

SiN Passivated AlScN-Barrier HEMTs Demonstrating Negligible Current Dispersion

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Principal Investigator(s): Huili Grace Xing

User(s): Hanqiao Zhang

Affiliation(s): School of Electrical and Computer Engineering, Department of Materials Science and Engineering

Contact: grace.xing@cornell.edu, hz587@cornell.edu

Primary CNF Tools Used: PECVD, PT770, GaN LPCVD, e-beam evaporator, JEOL-6300, MLA150

Abstract:

Aluminum scandium nitride (AlScN) has emerged as a promising barrier and dielectric material for gallium nitride (GaN) high-electron-mobility transistors (HEMTs) due to its large spontaneous polarization, high dielectric constant, and the strain balance with GaN [1]. In addition, the high- k nature of AlScN allows thicker effective barrier layers that reduce gate leakage without sacrificing gate capacitance, providing a pathway toward simultaneous improvements in breakdown voltage and radio-frequency (RF) performance. In AlScN/GaN heterostructures, high drain current and speed have been demonstrated [1], [2]. In this work, we report significant suppression of current dispersion in AlScN HEMTs through low-pressure chemical-vapor-deposition (LPCVD) silicon nitride (SiN) passivation, an essential step towards building the next generation AlScN based RF electronics.

Summary of Research:

The AlScN/GaN heterostructure in this work was grown by plasma-assisted molecular beam epitaxy (MBE). As shown in Fig. 1, it consists of a GaN/Al_{0.84}Sc_{0.16}N/GaN/AlN top barrier on 830-nm GaN with AlN buffer grown on a semi-insulating 4H-SiC substrate. The energy band diagram of the full heterostructure is shown. Device fabrication started with definition of the source/drain regions using a SiO₂/Cr hard mask. After ICP etching through the barrier into the UID GaN using the hard mask, n+ GaN regrowth by MBE was performed. After removal

of masked regions, mesa isolation was performed, and ~ 74 -nm of near stoichiometric Si₃N₄ was deposited using LPCVD. A non-alloyed Ti/Au source/drain metal stacks were deposited through e-beam evaporation. Lastly, a gate-recess etch was performed via low-power timed SF₆ ICP etch, and gates were metallized by e-beam evaporation of Ni/Au = 40/350 nm. Following the MBE growth, Hall-effect measurements were performed at room temperature using soldered indium contacts to the 2-dimensional electron gas. The measurement reveals an electron mobility of 1180 cm²/V·s, 2DEG sheet density $n_s \sim 2.38 \times 10^{13}$ /cm², and $R_{sh} = 337 \Omega/\text{sq}$. DC transfer measurements were performed on a device with $L_G = 1 \mu\text{m}$ and $L_{SD} = 5 \mu\text{m}$. As shown in Fig. 2, at a fixed $V_{DS} = 5 \text{ V}$, a peak extrinsic transconductance of 0.42 S/mm was measured. The device exhibited negligible hysteresis and an extrapolated threshold voltage of -3.0 V. An on/off ratio of greater than 10^5 was measured, revealing excellent gate control. Fig. 3 shows the three-terminal off-state breakdown characteristics of the devices with varying L_{GD} . The breakdown was limited by gate-leakage current, far from the intrinsic material limits [2]. Fig. 4 reveals the three-terminal output characteristics of the device. A peak drain current of 1.7 A/mm was measured at $V_{GS} = 2 \text{ V}$. Pulsed I-V measurements were performed on the HEMT device with LPCVD SiN passivation using 500 ns long pulses with a 1 ms period. The sample exhibited negligible current collapse of less than 5% under bias conditions of $V_{GS,q} = -5 \text{ V}$, $V_{DS,q} = 0 \text{ V}$, and $V_{GS,q} = -5 \text{ V}$, $V_{DS,q} = 40 \text{ V}$.

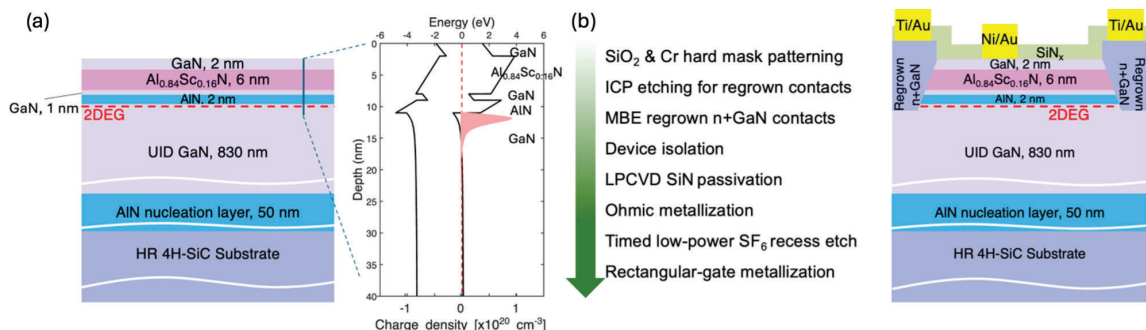


Figure 1: (a) cross-sectional representation of the GaN/Al_{0.84}Sc_{0.16}N/GaN/AlN heterostructure on SiC substrate and the energy band diagram evaluated by self-consistently solving Schrodinger and Poisson equations. (b) device process flow of AlScN/GaN HEMTs.

