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INVITED

Spin-orbit effects and hot-carrier transport in graphene-based devices

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Two-dimensional atomic crystals offer a unique platform to design new materials, in which proximity effects can help tailor their electrical, optical and spin properties. Amongst these materials, graphene has emerged as a centerpiece for future spintronics, owing to its tuneable electronic properties and ability to transport spin information over long distances [1]. However, spin manipulation remains an open challenge, which can be resolved with spin-orbit coupling (SOC) induced by proximity effects. Here, I will present recent results regarding spin dynamics in graphene-based van der Waals heterostructures. I will first review the microscopic mechanisms that influence the spin propagation in pristine graphene, including the presence of hot carriers [2,3] (Fig. 1). Then I will discuss proximity-induced SOC and spin-to-charge conversion in stacks of graphene and transition metal dichalcogenides (TMDC) and in graphene in contact with metals such as Pt. I will show that key information can be obtained from the spin-lifetime anisotropy, as it is determined by the preferential direction of the spin-orbit fields that cause the spin relaxation. Even though the spin-lifetime in graphene on SiO_x is isotropic, it becomes strongly anisotropic in bilayers comprising graphene and a TMDC [4], being one order of magnitude larger for spins pointing out of the graphene plane. This suggests that the strong spin-valley coupling in the TMDC is imprinted in graphene and felt by propagating spins (Fig. 2), a phenomenon that can also lead to an enhanced spin-to-charge conversion efficiency.

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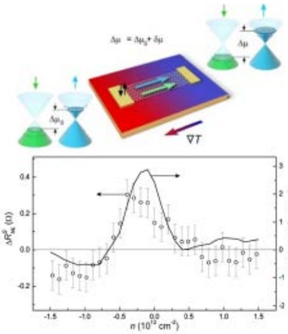

Figure 1. The two spin channels have different Seebeck coefficients due to spin accumulation (a), leading to a thermoelectric spin voltage driven by temperature gradients (b) [2,3].

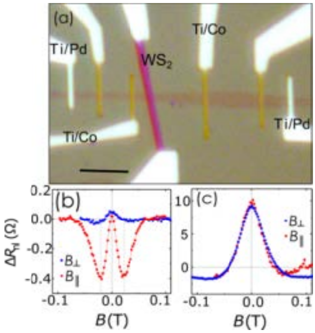

Figure 2. Spin relaxation anisotropy in graphene-tungsten disulphide. (a) Device. (b) Spin precession with out-of-plane and in-plane magnetic field. (c) ibid, in a reference device [4]