

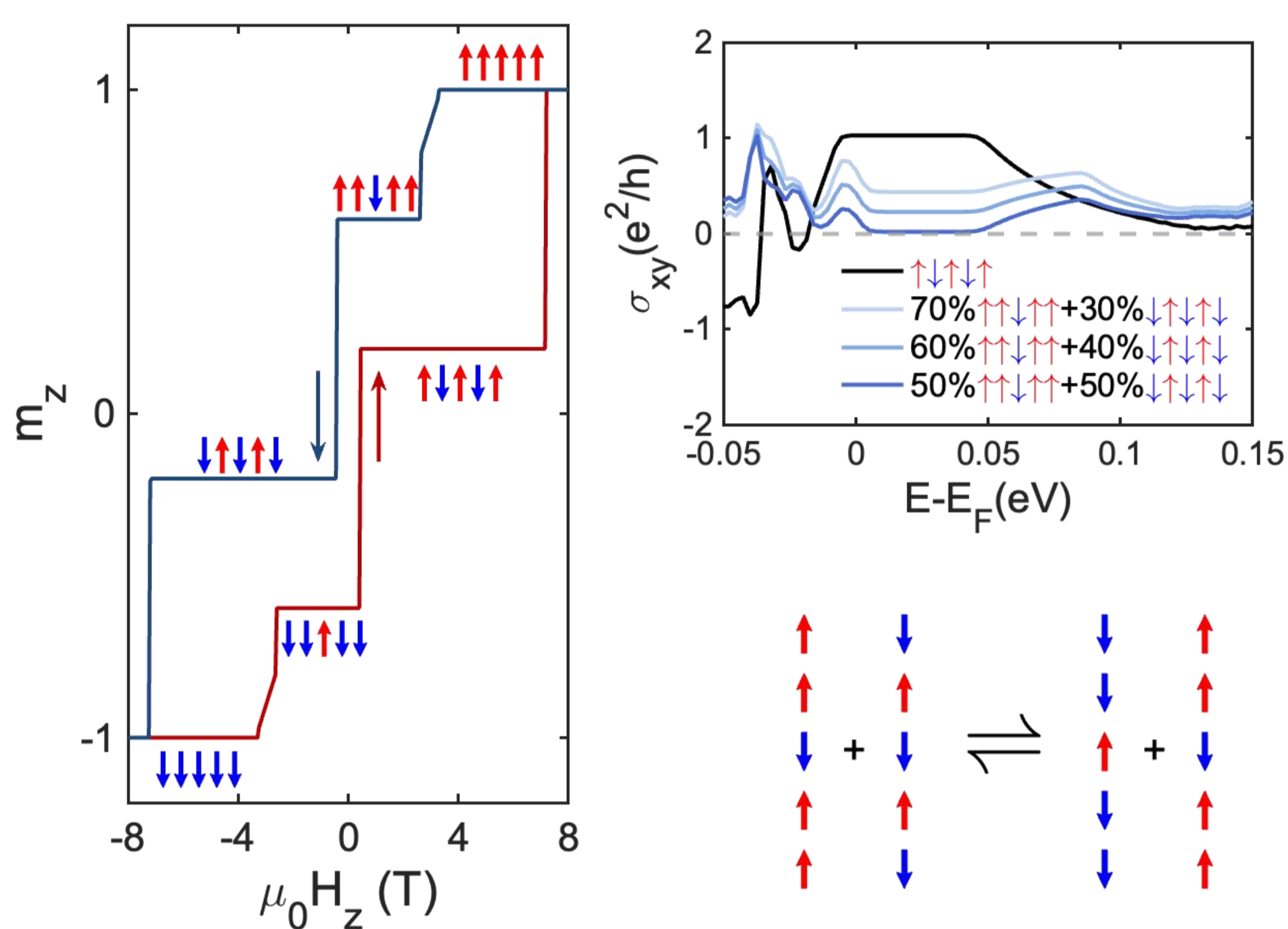
Topologically-Enhanced Spin-Orbit Torque for Deterministic Switching of Magnetic Order in MnBi_2Te_4

Jingyue Chen[#], Sheng Pan[#], Fucong Fei[#], Zihan Li[#], Yuda Zhang, Fengqi Song^{*}, Jiexiang Yu^{*}, Faxian Xiu^{*}

Abstract:

