Millimeter-Wave Large Signal Performance of AlN/GaN/AlN HEMTs

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Primary CNF Tools Used: AFM, i-line stepper, PT770 etcher, Oxford 81 etcher, CVC SC4500 odd-hour evaporator, JEOL 6300 EBL, Oxford PECVD, AJA sputter deposition, Woollam ellipsometer, Zeiss Ultra SEM, Leica critical point dryer, Glen1000 resist stripper, P7 profilometer

Abstract:

Gallium nitride high-electron-mobility transistors (GaN HEMTs) are ideal for high-power, gigahertz (GHz) frequency applications due to their wide bandgap and high electron saturation velocity. To further improve upon established GaN HEMTs, our group has introduced GaN HEMTs based on the aluminum nitride (AlN) platform using anAlN/GaN/AlN double heterostructure. In this report, we show the first large signal measurements forAlN/GaN/AlN HEMTs at millimeter wave frequencies (30+ GHz).

Summary of Research:

HEMTs were fabricated on the AlN/GaN/AlN heterostructure. The processing is highlighted by JEOL 6300 electron-beam lithography achieving T-gates with gate lengths as short as 60 nm. The AlN/GaN/AlN HEMTs showed on-currents over 3 A/mm and transconductance of over 0.7 S/mm. Small-signal characteristics for this device demonstrated a cutoff frequency (f_t) and maximum oscillation frequency (f_{max}) of 124 and 221 GHz, respectively. The HEMT was measured for large signal power sweep measurements at 30 and 94 GHz. At peak PAE, it showed associated output powers of 2.2 and 1.7 W/mm and gain of 7.1 and 3.1 dB, respectively. At peak output power, the HEMT demonstrated 2.6 and 2.2 W/mm at 30 and 94 GHz, respectively.

These numbers represent the record for HEMT on the AlN platform.

Conclusions and Future Steps:

The HEMTs in this report were limited by degradation in on-current and increased gate leakage during large signal measurement. This is likely caused by the lack of a surface pretreatment before the SiN passivation, leading to excessive surface states. An additional factor could be the thicker GaN channel, which increases the stress in top barrier, leading to degradation when further stressed at high biases. Therefore, the next generation ofAlN/GaN/AlN HEMTs will feature a 30 nm GaN channel to reduce stress in the barrier, and an *in situ* cleaning step to minimize surface states before SiN deposition.

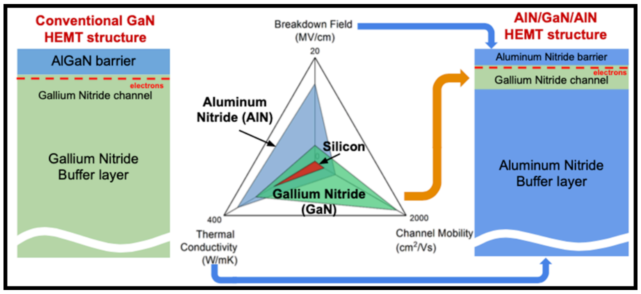

Figure 1: The cross-section of a conventional AlGaN/GaN heterostructure (left) and our group's AlN/GaN/AlN heterostructure (right). As highlighted by the radar plot (center), the AlN/GaN/AlN heterostructure takes full advantage of what both GaN and AlN have to offer.

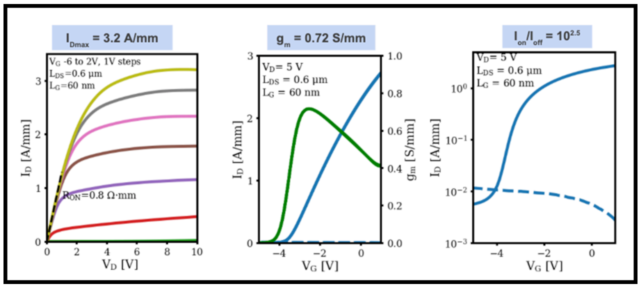

Figure 2: (left) Output characteristics of an AlN/GaN/AlN HEMT showing on-currents over 3 A/mm with high output resistance. (center) The transfer characteristics highlighted by a transconductance of 0.72 S/mm. (right) Log-scale transfer curves with an on/off ratio of $10^{2.5.}$

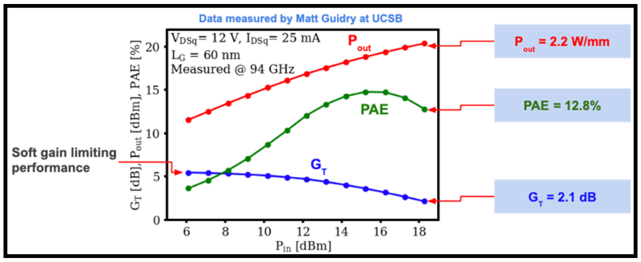

Figure 3: The load-pull power sweep of anAlN/GaN/AlN HEMT at 94 GHz. The result is highlighted by a measured output power of 2.2 W/mm.