

Abstract

This study investigates interfacial charge trapping in magnetic topological insulators on SrTiO₃ substrates at cryogenic temperatures. Bidirectional back-gate voltage (V_g) sweeps reveal a significant shift of approximately 40 V in both the positions of the longitudinal resistance peak (Dirac point) and the coercive field. These findings confirm that trapped charges dynamically shift the charge neutrality point, providing a crucial calibration model for precise Fermi level tuning in Quantum Anomalous Hall Effect (QAHE) applications.

Introduction

Magnetic topological insulators exhibit the dissipationless Quantum Anomalous Hall Effect (QAHE) at cryogenic temperatures, offering promising edge-state transport applications [1]. While SrTiO₃ substrates enable strong Fermi level tunability, severe interfacial charge trapping induces critical electric hysteresis. This study quantifies this interference to clarify how interfacial charge dynamics affect the physical stability and precise tuning of topological devices.

Experimental Methods

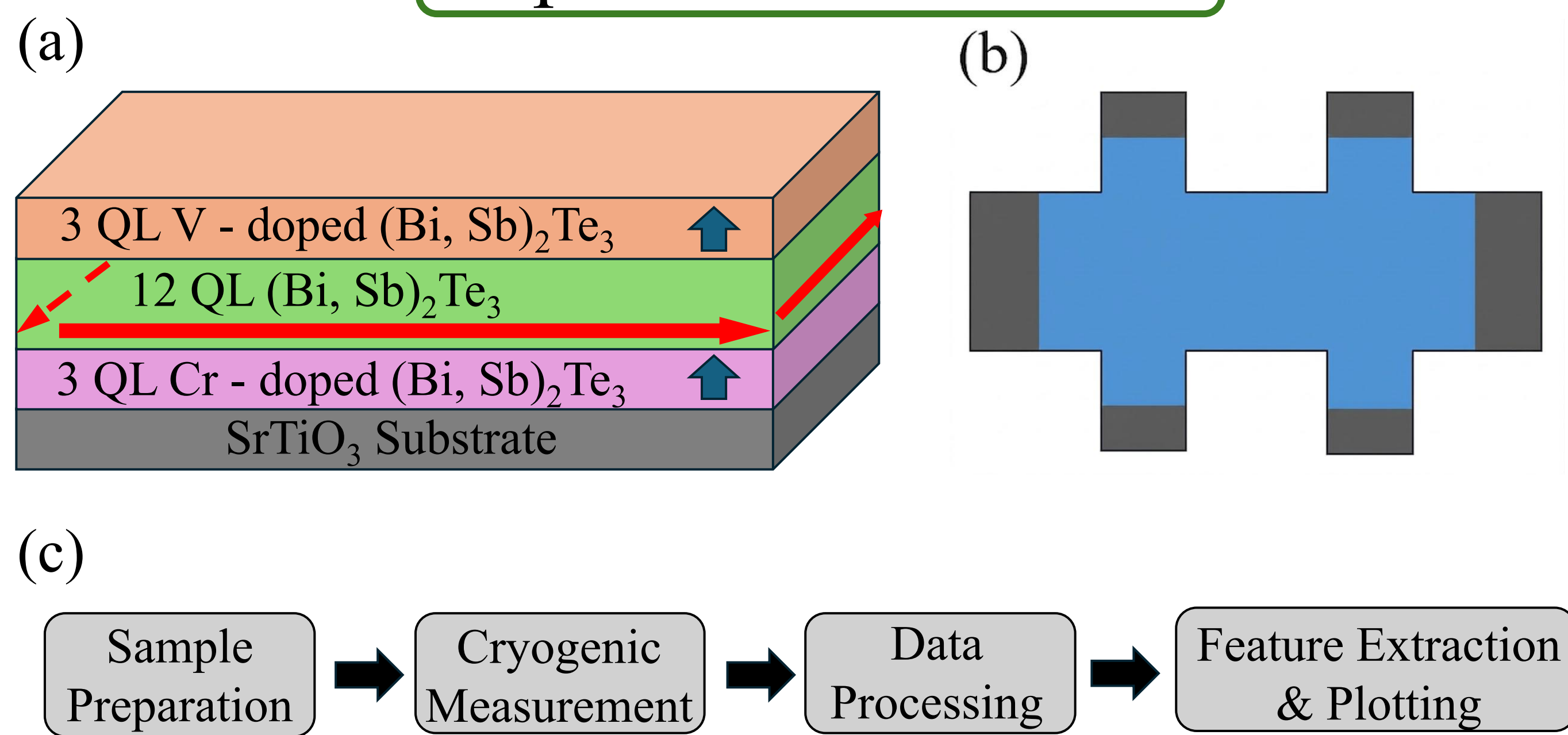


Fig. 1 (a) The magnetic topological insulator sandwich structure (3 QL (Quintuple Layer) V-doped (Bi, Sb)₂Te₃ / 12 QL (Bi, Sb)₂Te₃ / 3 QL Cr-doped (Bi, Sb)₂Te₃) grown on an SrTiO₃ (STO) substrate. The figure highlights the out-of-plane magnetization alignment of the magnetic layers and the induced dissipationless chiral edge states (red arrows) [2]. (b) The sample is patterned into a Hall bar to enable four-terminal measurements. (c) The overall experimental workflow: starting from cryogenic bidirectional V_g measurements in a dilution refrigerator and mathematical correction (extracting the pure Hall signal), to the final feature extraction and graphic analysis.

