Spin, valley, and exchange proximity effects in graphene van der Waals heterostructures

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Stacking graphene with other 2D materials opens up fascinating possibilities for spintronics, not feasible with conventional materials structures. Transition metal dichalcogenides are of particular interest due to their strong spin-valley coupling. Placing graphene on, say, MoS_2, as in Fig. 1., enables ptospintronics [1], whereby optically generated spins in MoS_2 are transferred into graphene. Even more fascinating are proximity effects allowing spin manipulation. Spin-valley locking in the substrate is manifested via the spin Zeeman splitting in graphene [2], which, in turn, yields giant spin relaxation anisotropy [3]. Since the structure of intrinsic spin-orbit coupling is dramatically altered by the proximity effect, novel pseudohelical edge states can emerge in graphene nanoribbons and flakes, protected against backscattering by time reversal symmetry [4], communicating between the edges by spin-flip wormhole tunneling reflectionless channels. Much greater playground for new physics is offered by bilayer graphene on 2D materials. Due to the locality of proximity effects, one can efficiently tune induced spin interactions via electric fields---gating. Thus, spin-orbit coupling can be turned on and off [5], opening prospects for novel spin transistors, see Fig. 2. Bilayer graphene can also be made into a synthetic ferromagnet, with engineered exchange coupling but without residing magnetic moments. Like spin-orbit, proximity exchange coupling can also be turned on and off, which is a desired control in a variety of magnetoelectronic device schemes [6]. Support from DFG SFB 1277 and EU Graphene Flagship is acknowledged.

References

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Figures

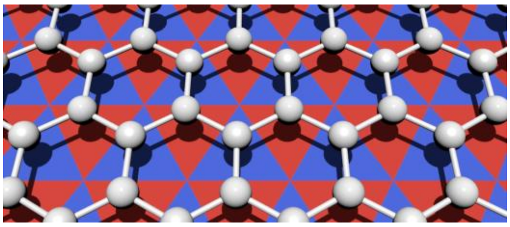

Figure 1: Graphene on transition-metal dichalcogenides such as WSe2 inherits strong spin-valley coupling manifested by the presence of valley Zeeman splitting [4].

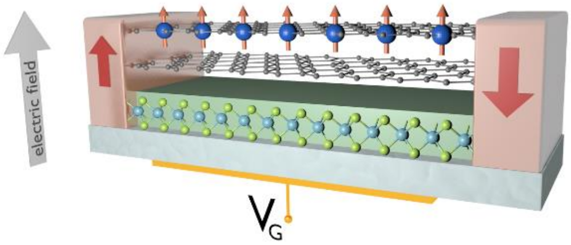

Figure 2: Bilayer graphene on transition-metal dichalcogenides experience layer-selective giant spin-orbit coupling which can be exploited by field-effect spin transistors [5].