

Ferroelectric Control of Metallicity and Magnetism in Ultrathin Sr₂IrO₄ Films

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The Ruddlesden-Popper 5d iridate Sr₂IrO₄ is an antiferromagnetic Mott insulator in which the electronic, magnetic, and structural states are strongly coupled. Achieving nonvolatile voltage control of its electronic and magnetic properties is of significant fundamental and technological interests. Here, we report the ferroelectric control of metallicity and magnetism in ultrathin Sr₂IrO₄ via interfacial ferroelectric PbZr_{0.2}Ti_{0.8}O₃ (PZT) [1]. Reversing the polarization of PZT induces nonvolatile, reversible resistance modulation in Sr₂IrO₄. The conductance of PZT/Sr₂IrO₄ in both polarization states is predominantly above the quantum conductance of e^2/h with $\ln(T)$ behavior (Figure 1(a)), which is characteristic of a 2D weakly localized metal. This behavior is in sharp contrast to the 3D variable range hopping (VRH) behavior observed in single-layer Sr₂IrO₄ (Figure 1(b)), suggesting that interfacing with PZT induces a metal-insulator transition and dimensionality crossover. X-ray photoelectron spectroscopy reveals significant charge transfer at the interface, corroborated by Hall effect measurements, which can account for the enhanced metallicity.

In the single-layer sample, the in-plane MR exhibits low-field hysteresis associated with the antiferromagnetic spin-flip transition below 160 K, together with a large negative MR (Figure 1(d)). In contrast, the heterostructure shows negligible low-field hysteresis with positive MR dominating down to 6 K (Figure 1(c)). Below 6 K, the MR exhibits an opposite field-dependence compared with the single-layer sample, i.e., positive MR at low field followed by negative MR at high field, with a magnitude one order smaller. In addition, field-sweep-rate-dependent resistance dip is observed in the heterostructure, possibly associated with an incipient ferromagnetic state.

Switching the polarization of PZT modulates the out-of-plane anisotropic magnetoresistance R_{AMR} . For the polarization up state, unusual multi-level resistance pinning appears in R_{AMR} below 30 K, indicating polarization modulation of magnetic anisotropy. These results reveal the charge-mediated emergent phenomena at the ferroelectric/Sr₂IrO₄ heterointerface.

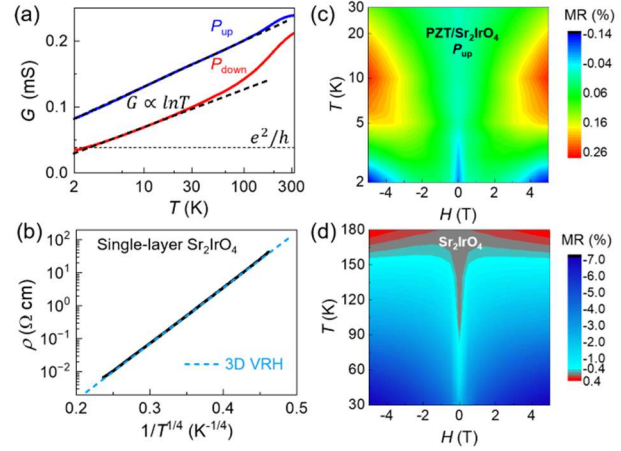


Figure 1 (a) $G(T)$ for PZT/Sr₂IrO₄ in polarization up (P_{up}) and down (P_{down}) state. (b) $\rho(T)$ for single-layer Sr₂IrO₄ with fits to 3D VRH. (c-d) Contour plots of MR vs. H and T for PZT/Sr₂IrO₄ (c) and single-layer Sr₂IrO₄ (d). Adapted from Ref. [1]

Supplementary Information

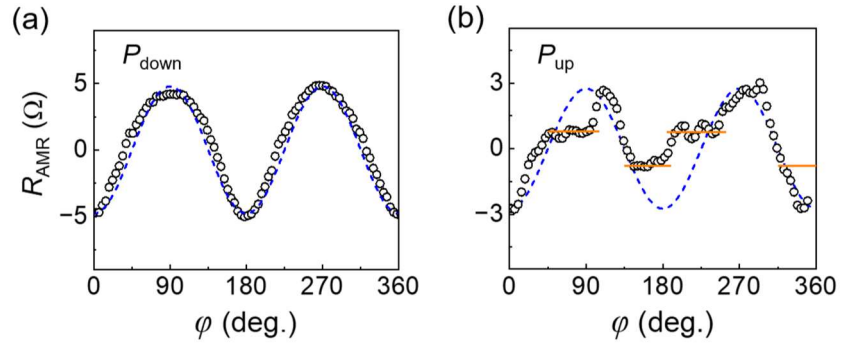


Figure 2 Out-of-plane angular dependence of R_{AMR} at 5 T and 20 K for PZT/Sr₂IrO₄ in the (a) P_{down} and (b) P_{up} states. Clear resistance pinning is observed in the P_{up} state. Adapted from Ref. [1]

[1] Y. Zhang, Q. Wu, Y. Hao, et al., Adv. Phys. Res. 4, 2400208 (2025).