Electronic Thermal Conductivity Measurements in Graphene

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The electronic thermal conductivity in graphene describes how energy is transported by the charge carriers in graphene, and how these carriers lose their energy via diffusion and interactions with phonons and impurities. Understanding these interactions can shed light on electron-phonon scatterings, thermal relaxation processes, and the electron cooling mechanisms in graphene. We developed a method to experimentally isolate the electronic thermal conductivity in suspended graphene transistors using two-point DC electron transport measurements. We adapted a Joule self-heating method to measure and control the temperature of electrons. We studied our samples at low bias voltages and intermediate temperatures where the electron and lattice temperatures are decoupled. We extracted the electronic thermal conductivity, K_e, as a function of electron temperature and charge carrier density.

We found that K_e has a strong temperature dependence, ranging from 0.5 to 11 W/m.K over a temperature range of 20 to 300 K [1]. The data are consistent with a model in which heat is carried by quasiparticles with the same mean free path and velocity as graphene's charge carriers. We doped our devices using the back-gate electrode, and extracted K_e in doped graphene over a temperature range of 50 to 160 K. We found that K_e is proportional to the charge conductivity times the temperature, and thus the Wiedemann-Franz Law is obeyed in suspended graphene. We observed a strong thermal transistor effect in our devices as the charge carrier density is changed from ≈ 0.5 to 1.8×10^{11} cm^{-2}, showing that K_e can be tuned by more than a factor of 2 by applying a few volts of gate voltage [2].

References:

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[2] S. Yiğen and A. R. Champagne, "Wiedemann-Franz Relation and Thermal-Transistor Effect in Suspended Graphene", Nano Lett. 14, 289 - 293 (2014).