Spin-orbit proximity in van der Waals heterostructures

Fèlix Casanova

CIC nanoGUNE BRTA, Tolosa Hiribidea 76, 20018 Donostia-San Sebastian, Basque Country(Spain)

f.casanova@nanogune.eu

Two-dimensional materials are an exciting new material family that has the capability to advance toward the implementation of novel spin-based devices. For these atomically-thin layers, the proximity effect is especially important and opens ways to transfer properties from one material into another. In van der Waals heterostructures, transition metal dichalcogenides (TMD) can be used to enhance the spin-orbit coupling of graphene, leading to new spin transport channels with unprecedented spin textures [1]. We have optimized bilayer graphene/ TMD heterostructures to achieve magnetic-field-free spin precession. Remarkably, we observe in graphene/WSe_2 devices that the sign of the precessing spin polarization can be tuned electrically by a back gate voltage and by a drift current [2]. Our result is the first realization of a spin field-effect transistor at room temperature in a diffusive system, a long-awaited goal of spintronics that could be a cornerstone for the implementation of energy efficient spin-based logic.

Another notable consequence of the spin-orbit proximity in graphene/TMD van der Waals heterostructures is the occurrence of spin-to-charge conversion (SCC) due to the spin Hall effect (SHE), which was first observed by our group using MoS_2 as the TMD [3]. To quantify the SCC, the significant figure of merit is the SCC length which can be calculated by the product of spin Hall angle, θ_{SH}, and the spin diffusion length, λ_s. The combination of long-distance spin transport and SHE in the same material gives rise to an unprecedented SCC length of up to 41 nm solely due to the SHE in graphene proximitized with WSe_2. Furthermore, a gate-tunable SCC is observed [4]. Such highly efficient and gate-tunable SCC up to room temperature will play a crucial role for the future integration of spintronic devices into existing electronic infrastructure.

References

[1] M. Gmitra and J. Fabian, Phys. Rev. B, 93 (2016) 155104.
[2] J. Ingla-Aynés, F. Herling, J. Fabian, L. E. Hueso and F. Casanova, Phys. Rev. Lett. 127 (2021) 047202.
[3] C. K. Safeer, J. Ingla-Aynés, F. Herling, J. H. Garcia, M. Vila, N. Ontoso, M. R. Calvo, S. Roche, L. E. Hueso, and F. Casanova, Nano Lett. 19 (2019) 1074.
[4] F. Herling, C. K. Safeer, J. Ingla-Aynés, N. Ontoso, L. E. Hueso, and F. Casanova, APL Mater. 8 (2020) 071103.

Figures

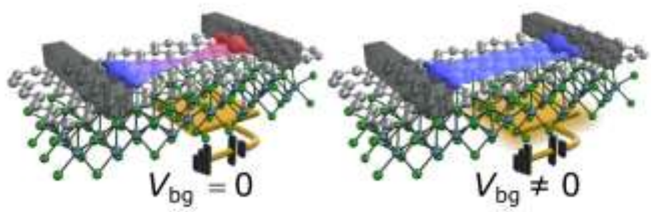

Figure 1: Sketch of a spin field-effect transistor operating at the strong spin-orbit coupling regime, where the valley-Zeeman induced spin precession is tuned by a back gate voltage to control the sign reversal.