Influence of chirality on phonon-drag thermopower in monolayer and bilayer graphene

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Graphene possesses many unique features and due to its high electron mobility and high magnitude of thermoelectric power it is very attractive for applications. Recent realization of suspended monolayer graphene (MLG) and bilayer graphene (BLG) samples has made possible a direct probe of their intrinsic properties. A detailed study of the (intrinsic) scattering mechanisms, like electron-phonon-interaction, is therefore of large interest. A quite sensitive tool for investigating the coupling of electrons to acoustic phonon modes in 2D systems is the phonon-drag thermopower S^{g}. S^{g} arises from the momentum exchange between electrons and nonequilibrium phonons in the presence of a weak in-plane temperature gradient. There are two principal sources of the interaction between electrons and acoustic phonons in graphene. On the one hand electrons interact with acoustic phonons via a deformation potential proportional to the local contraction or dilatation of the lattice; on the other hand electrons couple to acoustic phonons by changes in bond length and bond angle between the carbon atoms [1]. The latter interaction can be described by an effective gauge field. While the deformation potential coupling is restricted to in-plane longitudinal acoustic (LA) phonons and out-of-plane (flexural) acoustic phonons (the latter coupling is by 2-phonon processes), the gauge field allows also coupling to in-plane transverse acoustic (TA) phonons.

In this study, we focus our attention on the effect that has chirality on the electron-phonon coupling and therefore on S^{g}. MLG and BLG not only exhibit a different low-energy electronic band structure, but also a different degree of electron chirality. While the charge carriers in MLG are massless quasiparticles characterized by a Berry phase of π, the electrons in BLG can be viewed as massive fermions with Berry phase 2π.

We have calculated S^{g} in doped MLG and BLG as function of temperature between 1K and 50K for different carrier densities. In contrast to former studies [2] where only LA phonons and an unscreened deformation potential interaction were considered, we have included the coupling by deformation potential and gauge field, the screening of deformation potential as well as the contributions of LA, TA and flexural phonons. For these purposes we have generalized the Cantrell-Butcher formalism [3] for the phonon-drag thermopower to allow also for 2-phonon processes.

For reasonable values of coupling constants and not too low temperatures our results show that the main contribution to S^{g} is due to the gauge field coupling by in-plane phonons. The chiral character of the electrons reduces both the contribution of deformation potential and the contribution of gauge field. However, the effect varies greatly, depending on the degree of chirality. With the change from MLG to BLG we observe for $T > 10\mathrm{K}$ a reduction of the contribution of the gauge potential and an increase of the contribution of the deformation potential. For temperatures below 10K the electron scattering by out-of-plane phonons cannot be neglected. Therefore we have also examined the differences between S^{g} in MLG and in BLG due to the coupling of electrons to flexural phonons.

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