

Spin Filtering at the Interface with 2D Semiconductors

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Spintronics exploits the electron's spin as an information carrier, enabling fast, energy-efficient, technologies such as spin-transfer-torque (STT) and spin-orbit-torque (SOT) Magnetic Random Access Memories (MRAMs). Beyond these established applications, spintronics now aims to develop advanced architectures that integrate in-memory processing with emerging paradigms such as neuromorphic, stochastic, and quantum computing. To this effect, 2D materials have recently attracted significant attention, offering unique opportunities for spin devices design with properties such as atomic thickness control, 2D barriers and interfaces, impermeable membranes, tuneable magnetic anisotropy and texture, spin filtering, spin-orbit torque engineering, and environmental or electrostatic gating. Starting with graphene, this has opened novel exciting opportunities in terms of functionalities and performances for spintronics devices.[1] A wide exploration of a large variety of 2D crystals for spintronics is now on-going, with the hope to exploit some of their unique properties in spin valves.[2]

We will present here experimental results concerning integration of 2D materials in vertical Magnetic Tunnel Junctions (MTJ), with a focus on 2D materials beyond graphene, including 2D semiconductors such as transition metal dichalcogenides (TMDs). We will first discuss integration and spin filtering effects observed in reference devices based on exfoliated crystals.[3] We will then expand the discussion to a novel pulsed laser deposition (PLD) approach for the definition of complex van der Waals heterostructures of 2D materials.[4] We will show how this PLD growth approach unlocks the association in heterostructures of multifunctional 2D materials, including the most delicate ones. Finally, the direct integration of TMDs with ferromagnetic spin sources enabled by this in-situ large scale PLD approach will be shown to lead to MoS₂ band structure evolution upon hybridization, introducing a pronounced exchange-induced spin splitting and resulting in an unusual bimodal spin response in MoS₂ based 2D-MTJs.[5] The different presented experiments unveil promising approaches for the quantum engineering of multifunctional 2D materials heterostructures for spintronics.

References

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