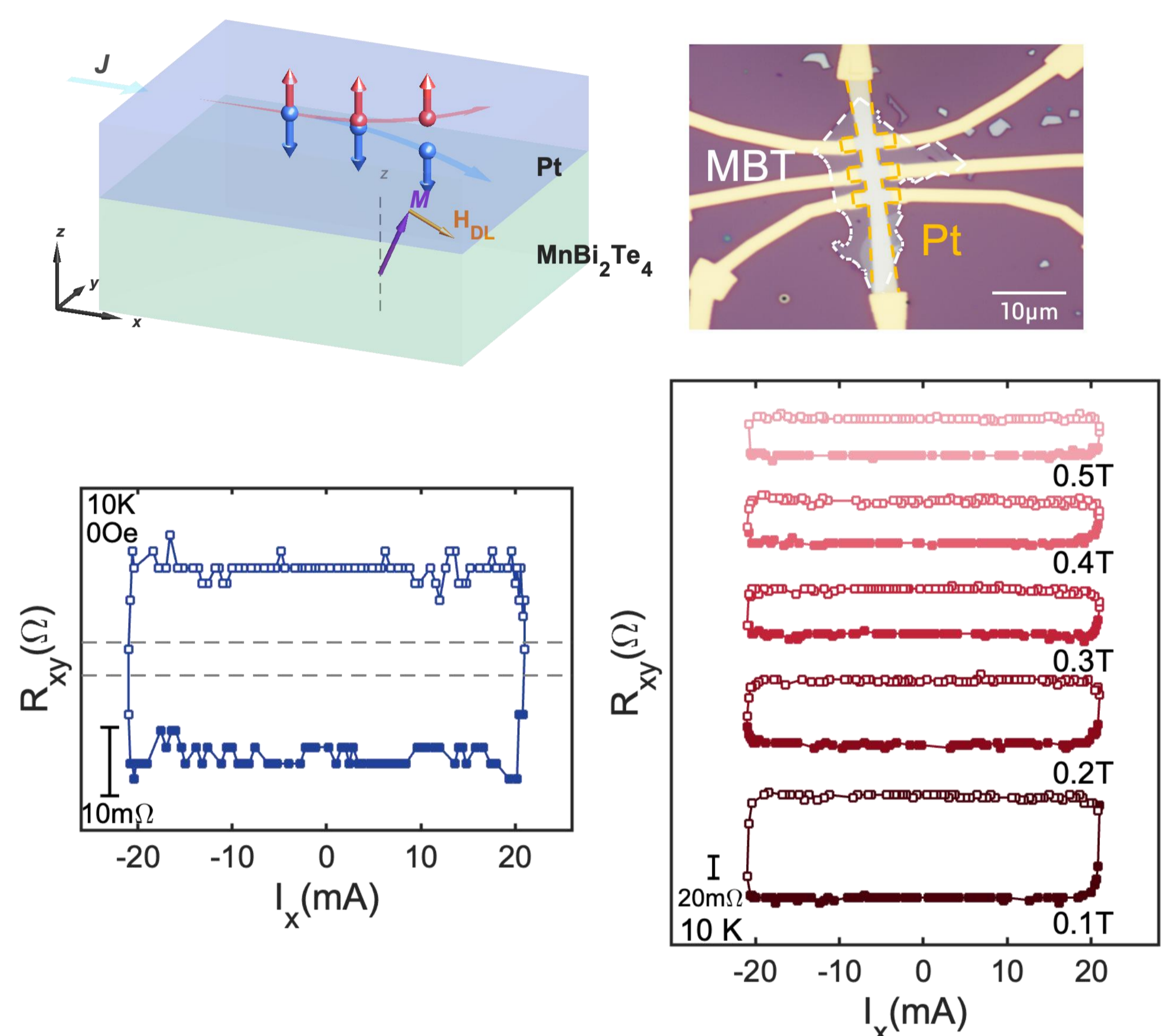
Here, we reveal that this degradation inherently stems from a severe macroscopic compensation caused by field-induced multi-domain fragmentation. To bypass this thermodynamic bottleneck, we utilize current-induced spin-orbit torque (SOT) in odd-layer MBT/Pt heterostructures. We demonstrate that SOT not only realizes deterministic field-free magnetization switching but also acts as a dynamic driving force to actively reconstruct the magnetic order. This reconstruction drives the system into a completely uncompensated antiferromagnetic ground state, yielding a Hall switching amplitude that is several times larger than conventional field-driven levels. Furthermore, exploiting the unique semi-insulating nature of MBT, we achieve an electrostatic modulation of the interfacial spin transport. Tuning the Fermi level into the topological surface state regime triggers a more-than-twofold amplification in the SOT switching efficiency. This giant enhancement demonstrates that the phase-coherent orbital hybridization of spin-momentum-locked Dirac fermions plays an important role in the interfacial spin transparency.