Results

Fundamental Magnetotransport Characteristics

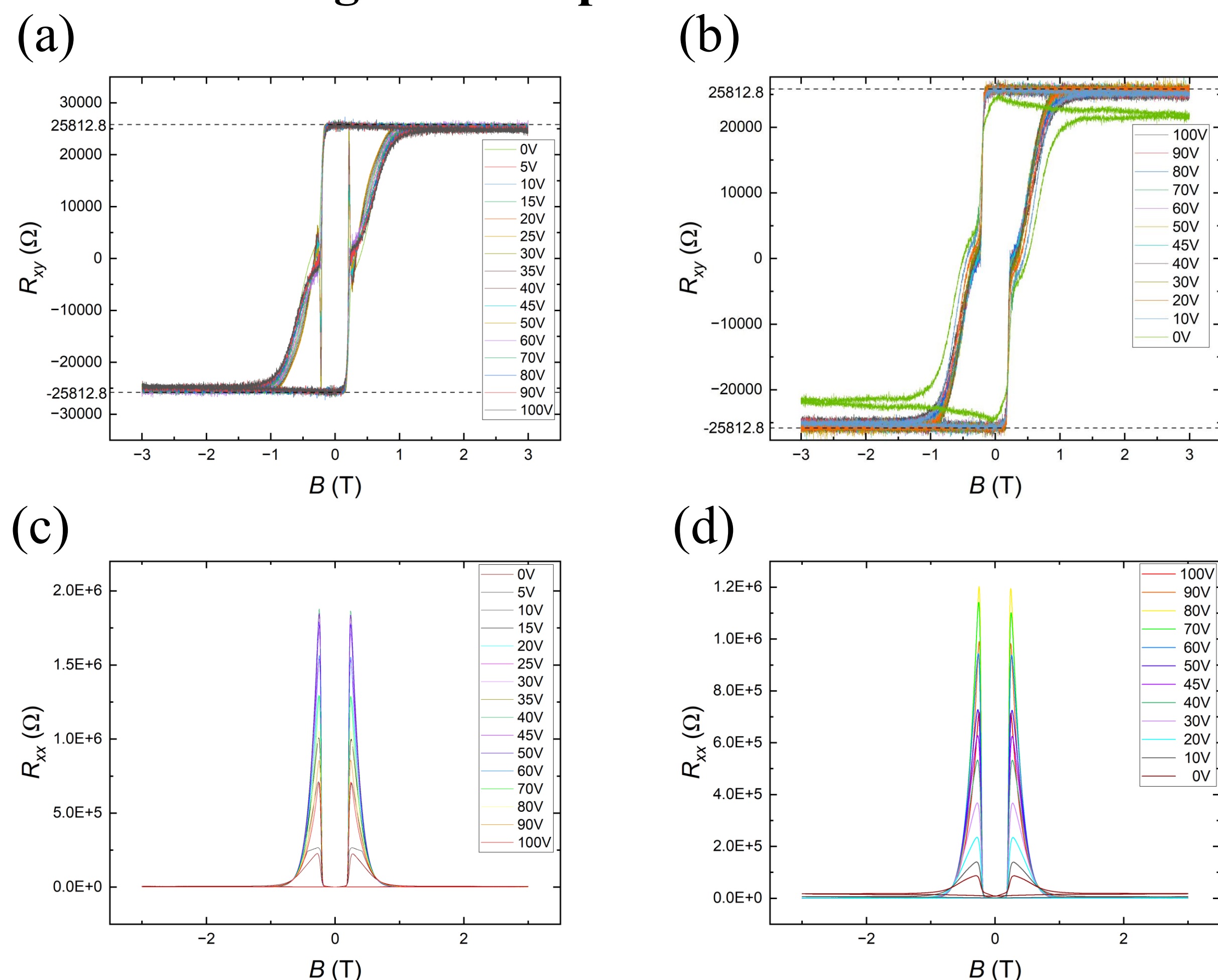


Fig. 2 (a)(b) The transverse Hall resistance (R_{xy}) - B curves clearly exhibit perfect square hysteresis loops with well-defined quantized plateaus at zero magnetic field, confirming that the sample has successfully entered the Quantum Anomalous Hall regime.

(c)(d) Concurrently, the longitudinal resistance (R_{xx}) - B curves display sharp dissipation peaks driven by domain wall scattering precisely at the magnetization reversal critical points (coercive field, B_c). An initial comparison of the up-sweep (a, c) and down-sweep (b, d) profiles reveals inconsistent magnetoresistance contours, indicating strong internal electric hysteresis.

