First Demonstration of AlBN/GaN High Electron Mobility Transistors

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Primary CNF Tools Used: Autostep i-line Stepper (GCA AS200), Heidelberg Mask Writer DWL2000, P7 Profilometer, FilMetrics, AFM Veeco Icon, Zeiss SEM, PT770, Oxford81, Oxford PECVD, Oxford ALD, SC4500 Evaporators, AJA Sputter Deposition tools, RTA AG610, JEOL 9500

Abstract:

Epitaxial aluminum boron nitride (AlBN) is a potential barrier material for gallium nitride (GaN) high electron mobility transistors (HEMTs) due to large energy bandgap high-κ dielectric properties [1,2]. This work reports the first demonstration of AlBN/GaN HEMTs.

Summary of Research:

A 2 nm GaN passivation layer / 2 nm AlBN high-κ barrier / 600 nm GaN channel / 125 nm AlN buffer structure was grown on a 6H silicon carbide substrate using plasma-assisted molecular beam epitaxy (PA-MBE) (Figure 1(a)). Hall-effect measurements at room temperature revealed a two-dimensional gas (2DEG) sheet concentration of 9.25×10^{12} /cm^2, electron mobility of 524 cm^2/V·s, and sheet resistance of 1290 Ω/sq.

First, BCl_3 inductively coupled plasma (ICP) etching was performed for device isolation, followed by ohmic metallization. A Ta/Al/Ni/Au (20/150/50/50 nm) metal stack was deposited using an electron-beam evaporator (SC4500) and alloyed in N_2 ambient using a rapid thermal annealing system (RTA AG610). The resulting contact resistance was ~ 2 Ω·mm. A gate metal stack of Ni/Au (30/220 nm) was deposited directly on the sample surface using SC4500. Gate lengths were defined via photolithography (L_g = 1.3 μm) using an Autostep i-line stepper (GCA AS200).

Figure 1(b) shows the scanning electron microscope (SEM) image of the completed AlBN/GaN HEMT.

Figure 2 shows the 500 kHz *C-V* results of AlBN/GaN and AlN/GaN Schottky barrier diodes. The extracted dielectric constants of AlBN from on-wafer capacitance measurements at various frequencies exibit higher values than AlN.

Figure 3(a) shows the measured output characteristics of the AlBN/GaN HEMTs of 1.3 μm gate length, and 2.3 μm source-drain distance. The saturated on-current reaches 266 mA/mm, and repeatable current saturation, pinch-off, and similar performance is measured for several devices of similar size. Figure 3(b) shows the transfer characteristics of the Schottky-gated AlBN/GaN HEMTs, which exhibit an on/off ratio of > 10^3. Since this is limited by the gate leakage of the Schottky diode. Figure 3(b) also shows the threshold voltage of -0.5 V and the subthreshold slope of 150 mV/dec. Figure 3(c) shows a peak $gm_{,ext}$ of 139 mS/mm, all at room temperature. The promising first AlBN/GaN HEMT performance will be boosted by higher mobility in the future.

References:

[1] Chandrashekhar Savant, et al., 65th EMC, O10 (2023).
[2] J. Hayden, et al., Physical Review Materials, 5, 044412 (2021).

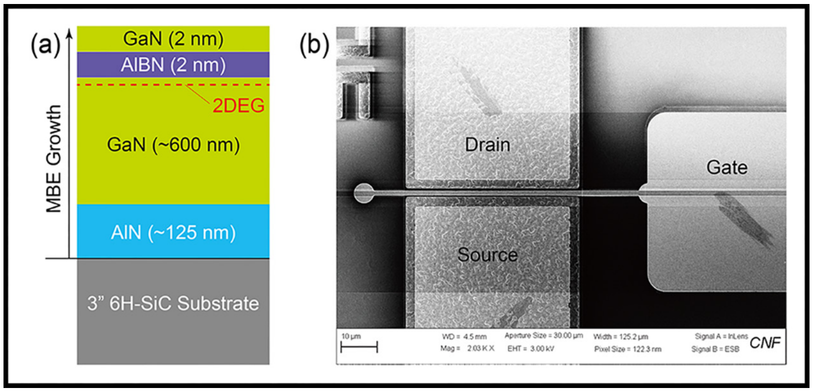

Figure 1: (a) Layer structure of the epitaxial film grown by MBE, dashed line indicating where a high-density 2D electron gas (2DEG) is present. (b) 70° angled-view SEM image of the fabricated AlBN/GaN HEMT with L_g *= 1.3 µm,* W_g *= 50 µm, and* L_{sd} *= 2.3 µm.*

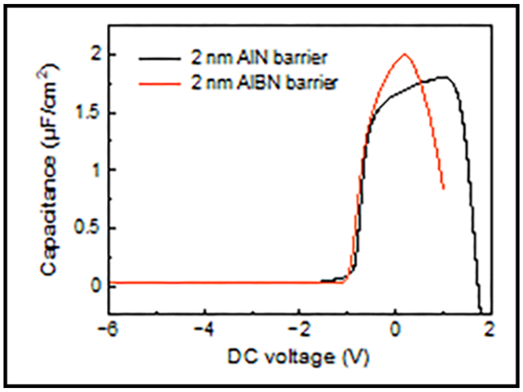

Figure 2: C-V *data at 500 kHz of AlBN and AlN showing higher dielectric constant of AlBN.*

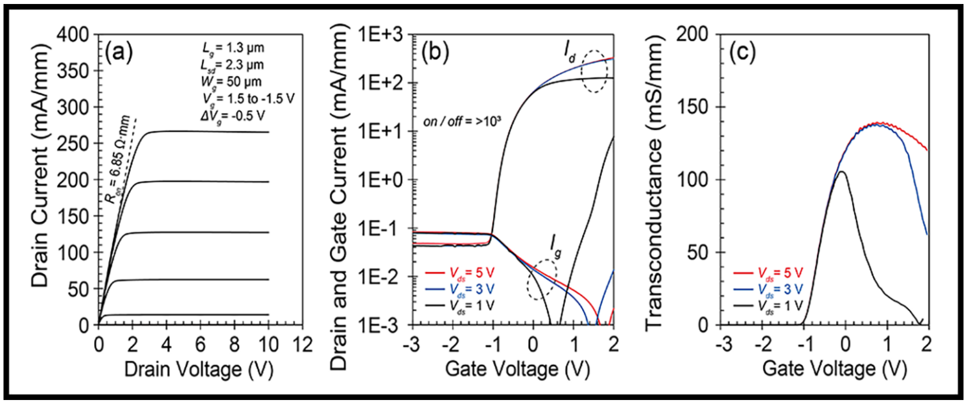

Figure 3: (a) Output I-V *curves show current saturation and an on-resistance of 6.85 Ω·mm at* V_g *= -1.5 V. (b) Log-scale transfer curves show more than three orders of* I_{on} / I_{off} *modulation, limited by Schottky gate leakage. (c) The linear-scale transfer curve shows normally-on operation and a peak* $gm_{,ext}$ *of 139 mS/mm at* V_d *= 5 V.*