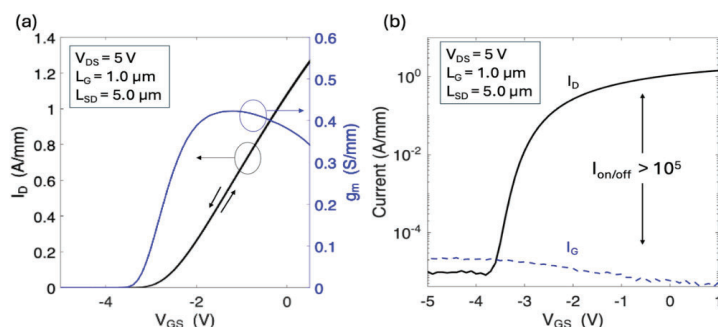


Figure 2: (a) Transfer characteristics of a HEMT device in linear scale, and peak extrinsic transconductance of 0.42 S/mm. (b) Transfer curve in semi-log scale with gate leakage current shown in dotted blue line, demonstrating an on/off ratio greater than 10^5 .

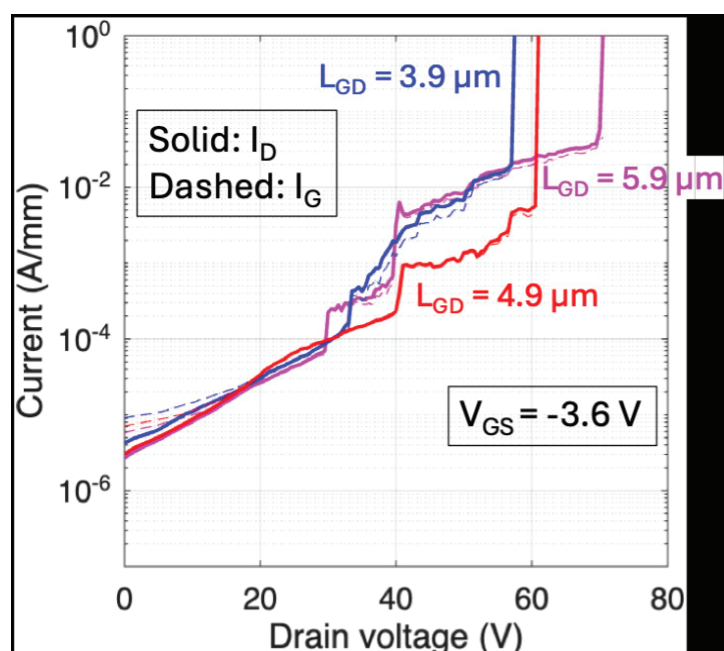


Figure 3: The three terminal off-state breakdown measurements with different gate-drain distance.

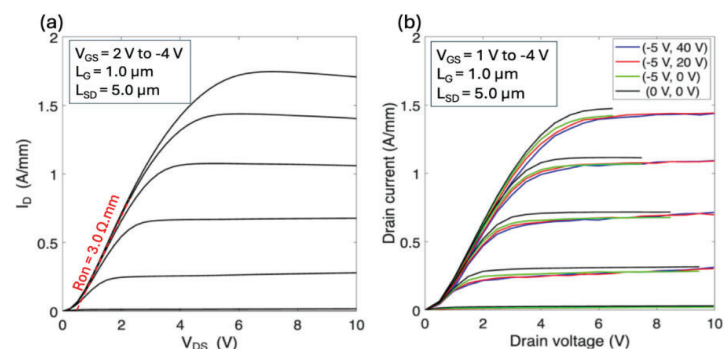


Figure 4: (a) I - V output characteristics of the HEMT device demonstrating a maximum drain current density of 1.7 A/mm. (b) pulsed output measurements of a HEMT device with LPCVD SiN surface passivation demonstrating negligible current dispersion.

Conclusions and Future Steps:

The fabricated AlScN/GaN HEMT is well-suited for RF amplifications due to effectively suppressing current dispersion through LPCVD SiN deposition.

References:

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