Origin of Hall Suppression



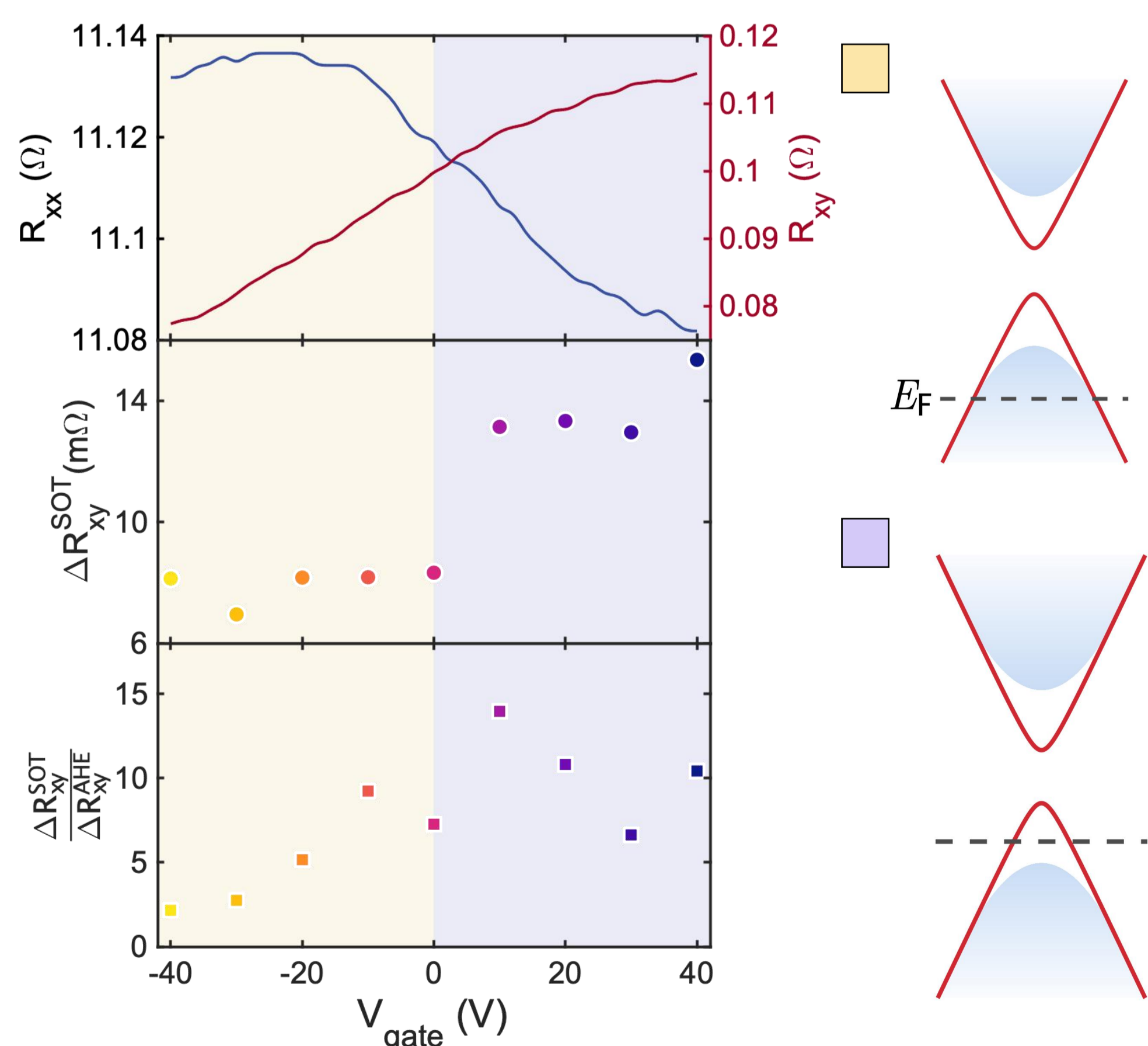
- Under global out-of-plane field sweeps, the 5_SL MBT is thermodynamically trapped in mixed multi-domain configurations.

