First demonstration of N-polar high Al-content AlGaN channel HEMT grown by plasma-assisted molecular beam epitaxy

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Introduction

AlGaN channel HEMTs exhibit a tunable direct bandgap (3.4–6.1 eV), superior breakdown characteristics (>10 MV/cm), high electron mobility, and fast saturation velocity, making them strong candidates for next-generation electronic and optoelectronic systems [1-3]. Increasing the Al mole fraction in the channel further widens the bandgap and enhances the breakdown capability, which translates into improved voltage handling and a higher Johnson's figure of merit. Similar to GaN, N-polar AlGaN theoretically offers superior performance, particularly when it comes to ohmic contacts; for N-polar, the surface is the channel, rather than the barrier. Here we present the first N-polar high Al-content AlGaN HEMT grown by PAMBE. A 3nm GaN cap is grown in-situ to prevent the oxidation of the surface, while still allowing for an ohmic contact to the channel using molecular beam epitaxy (MBE) regrown contacts.

Experimental Procedures

Devices were mesa isolated using a BCl_3/Cl_2 dry etch. An Al_2O_3/SiO_2 hard mask was deposited and patterned to selectively grow heavily Si-doped reverse compositionally graded AlGaN to form ohmic contacts to the channel. The GaN cap over the gate was etched, and LPCVD SiN was deposited as a gate insulator. Ti/Al/Ni/Au source/drain contacts were deposited on the regrown AlGaN and annealed, and Ti/Au gates were deposited. Devices were measured at room temperature and up to 300°C. 5x5 mm pieces were co-loaded during growth, and Hall measurements were taken on these from room temperature to 500°C.

Results and Discussion

Temperature-dependent TLM and Hall measurements indicated a reduction in channel resistance with increasing temperature, attributed to enhanced carrier density and mobility. TLM measurements demonstrate ohmic behavior at all temperatures. The device presented has a peak drain current density of 0.12 mA/mm at room temperature and 0.8 mA/mm at 300 °C. Transconductance also increased from 53 µS/mm at room temperature to 262 µS/mm at 300 °C. The device recovers its performance completely after returning to room temperature from 300°C with no degradation in current. This work shows a framework for forming robust ohmic contacts to AlGaN channel devices.

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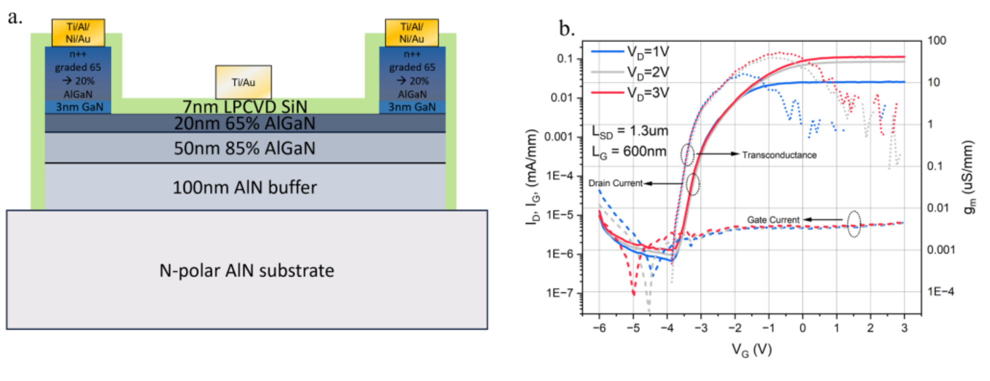

Figure 1: (a) Fabricated HEMT epi structure and (b) room temperature device performance

References

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