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Spin-orbit proximity phenomena and tunable spin-to-charge conversion in graphene

Graphene has emerged as a centerpiece for future spintronics, owing to its tunable electronic properties and ability to transport spin information over very long distances [1]. For active devices, however, spin manipulation remains an open challenge. Such a challenge can be resolved with spin-orbit coupling (SOC) induced by proximity effects. Here, I will discuss our recent experiments on proximity-induced SOC and spin-to-charge interconversion (SCI) in stacks of graphene and transition metal dichalcogenides (TMDC) [2,3]. 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. Indeed, the spin-lifetime varies over one order of magnitude depending on the spin orientation and is largest for spins pointing out of the graphene plane, even at room temperature [2]. This suggests that the strong spin-valley coupling in the TMDC is imprinted in graphene and felt by propagating spins. I will further demonstrate that the proximity-induced SOC leads to strongly enhanced room-temperature SCI [3]. By performing spin precession experiments in appropriately designed Hall bars, we are able to separate the contributions of the spin Hall effect (SHE) and the spin galvanic effect (SGE). Remarkably, their corresponding conversion efficiencies can be tailored by electrostatic gating in magnitude and sign (Fig. 1), peaking near the charge neutrality point with an equivalent magnitude that is comparable to the largest efficiencies reported to date.

References

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[3] L. A. Benítez et al., Nature Mater. (2020) doi:10.1038/s41563-019-0575-1.

Figures

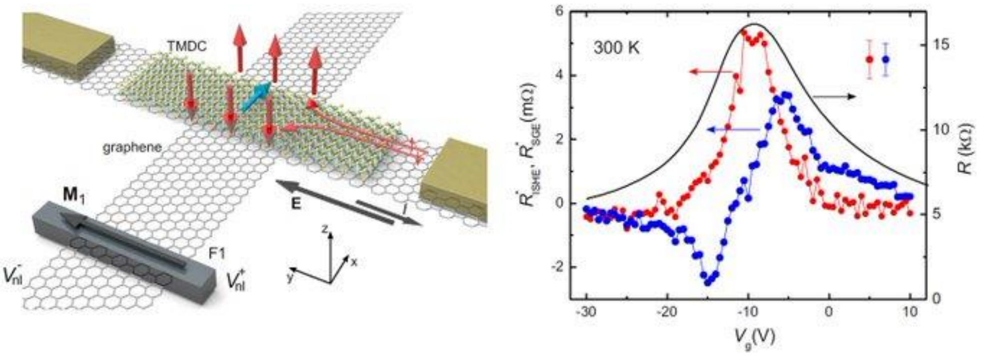

Figure 1: Left: Schematics of the device to measure spin-charge interconversion (SCI) in graphene by proximity of a TMDC. A current *I* generates a transverse spin current owing to the SHE (red arrows) and an in-plane spin density due to the inverse SGE (blue arrow). **Right:** Tunable SCI as a function of carrier density, modulated by the gate voltage V_g.