deterministic field-free magnetization reversal by spin-orbit-torque

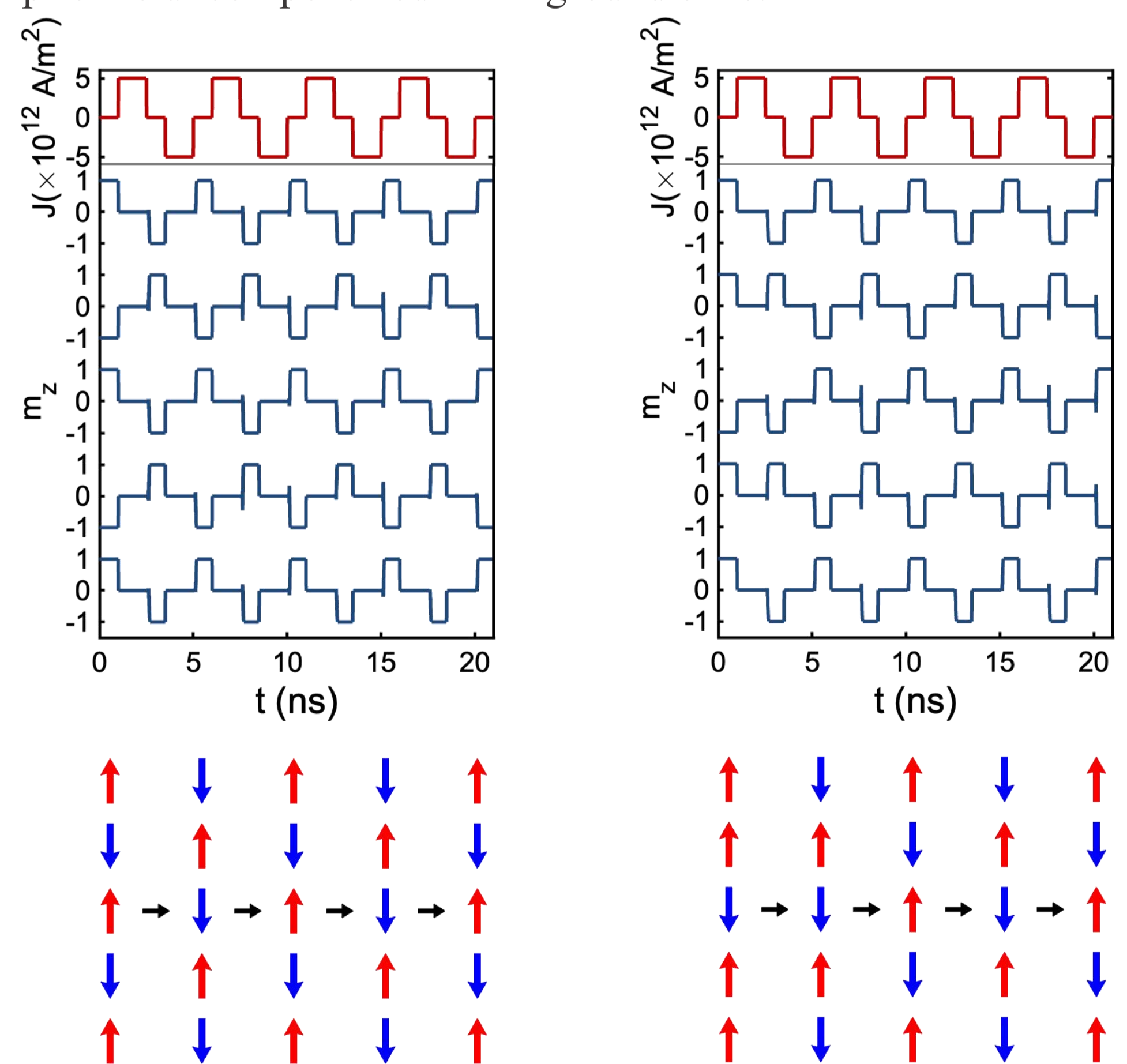


- SOT achieves deterministic field-free magnetization reversal with Hall amplitudes far exceeding field-driven sweeps, reconstructing the pristine uncompensated AFM ground state.

Gate-Tunable Spin Transparency



- Surface-localized Dirac wavefunctions maximize p-d orbital overlap and symmetry matching with Pt, boosting the interfacial spin-mixing conductance and spin transparency.



Conclusion

SOT establishes deterministic electrical switching of antiferromagnetic order in MBT, while topological surface states act as an active knob amplifying interfacial spin torques, opening a route toward topology-empowered antiferromagnetic spintronics.