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Graphene-based heterostructures as spintronic devices

The integration of the spin degree of freedom in charge-based electronic devices has revolutionized both sensing and memory capability in microelectronics. Further development in spintronic devices requires electrical manipulation of spin current for logic operations. In this presentation we will show two examples of graphene-based devices that work along this direction.

The mainstream approach followed so far, inspired by the seminal proposal of the Datta and Das spin modulator [1], has relied on the spin-orbit field as a medium for electrical control of the spin state [2-4]. However, the still standing challenge is to find a material whose spin-orbit coupling (SOC) is weak enough to transport spins over long distances, while also being strong enough to allow their electrical manipulation. In our recent work [5], we demonstrate a radically different approach by engineering a van der Waals heterostructure from atomically thin crystals [6], and which combines the superior spin transport properties of graphene with the strong SOC of MoS_2, a transition metal dichalcogenide with semiconducting properties (Fig. 1). The spin transport in the graphene channel is modulated between ON and OFF states by tuning the spin absorption into the MoS_2 layer with a gate electrode [5]. Our demonstration of a spin field-effect switch using two-dimensional materials identifies a new route towards spin logic operations for beyond CMOS technology. Furthermore, the van der Waals heterostructure at the core of our experiments opens the path for fundamental research of exotic transport properties predicted for transition metal dichalcogenides [7], in which electrical spin injection has so far been elusive.

An alternative way to exploit spin currents for logic operations is the recent proposal of a spin-orbit logic [8] which takes advantage of the discovery of new spin-to-charge conversion effects (spin Hall effect, Rashba-Edelstein effect, spin-momentum locking). Finding routes to maximize the conversion efficiency is thus crucial. We show how to achieve a very large spin-to-charge voltage output at room temperature by combining Pt with a graphene channel [9], opening up exciting opportunities towards the implementation of these spin-orbit-based logic circuits.

Figures

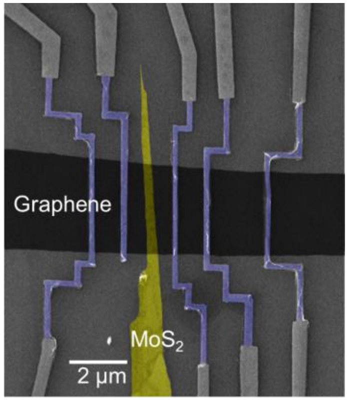

Figure 1: False-coloured SEM image of the 2D van der Waals heterostructure to be used for switching the spin transport. Purple nanostructures are Co electrodes used for spin current injection and detection in the graphene channel. The spin current flowing through the graphene can be switched ON and OFF by modulating the conductivity of MoS_2 with a backgate voltage.

References

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