Highlights

RESEARCH AREA 3 - Quantum Science and technologies - 2023

Coexistence and coupling of ferroelectricity and magnetism in an oxide two-dimensional electron gas

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Multiferroics are compounds in which at least two ferroic orders coexist, typically ferroelectricity and some form of magnetism. While magnetic order can arise in both insulating and metallic compounds, ferroelectricity is in principle only allowed in insulators, although ferroelectric metals have been proposed and several two-dimensional systems have been reported to behave in this way. However, their combination with and coupling to magnetic order have not been realized thus far. Here we show the coexistence of ferroelectricity and magnetism in an oxide-based two-dimensional electron gas. We report a modulation of the Ti-O polar displacements depending on the ferroelectric polarization direction, and a voltage-induced hysteresis of the sheet resistance that is reminiscent of the ferroelectric polarization loop. The transport properties of the electron gas display an anomalous Hall effect and magnetoresistance that can both be modulated and cycled by switching the remanent polarization, demonstrating a magnetoelectric coupling. Our findings provide new opportunities in quantum matter that stem from the interplay between ferroelectricity, ferromagnetism, metallicity and Rashba spin–orbit coupling.

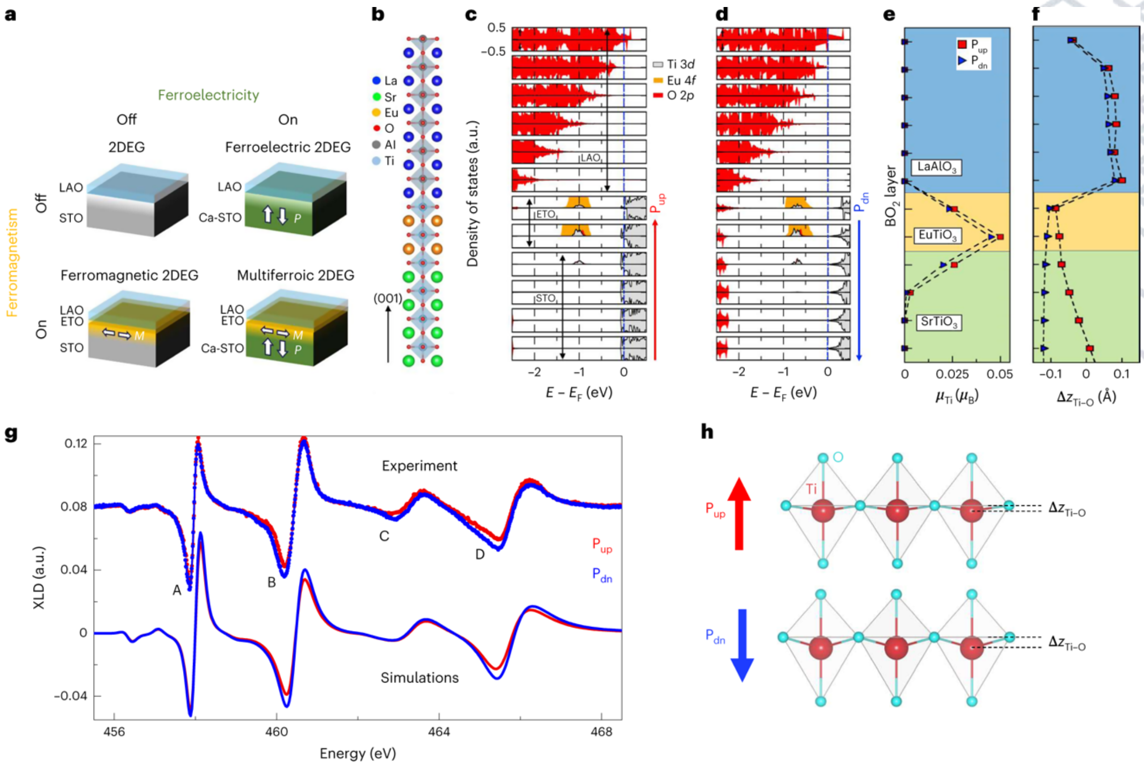

Fig. 1: (a) Multiferroic 2DEG. (b) A sketch of the slab configuration. (c,d) Layer-decomposed projected density of states on O 2p and Ti d states as a function of a polarization pointing toward (c) and outward from (d) the interface. (e) Computed magnetic moments on Ti cations for the two polar states. (f) The relative displacement of the B cation. (g) The X-ray linear dichroism spectra at the Ti $L_{3,2}$ edge measured at 2 K and the ferroelectric remanence for P_{up} and P_{dn} (top) and atomic multiplet simulations (bottom). (h) Sketches of the TiO_6 octahedra.

Reference: [1] J. Bréhin, et. al., Nat. Phys. 19, 823 (2023). [2] D. Stornaiuolo, et. al., Nat. Mater. 15, 278 (2016).

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