Results

Macroscopic Dirac Point Shift

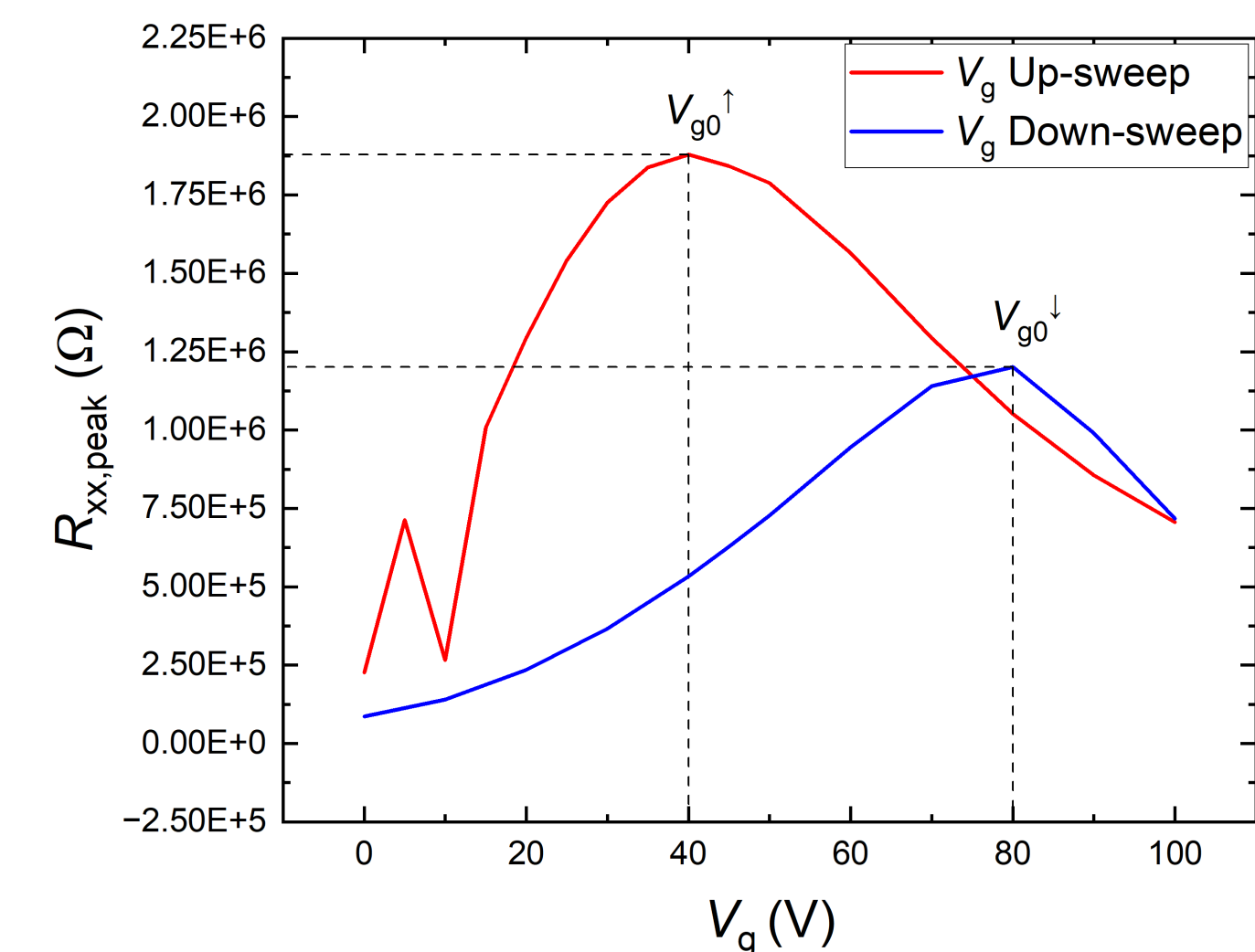


Fig. 3 Tracking the R_{xx} dissipation peak (Dirac point) reveals that it occurs at $V_g \approx 40$ V during the up-sweep and shifts significantly to $V_g \approx 80$ V during the down-sweep. This massive shift of $\Delta V_g \approx 40$ V directly proves that interfacial charge trapping between the STO substrate and the topological insulator film, creating a built-in field that severely screens the external gate voltage

