Quantum Transport in 2DEGs in Epitaxial GaN Quantum Wells on Superconducting NbN

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Introduction

Recent progress in molecular beam epitaxy has enabled the integration of the most important semiconductor family after silicon, III-V nitrides, with the technologically relevant superconductor NbN [1,2]. What can be accomplished by an all epitaxial super-/semi-conductor platform is only beginning to be understood. Crucial to progress in this field is the ability to realize transistors of the highest epitaxial quality directly on superconducting layers. Such epitaxial super/semi-heterostructure multilayers promise topologically protected electron transport, with applications in new forms of classical and quantum computation.

Experimental

We conducted magnetotransport measurements on gated GaN/AlGaN transistors grown on NbN epi-metal layers. The dependence of quantum oscillations was characterized as a function of temperature and gate-voltage in the top-loading cryostat in cell 12 at the NHMFL.

Results and Discussion

The measured Landau spectra show an expected strong dependence on gate voltage. We were able to measure to the 3rd Landau level at a gate voltage of -5 V before the oscillation amplitude was suppressed below a measurable value. Unexpectedly, below the threshold voltage (-7 V), quantum oscillations *reappeared*, and this needs further investigation. Temperature dependence of the oscillation amplitude confirmed the low field electron effective mass of 0.22 m_e. At the highest fields measured, spin-splitting is seen. Analysis of this splitting suggests a g-factor of 2 but confirmation at higher fields is necessary. The quantum scattering rate of ~45 femtoseconds was extracted and found to be independent of gate voltage.

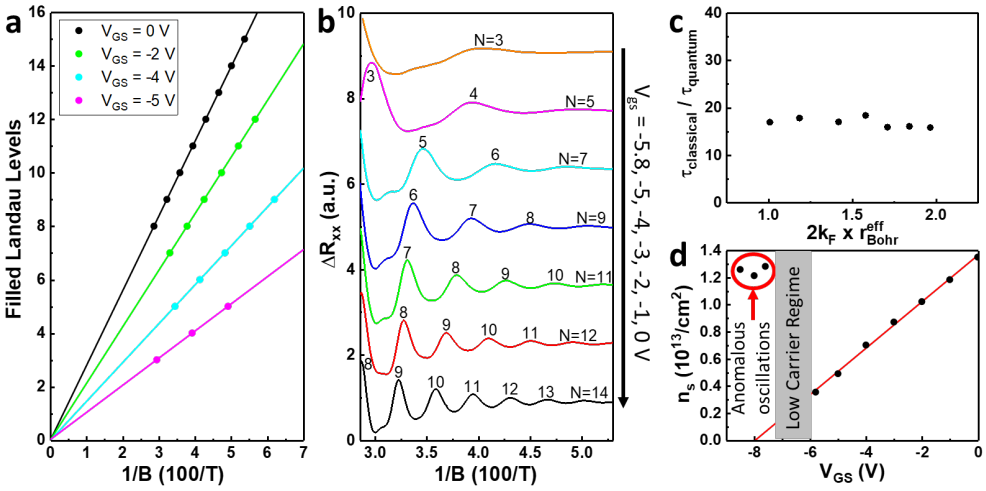

Figure 1: (a) Landau plot as a function of gate voltage. (b) Background-subtracted magnetoresistance oscillations as a function of 1/B, parametrized by gate voltage. Clear spin splitting is seen in the minima at small inverse magnetic fields. (c) Ratio of classical and quantum scattering times as a function of the dimensionless parameter $2\,k_F \times r_{Bohr}^{eff}$. (d) Carrier concentration as a function of gate voltage. In the shaded region, oscillations could not be resolved. Anomalous oscillations began to appear at very large negative gate voltage beyond the threshold voltage.

Conclusions

High magnetic field magnetotransport measurements suggest that 2D electron gases in nitride transistors grown on epi-metal layers are of excellent quality with properties robust over a broad range of gate voltages. This is a crucial first step in the development of integrating semiconductor and superconductors. An open question resulting from this study is the nature of the anomalous oscillations seen at sub threshold. Further increase in interface and sample quality while minimizing the separation between the 2DEG and superconducting layers will drive advances in nitride electronics and photonics.

Acknowledgements

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References

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