ThIE3

INVITED

Giant magneto-drag in graphene at the charge neutrality

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Keywords: magneto-drag, Nernst-Ettingshausen effect, charge neutrality, hydrodynamic approach

Recent measurements [1] of frictional drag in graphene-based double-layer devices revealed the unexpected phenomenon of giant magneto-drag at the charge neutrality point: applying external magnetic fields as weak as 0.3 T results in the reversal of the sign and a dramatic enhancement of the amplitude (by orders of magnitude) of the drag resistance. If the device is doped away from the Dirac point, the effect of such a weak field on the drag resistance remains negligible. The observed effect is most pronounced at temperatures above 150 K and is apparent already at 50 mT. Moreover, the negative drag disappears in high magnetic fields and at low temperatures, hinting at the classical origin of the phenomenon.

Using the quantum kinetic equation framework [2], we derived a hydrodynamic description of transport in double-layer graphene-based devices [3] that accounts for the observed behavior. In the presence of disorder, the hydrodynamic equations provide a generalization of the standard Drude theory to the case of Dirac fermions in graphene [4]. Remarkably, already at this simplest level, the theory yields the giant negative magneto-drag at the neutrality point. At the same time, the theory predicts the existence of non-zero Hall drag in doped graphene in agreement with experiment [4].

Physically, the magneto-drag is intimately related to the anomalous Nernst-Ettingshausen effect in graphene. At the charge neutrality point, electrons and holes in different sub-bands experience a unidirectional drift in weak magnetic field which can be interpreted as a quasi-particle (or heat) flow in the direction perpendicular to the electric current. Such a mode is efficiently transferred by Coulomb interactions to the passive graphene layer where it induces a drag voltage by means of the inverse thermoelectric effect. Similar physics leads to the unusual Hall drag resistance.

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