Hole Transport in GaN: Growth, Metrology, and Strain Engineering

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Introduction

P-type GaN has already revolutionized solid state lighting by enabling the blue LED. In the arena of electronics, perhaps the most important task bestowed upon p-type GaN is for it to be integrated with n-type GaN to enable monolithic GaN-based CMOS. Even with several successful demonstrations of GaN CMOS [1-5], a glaring flaw remains – severely imbalanced n-channel and p-channel device performances – due to a drastic mismatch between electron and hole mobilities. To address this bottleneck, we must turn our attention to fundamental questions – what is the maximum achievable hole mobility in the most pristine GaN crystal currently obtainable, and how can we further enhance it by leveraging new fundamental insights on the valence bands of GaN?

Experimental Procedures

GaN/AlN two-dimensional hole gas (2DHG) heterostructures were epitaxially grown by plasma-assisted molecular beam epitaxy (PA-MBE). Metal (Al, Ga, Mg) fluxes were provided by effusion cells containing high-purity elemental sources. Active nitrogen flux was provided by high-purity N_2 gas flowing at a rate of 0.3 sccm through an RF plasma source operating at a power of 400 W. The resulting heterostructure is 10 nm of pseudomorphically strain, unintentionally doped (UID) GaN on top of bulk AlN. An 8 nm Mg-doped $In_{0.08}Ga_{0.92}N$ [Mg~5e19 cm^{-3}] capping layer is grown on the top of the UID GaN to facilitate ohmic contact for electrical transport measurements.

Results and Discussion

We show that polarization-doping at a GaN/AlN interface induces enough holes to degenerately occupy the light hole (LH) and the heavy hole (HH) bands without thermal freeze-out. At 300 K, a LH-HH-averaged mobility of 32 cm^2/Vs is observed [1]. At 2 K, we can obtain band-resolved mobilities for the LHs and HHs, yielding mobilities of ~2000 cm^2/Vs and ~400 cm^2/Vs for the LHs and HHs, respectively. These record-high mobility values are a result of major advances in the past few years on nitride MBE. We also demonstrate the growth of this 2DHG on a 2-inch bulk AlN wafer, achieving a wafer-averaged sheet resistance of 3.9 kΩ/sq. We show characterization of the LH and HH bands by high magnetic field cyclotron resonance experiments [2], and we show Multiphysics simulations of strain-engineered transport in a 2DHG channel.

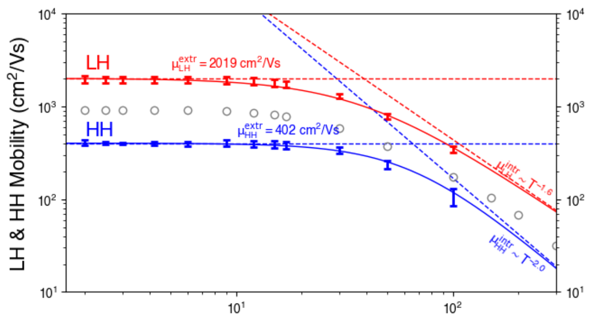

Figure 1. Band-resolved mobilities for the LHs (red) and HHs (blue), and LH-HH averaged mobility (hollow circles), as a function of temperature.

Acknowledgement

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References

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