluation of the influence of each effect on the HEMT performance. Using this method, we have determined the thermal and gate-lag time-constants in transient drain current. We have also extracted channel temperature versus dissipated power for HEMTs grown on sapphire and SiC substrates, as shown in Figure 3. We will discuss these results and other issues related to self-heating and trapping effects in these devices including surface passivation, thermal impedance, and walkout in gate-drain breakdown voltage.

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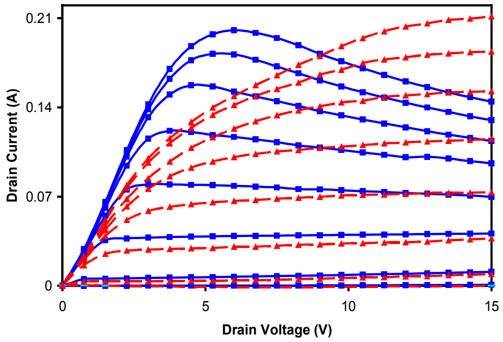

**Figure 1.** DC (■$V_{gs}$= *-6V, -5V, … , 1V*, bottom up) and 1µs after pulse (▲) drain IV characteristics. Conditions: $V_{gs}$ is pulsed from -10V to $V_{gs}$= *-6V, -5V, … , 1V*, bottom up. $V_{ds}$ sweeps with no pulsing ($V_{dson}$=$V_{dsoff}$).

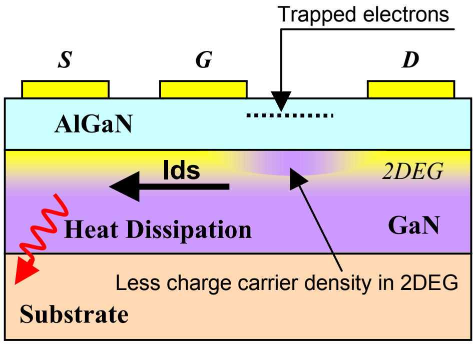

**Figure 2.** Nitrde HEMT structure showing trapping process of electrons that reduces 2 DEG density and self heating as a results of power dissipation in 2DEG.

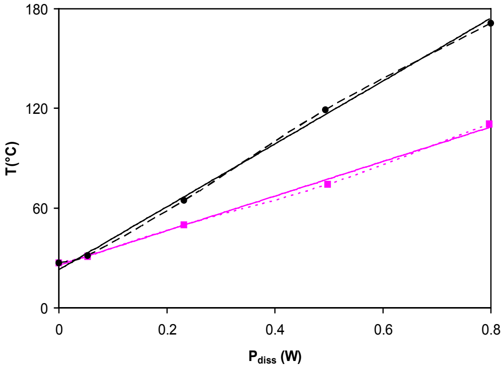

**Figure 3.** Channel temperature versus dissipated power of AlGaN/GaN HEMT devices on (●) sapphire and (■) SiC substrates. Extracted thermal resistances are 189°C/W and 104°C/W for HEMTs on sapphire and SiC, respectively.

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