Could Graphene and 2D Materials revolutionize Spintronics?
Current challenges & opportunities

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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. Many technological roadblocks and lack of fundamental knowledge are however limiting today´s progress. Indeed, 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 angles (figure of merit for spin Hall effect-SHE) could be generated by using chemical functionalization with hydrogen or Au/Cu ad-atoms, or interfacing graphene with WS_2 substrate [2]. Those results are however fiercely questioned [3].

In this talk, I will discuss spin transport in graphene-based materials, accounting for the effect of substrate, impurities, and ad-atoms and using a fully quantum derivation of spin dynamics and calculation of multiterminal quantum resistance, going beyond the usual semi-classical theory and conventional approximations made in the literature. The role of pseudospin in driving spin dephasing and relaxation will be unveiled in the ultraclean limit for which electron-hole puddles and micron eV spin-orbit interaction are determining the fundamentals of spin lifetimes, giving foundations to experimental features [4]. Second, I will discuss the impact of chemical functionalization (fluorine, gold and thallium ad-atoms) and proximity effects with other 2D materials in generating spin-dependent phenomena such as spin filters, quantum spin Hall and tunable spin Hall effects in graphene.

Bibliography

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