T-Gated AlN/GaN/AlN HEMTs with I_D > 3 A/mm, f_{max} = 230 GHz

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

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Abstract:

In this work, we report record on-current and f_t/f_{max} product for the AlN/GaN/AlN HEMT. The devices demonstrated record on-currents over 3 A/mm with an on-resistance of 1 Ω·mm and excellent saturation. Transfer characteristics revealed I_{on}/I_{off} ratio of 10^3 and peak transconductance of 0.6 S/mm. Bias-dependent S-parameters were measured in the range of 0.05-40 GHz. The extracted f_t/f_{max} = 132/233 GHz (L_G = 45 nm) is the highest f_t/f_{max} product reported on the AlN platform.

Summary of Research:

Next-generation (6G) wireless communication and high-resolution radar systems target high-power operation in the terahertz regime. Gallium nitride high-electron-mobility transistors (GaN HEMTs) are well-suited for this high-power, high-frequency application. However, the conventional AlGaN/GaN heterostructure provides poor quantum confinement of the two-dimensional electron gas (2DEG), generating short channel effects at high frequencies. Additionally, its RF power performance is limited by the breakdown voltage. The AlN/GaN/AlN heterostructure offers material and device design advantages over the conventional AlGaN/GaN HEMT: the AlN buffer tightly confines the 2DEG and offers a higher thermal conductivity path than a thick GaN buffer, and the AlN barrier induces higher density 2DEGs at thinner distances (5 nm). AlN also maximizes the barrier bandgap, improving breakdown voltage.

Recently, fully realized T-gated AlN/GaN/AlN HEMTs were fabricated and characterized. The T-gates were defined via electron-beam lithography using a trilayer resist stack, and Ni/Au (50/200 nm) gate metal was deposited via e-beam evaporation. The resulting structure is shown in Figure 1.

The devices demonstrated record on-currents over 3 A/mm with an on-resistance of 1 Ω·mm and excellent saturation. Transfer characteristics revealed I_{on}/I_{off} ratio of 10^3 and peak transconductance of 0.7 S/mm. All DC characteristics are shown in Figure 2.

Bias-dependent S-parameters were then measured in the range of 0.05-40 GHz. The system was de-embedded via a short-open-load-through (SOLT) impedance standard substrate and on-wafer open/short structures. The device measured for dispersion also demonstrated f_t = 123 GHz, f_{max} = 233 GHz, as shown in Figure 3. This is the highest f_{max} reported for devices on the AlN/GaN/AlN heterostructure, and can be attributed to the incorporation of the T-gate geometry.

This excellent combination of on-current and f_{max} demonstrates the exciting potential for HEMTs on the AlN platform to enable the next generation of high-power, mm-wave communication.

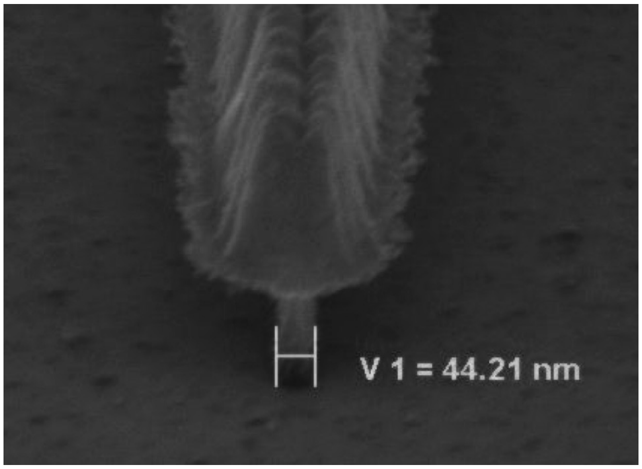
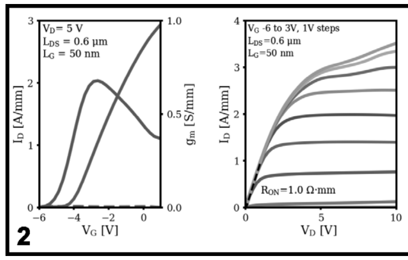


Figure 1: T-gate demonstrating a gate length of 44 nm.



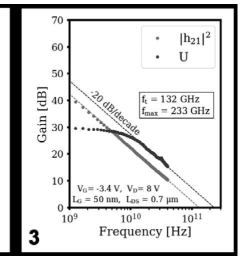


Figure 2, left: *DC characteristics for AlN/GaN/AlN HEMT.* ***Figure 3, right:*** *Small signal characteristics for the T-gated AlN/GaN/AlN HEMT.*