Spin- and valley-dependent transport effects in twisted graphene on semiconducting and magnetic van-der-Waals crystals

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Spin-orbit interaction leads to various novel states and phases of matter, like chiral spin textures or interfacial and surface spin-polarized states. It also gives a unique possibility of pure-electrical control of the spin degree of freedom, which is of great practical importance. Consequently, spin-orbit-driven phenomena – like the spin Hall effect and current-induced spin polarization [1] – are of particular interest as, on one side, they reveal fundamental aspects of solid-state physics and, on the other side, have great potential for practical applications in spintronics and nanoelectronics. Many recent experiments performed on graphene-based hybrid structures revealed spin-orbit proximity effects strong enough to make spin currents or spin polarization measureable up to room temperatures [2]. This, in turn, opened a new era of spintronics, i.e., a van-der-Waals spintronics, that couples charge, spin, and valley degrees of freedom.

We will present a detailed study of anomalous, spin, and valley Hall effects as well as current-induced spin polarization in graphene twisted with respect to a monolayer of semiconducting TMDCs (MoS2, WS2, MoSe2, WSe2) and in graphene twisted with respect to a monolayer of Cr-based transition metal trihalides (CrI3, CrCl3). We will show that the twist angle strongly modifies band structure and spin polarization of quasiparticles at the Fermi level (spin-momentum locking), as well as Berry curvature.

Our theoretical calculations are based on Green function formalism in the linear response limit adapted to effective low-energy Hamiltonians derived from symmetry analysis and DFT calculation [3]. The parameters describing effective Hamiltonian for twisted graphene on TMDCs have been taken based on DFT study published recently by Zollner et al. [4] and S. Lee et al. [5]. In turn, for CrX3 (X=I, Cl), we performed our DFT calculations [6] that will also be presented.

References

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