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Advances in 2D Materials-based Spintronics: A theoretical perspective

Graphene has been heralded as the ideal material to achieve long spin propagation and further control the spin degree of freedom, in the quest of advancing non-charge-based information processing and computing, and for creating a new generation of active (CMOS compatible) spintronic devices together with non-volatile low energy MRAM memories. However, despite ultralow intrinsic and Rashba spin-orbit couplings (SOC) in clean graphene (μeV range), measured spin lifetimes remain in the range of several nanoseconds. This is orders of magnitude shorter than initially predicted, but already enough to envision disruptive non-charge-based room-temperature applications [1].

Besides, the physics of graphene "can be enriched and manipulated" by harvesting the large amount of possibilities of proximity effects with magnetic insulators, strong SOC materials, topological insulators, etc. One challenge is to endow a sizable spin-to-current conversion efficiency by enhancing spin-orbit interaction (say up to meV). Claims have been made that very large spin Hall effect could be generated by using chemical functionalization with hydrogen or Au/Cu ad-atoms, or interfacing graphene with WS2 substrate [2]. Those results are however fiercely questioned [3] and the understanding of spin dynamics for Dirac fermions in presence of enhanced SOC remains elusive.

In this talk, I will discuss the fundamentals of spin transport for Dirac fermions propagating in graphene supported onto substrates or interfaced with metal transition dichalcogenides. The role of "pseudospin" in driving spin dephasing and relaxation will be analysed in the ultraclean limit and the impact of strong SOC proximity effects on spin lifetime anisotropy weak antilocalization and spin Hall effects will be presented and compared to experimental literature [4].

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