Spin on 2D Quantum Matter

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Exploring spin, orbital, and topological properties of two-dimensional (2D) quantum materials represents a new platform for realizing novel quantum and spin-based phenomena and device applications. We showed that the unique band structure and lower crystal symmetries of WTe2 and TaIrTe4 can provide an unconventional spin-polarized current [1] and out-of-plane spin-orbit torque [2] needed for field-free magnetization switching. On the other hand, 2D magnets are promising owing to their tunable magnetic properties. We reported above room temperature 2D magnet-based spin-valve devices in heterostructure with graphene [3,4]. We further utilized such 2D magnets with co-existence of ferromagnetic and anti-ferromagnetic orders with intrinsic exchange bias in the system, giving rise to a canted magnetism [5]. Such canted magnetism of 2D magnets helps in achieving field-free magnetization switching with conventional spin orbit materials such as Pt [5,6]. Combining such 2D quantum materials in van der Waals heterostructures can offer a promising platform for efficient control of magnetization dynamics for non-volatile spin-based memory. Recently, we demonstrated energy-efficient field-free spin-orbit torque (SOT) switching and tunable magnetization dynamics in 2D heterostructure comprising out-of-plane magnet Fe3GaTe2 and topological Weyl semimetal TaIrTe4 [7]. In TaIrTe4/Fe3GaTe2 devices, an energy-efficient and deterministic field-free SOT magnetization switching is achieved at room temperature with a very low current density [7]. These results show that 2D heterostructures provide a promising route to energy-efficient, field-free, and tunable SOT-based spintronic memory devices [8].

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