Bilayer Graphene as a Model Hydrodynamic Semicondutor

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Hydrodynamic electronic transport occurs when carrier-carrier collisions constitute the dominant scattering mechanism. This regime has attracted intense recent interest with its discovery in two dimensional materials, for which interactions are intrinsically strong and disorder plays a minimal role. Here we show that bilayer graphene is a model hydrodynamic semiconductor, in which carrier-carrier collisions play a dominant role over a wide range of temperature and carrier density. Remarkably, a simple model captures the complex interplay between carrier-carrier scattering and conventional dissipative scattering. This model, depicted in Figure 1 below, consists of a universal Coulomb drag contribution that dominates at charge neutrality and decays with increasing density, and a non-universal dissipative contribution corresponding to collective motion of the electron-hole plasma. We compare this model to electrical transport measurements of ultraclean bilayer graphene encapsulated within hBN, with dual gates providing independent control over carrier density and bandgap. At charge neutrality, these samples show electron-hole limited conductivity over a wide temperature range (Fig. 2a). A single set of fit parameters provides quantitative agreement with experiments at all densities, temperatures, and gaps measured, allowing for separate extraction of the electron-hole and dissipative contributions (Fig. 2b). Our work provides an intuitive understanding for electron-hole limited transport in a semiconductor across a wide range of parameters and provides a unique link between semiconductor physics and the emerging field of viscous electronics.

REFERENCES

[1] C. Tan, D. Y. H. Ho, L. Wang, J. I. A. Li, I. Yudhistira, D. A. Rhodes,T. Taniguchi, K. Watanabe, K. Shepard, P. L. McEuen, C. R. Dean, S. Adam, J. Hone, submitted.

FIGURES

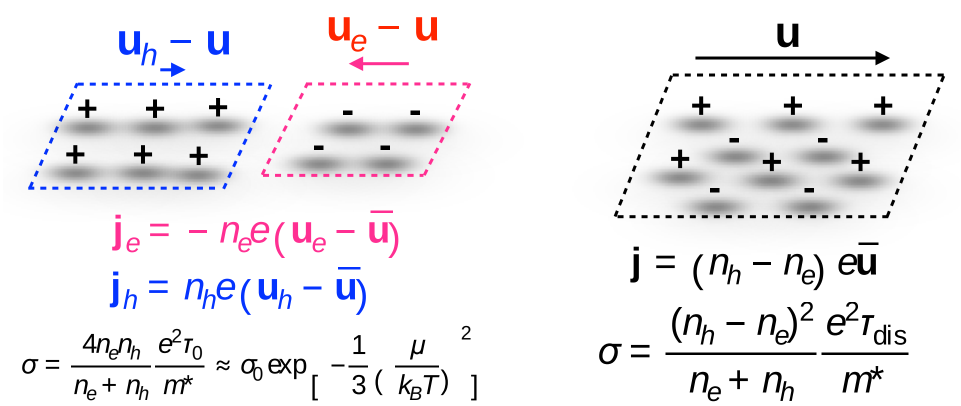

Figure 1: Schematic of Coulomb drag and center-of-mass contributions to hydrodynamic conductivity.

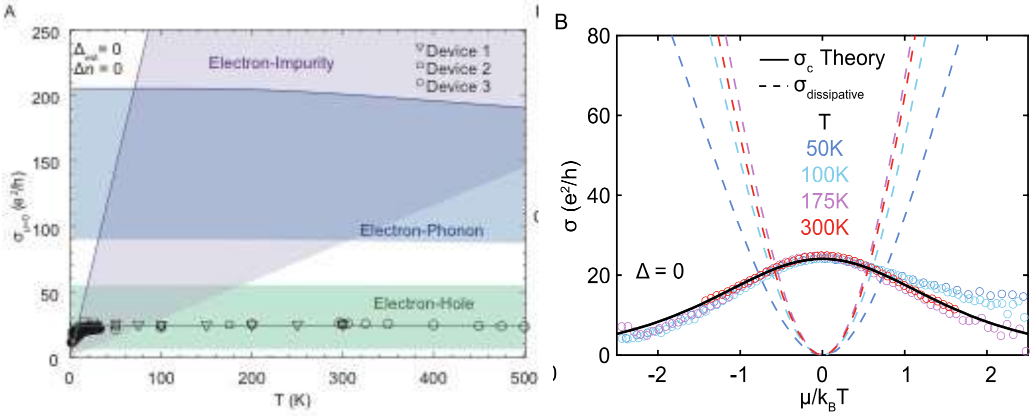

Figure 2: (A) Measured conductivity of bilayer graphene at charge neutrality, with predicted contributions from impurity, phonon, and electron-hole scattering. (B) Extraction of the universal Coulomb drag and non-universal dissipative terms.