Electromagnetic coupling and transport in a topological insulator–graphene heterostructure

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Abstract

The electromagnetic coupling between heterostructures made of different materials is of great interest, both from the perspective of discovering new phenomena, as well as for its potential applications in novel devices. In this work, we study the electromagnetic coupling of a heterostructure made of a topological insulator (TI) slab and a single graphene layer (Fig. 1), where the later presents a diluted concentration of ionized impurities. We explore the topological effects of the magnetoelectric polarizability of the TI, as well as its relative dielectric permittivity on the electrical conductivity in graphene at low but finite temperatures.
We consider a heterostructure composed of a TI slab and a single graphene layer, and we further assume that a diluted concentration of ionized impurities is present in the graphene monolayer. The presence of such charged impurities will induce a local distortion of the charge density of the 2D electron gas, leading to a nontrivial electromagnetic coupling between the TI and the graphene monolayer in the heterostructure. As a probe of this coupling, we further studied the electrical conductivity as a function of temperature, by including the scattering effects with the local electromagnetic field configuration via the Kubo linear response formalism. We applied our theoretical results to model the electromagnetic coupling in heterostructures made of different TIs (PbTe, Bi2Te3, PbSe, PbS, Bi2Se3, TlBiSe2, TbPO4). Our analytical and numerical results suggest that, among the properties of the TIs, the dielectric permittivity ε1 is the most relevant at tuning the electronic transport in the coupled graphene monolayer. On the other hand, we also observed that the topological effects arising from the presence of the MEP coefficient θ are comparatively very small even at zero temperature.

References

[1] D. Bonilla, J. Castaño-Yepes, A. Martín-Ruiz, E. Muñoz, Physical Review B 107, 245103 (2023).

Figures

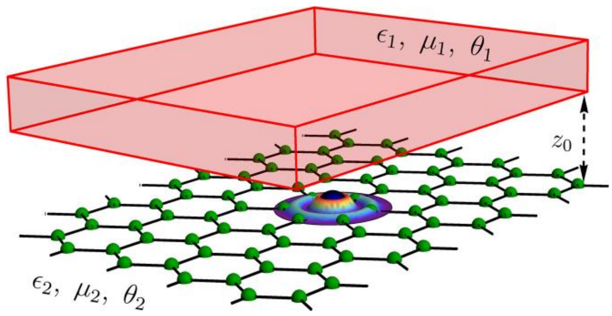

Figure 1: Graphene-TI heterostructure considered in this work

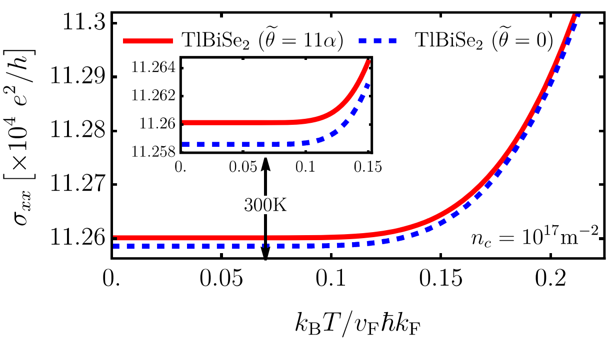

Figure 2: Electrical conductivity in the graphene monolayer as a function temperature