Quantum Oscillations in GaN/AlN 2D Hole Gas and Extraction of Light Hole Effective Mass

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Gallium Nitride (GaN) has been a leading contender in commercial high-frequency and high-power applications due to its internal polarization field and a wide bandgap of 3.4 eV [1]. However, while n-channel high-electron mobility transistors (HEMT) based on GaN's polarization-induced two-dimensional electron gas (2DEG) progress towards higher performance, its p-type counterpart has been lagging due to the low mobility of the polarization-induced two-dimensional hole gas (2DHG), hindering the development of GaN-based CMOS and an extraction of hole effective mass by Shubnikov de-Haas (SdH) oscillations and cyclotron resonance. In the absence of reliable and uniform experimental data, researchers have had to rely on theoretical calculations [3].

In this talk, we report the first observation of SdH oscillations in any p-type GaN platform and subsequent extraction of hole effective mass. Here, a technique pioneered by Chaudhuri *et. al.* [2] is used to form a high-density (~5×10^{13} cm^{-2} at 300 K) 2DHG at the heterointerface between GaN and a AlN substrate via the large internal electric fields induced by spontaneous and piezoelectric polarization. Magnetoresistance measurements up to 63 T is performed at the National High Magnetic Field Laboratory Pulsed Field Facility, showing Shubnikov de-Haas (SdH) oscillations with an onset at around B=25 T (Fig. 1). Fig. 2a shows R_{xx} with a polynomial background subtracted plotted against B^{-1} and Fig. 2b shows its power spectrum. A strong peak is located at f =168 T in the power spectrum at all temperatures corresponding to a density of 8.2×10^{12} cm^{-2}. In lower magnetic fields (< 9T), $R_{xx}(B)$ and $R_{xy}(B)$ are fitted to a classical two-band model (Fig. 3), revealing the coexistence of two carrier populations – low-mobility (~230 cm^2/Vs) heavy holes with a density of 4.2×10^{13} cm^{-2} and high-mobility (~1400 cm^2/Vs) light holes with a density of 7×10^{12} cm^{-2} in agreement with the density extracted from SdH frequency. Attributing the oscillations to the light holes, we extract their effective mass from the temperature-dependence of the amplitudes, yielding a value of $0.48 \pm 0.02\ m_0$.

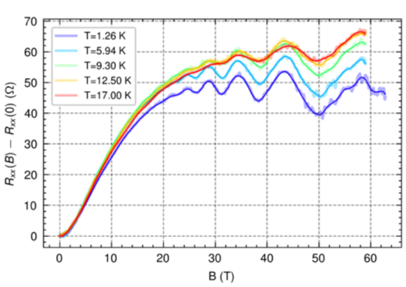

Fig 1. SdH oscillations in R_{xx}.

References
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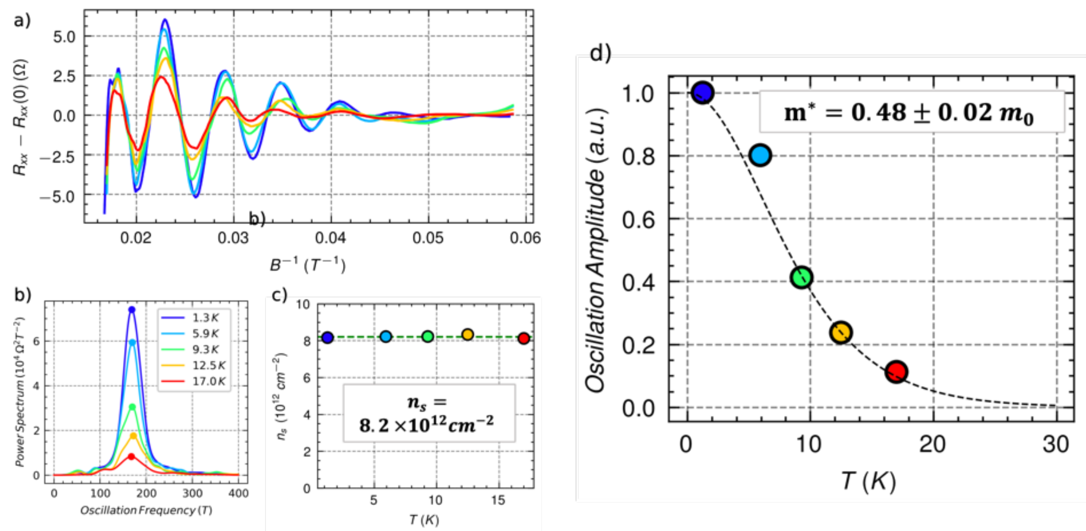

Fig 2. (a) R_{xx} vs B curves with polynomial background subtraction plotted against B^{-1}. (b) Power spectrum of (a), showing a single peak at f=168 T for all temperatures. (Inset) Density obtained from the frequency of the peak: n_s~8.2e12 cm^{-2}. (c) L-K fit of power spectrum amplitude as a function of T, yielding m^*=0.48 ± 0.02 m_0.

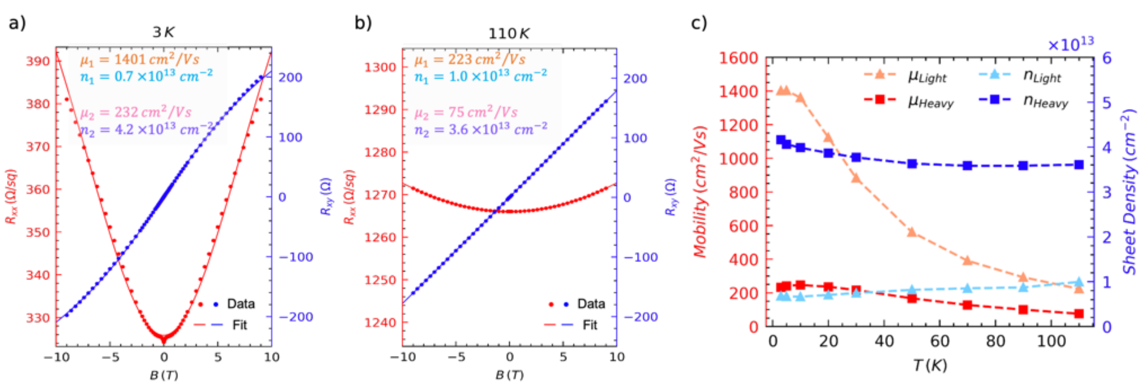

Fig 3. R_{xx} and R_{xy} vs B at (a) 3 K and (b) 110 K. Solid lines are simultaneous fits to the two-carrier Drude model. The best-fit values are shown. (c) Best-fit parameters as a function of temperature.