Giant Spin-Orbit Torque in Cr-based Janus Transition Metal Dichalcogenides

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The spin-orbit torque (SOT) mechanism provides an energy efficient method for electrical manipulation of a magnetization, offering new avenues for technologies such as magnetic random-access memories (MRAM) [1]. Tunable control of electric and spin properties in two-dimensional materials represent a breakthrough for such devices; however, their development has been limited to multi-layered devices constricted by interface quality, operating at temperatures up to ~100 K due to low Curie temperatures [2].

In this work, we report very large SOT capability of Cr-based transition metal dichalcogenides (TMD) in their low-symmetry Janus forms CrXTe, with X=S,Se. Using an *ab-initio* approach, we show that CrXTe materials are metallic with strong spin-orbit coupling and magnetic with high Curie temperature, like their non-Janus counterpart $CrTe_2$ [3]; with the additional feature of broken inversion symmetry, which enables a SOT response [1,2]. We develop Wannier tight-binding models presenting DFT-level accuracy, representing the system's symmetries within a 1% error. The structural inversion symmetry breaking inherent to Janus structures generates a giant Rashba splitting, which would be obtained by applying a symmetry-breaking transverse electric field of 100 V/nm in non-Janus $CrTe_2$, completely out of experimental reach. Using the Kubo-Bastin formalism, SOTs in Janus CrXTe are found to be as large as ~10^5 $\hbar/2e$ $(\Omega m)^{-1}$, comparable to the most efficient two-dimensional systems yet discovered [4], while additionally allowing for field-free magnetization switching with reasonable critical currents, enabled by the systems reduced in-plane symmetries [5]. Our findings evidence that magnetic Janus TMDs stand as a suitable candidate for ultimate all-in-one SOT-MRAM.

References

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Figures

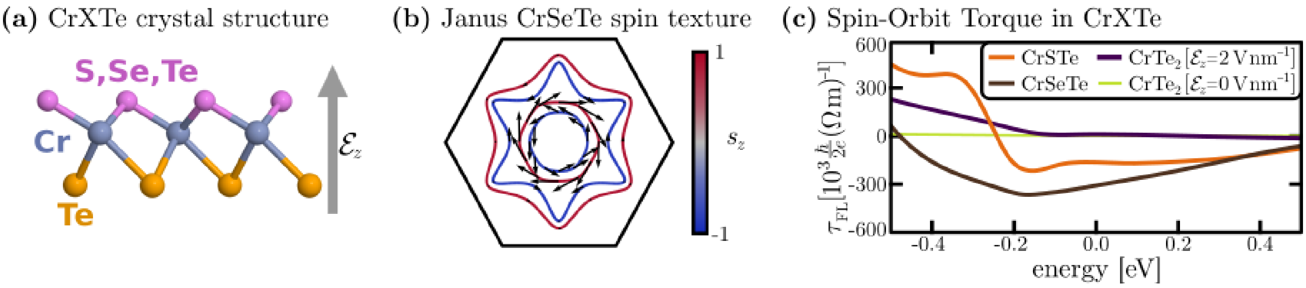

Figure 1: (a) Crystal structure of Cr-based TMDs. **(b)** Spin texture of CrSeTe, showing strong helical spin-momentum locking due to Rashba splitting. **(c)** SOTs in $CrTe_2$ (centrosymmetric and non-centrosymmetric with applied transversal field E_z), and Janus CrXTe, where the latter exhibits SOTs 10-100 times larger than non-Janus systems.