Coercive Field Shift & Memory Effect

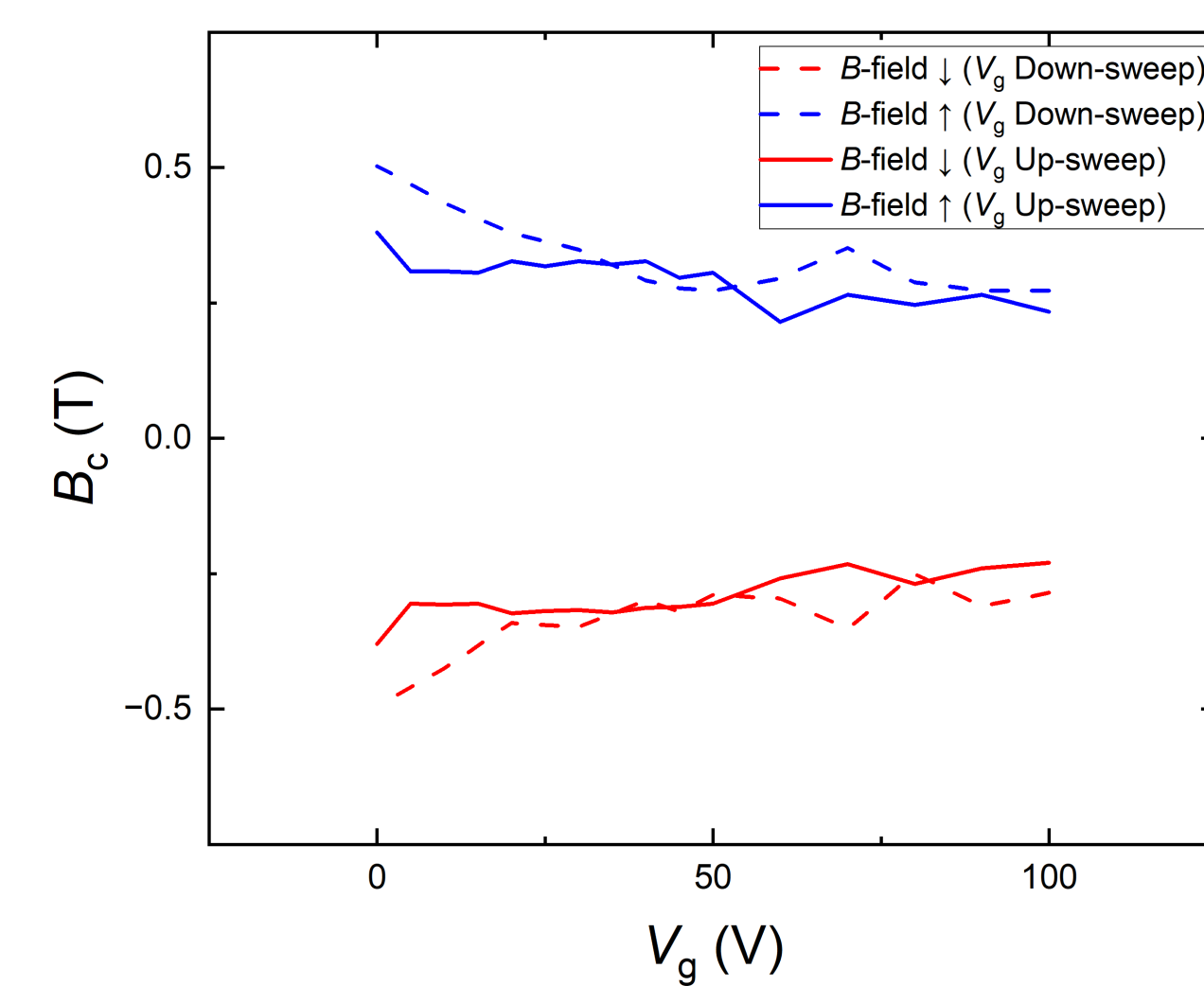


Fig. 4 The coercive field (B_c) pinning plateau exhibits an identical 40 V shift, moving from between 10 V and 50 V during the up-sweep to between 70 V and 80 V during the down-sweep. Furthermore, a strong memory effect occurs at $V_g = 0$ V, where B_c significantly increases from 0.38 T to 0.5 T after high-voltage polarization. This confirms that residual trapped electrons act as extra hole doping, enhancing magnetic anisotropy and the coercive field [3].

Conclusions

This study identifies dynamic interfacial charge trapping between the SrTiO₃ substrate and the topological insulator film as the physical origin of electrical hysteresis in magnetic topological insulators. Bidirectional gate sweeps reveal a highly consistent, shift ($\Delta V_g \approx 40$ V) in both the macroscopic Dirac point (R_{xx} peak) and microscopic domain pinning plateau (B_c). This dual electro-magnetic evidence directly explains the complex transport hysteresis. Furthermore, a pronounced memory effect at $V_g = 0$ V demonstrates that residual trapped electrons act as effective hole doping, which alters the magnetic anisotropy and significantly enhances the coercive field for domain reversal.

References

- [1] Klitzing, K. v., et al. 1980 Phys. Rev. Lett., 45, 494.
- [2] Qi, X.-L., et al. 2008 Phys. Rev. B, 78, 195424.
- [3] Checkelsky, J. G., et al. 2014 Nature Physics, 10, 731-736.