Probing Hydrodynamic Transport in Ultraclean Graphene

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Scattering of charge carriers defines the resistivity of conductors. In solid state physics the charge propagation is usually considered as either diffusive or ballistic depending on the relationship between the mean free path and the size of the conductor. If the mean free path is much smaller than the characteristic size of the specimen, the charge transport is diffusive and the current distribution can be fully described by the Poisson equation for electric potential. On the other hand if electrons travel across the whole conductor without scattering the transport is considered to be ballistic and the Buttiker formalism can be employed to explain conductance of such system. There is, however, another regime of the charge transport in homogenous media, which takes its origin from strong electron-electron interaction and can be interpreted as a viscous flow of the electronic quantum liquid [1,2]. If the electron-electron scattering rate is the highest scattering rate in the system the rapid momentum exchange between charge carriers results in the effective friction force between different parts of a charge flow. For properly chosen geometry of the device the local current may even flow in the direction opposite to the one expected in the diffusive regime forming “whirlpools” and resulting in the change of the sign of the four probe resistance.

Here we report the experimental observation of hydrodynamic transport in mono- and bilayer graphene devices prepared on hexagonal boron nitride. Viscous behavior of the electronic liquid become apparent at elevated temperatures (>100 K), when ballistic transport is significantly suppressed, but the electron-phonon scattering length is still larger than the electron-electron mean free path. The signature of hydrodynamic transport is seen as the change of the sign of the 4-probe resistance measured in the geometry traditionally employed for transverse magnetic focusing. The viscous flow of electronic liquid in monolayer graphene is observable up to room temperature suggesting possible application in novel electronic devices.

References

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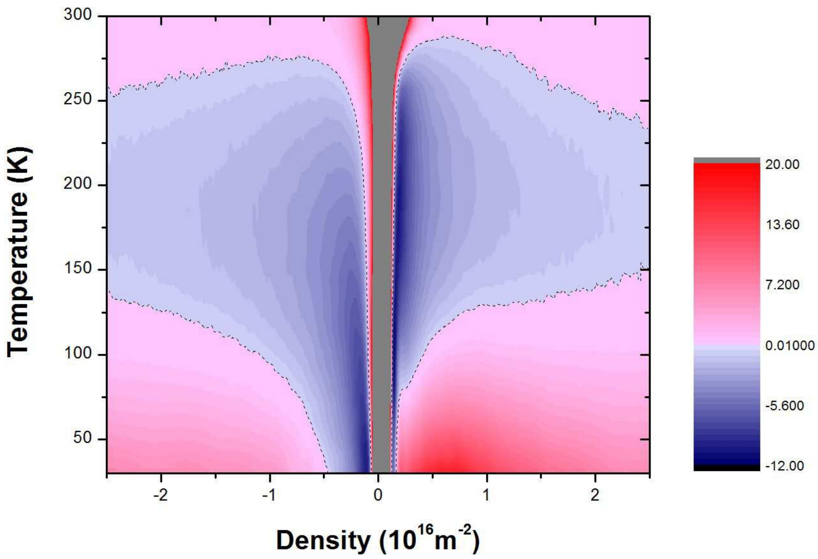

Figure 1: Four-probe resistance measured as function of the carrier concentration and temperature at B=0 in the geometry normally used for studying transverse magnetic focusing. Blue regions correspond to negative resistance, which originate from the finite viscosity of the electronic liquid.