Spin-Relaxation Phenomena in Graphene: Proximity-Induced Spin-Orbit Coupling Yields Novel Type of Ultrafast Spin Relaxation

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Abstract

Spin transport and spin relaxation are intriguing and strongly debated phenomena in graphene, first, because of unexpectedly short spin diffusion times despite vanishingly small intrinsic spin-orbit interaction and hyperfine coupling, but also because of controversially debated spin relaxation mechanisms.

On the other hand, proximity induced spin-orbit coupling can trigger interesting phenomena in graphene such as the quantum spin Hall effect [1], which can be realized by single ad-atom deposition [2]. Similarly, the intercalation of Au atoms between graphene and a Ni(111) surface has been shown to create giant spin-orbit splitting at the Dirac point reaching 100 meV [3] even for dilute cases, thus demonstrating the efficiency of such proximity effects.

We explore the effect of spin-orbit interaction induced by dilute ad-atom deposition on graphene by means of an efficient time-propagation approach. We monitor the spin-dynamics of initially polarized states that propagate in graphene under presence of such impurities and extract spin precession times and spin-relaxation times. From a comparison to the momentum scattering time we infer different relaxation mechanisms which can only partially be described with established Dyakonov-Perel and Elliot-Yafet mechanisms. We analyze various crossovers as a function of Fermi-level position and momentum scattering time which can be tuned by the disorder potential.

We will also comment on the influence of the direction of the initial spin polarization.

References


Figures

(a)      (b)

Fig. 1 (a) Graphene with ad-atom impurities adsorbed on hollow sides that induce an effective spin-orbit interaction. (b) Spin-polarization dynamics over time for out-of-plane spin injection. Spin decay depends on the Fermi energy.