Highlights

ACTIVITY C Innovative materials with strong interplay of spin orbital charge and topological degrees of freedom-2020

Berry phase engineering at oxide interfaces

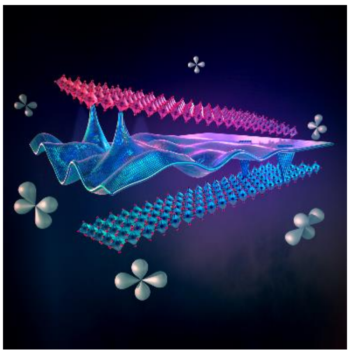
D. J. Groenendijk[1], C. Autieri[2,3], T. C. van Thiel[1], W. Brzezicki[2,3], J. R. Hortensius[1], D. Afanasiev[1], N. Gauquelin[4], P. Barone[2], K. H. W. van den Bos[4], S. van Aert[4], J. Verbeeck[4], A. Filippetti[5,6], S. Picozzi[2], M. Cuoco[2,7], and A. D. Caviglia[1]

[1]Kavli Institute of Nanoscience, Delft University of Technology, P.O. Box 5046, 2600 GA Delft, Netherlands
[2]Consiglio Nazionale delle Ricerche, CNR-SPIN, Italy
[3]International Research Centre MagTop, Institute of Physics, Polish Academy of Sciences, Aleja Lotników 32/46, PL-02668 Warsaw, Poland
[4]Electron Microscopy for Materials Science (EMAT), University of Antwerp, 2020 Antwerp, Belgium
[5]Dipartimento di Fisica, Università di Cagliari, Cagliari, Monserrato 09042-I, Italy
[6]CNR-IOM, Istituto Officina dei Materiali, Cittadella Universitaria, Cagliari, Monserrato 09042-I, Italy
[7]Dipartimento di Fisica "E. R. Caianiello" Università degli Studi di Salerno, 84084 Fisciano, Italy

PHYS. REV. RESEARCH 2, 023404 (2020)

Three-dimensional strontium ruthenate ($SrRuO_3$) is an itinerant ferromagnet that features Weyl points acting as sources of emergent magnetic fields, anomalous Hall conductivity, and unconventional spin dynamics. Integrating $SrRuO_3$ in oxide heterostructures is potentially a novel route to engineer emergent electrodynamics (Fig. 1), but its electronic band topology in the two-dimensional limit remains unknown. Here we show that ultrathin $SrRuO_3$ exhibits spin-polarized topologically nontrivial bands at the Fermi energy. Their band anticrossings show an enhanced Berry curvature and act as competing sources of emergent magnetic fields (Fig. 2). We control their balance by designing heterostructures with symmetric and asymmetric interfaces. Symmetric structures exhibit an interface-tunable single-channel anomalous Hall effect, while ultrathin $SrRuO_3$ embedded in asymmetric structures shows humplike features consistent with multiple Hall contributions (Fig. 2). The band topology of two-dimensional $SrRuO_3$ proposed here naturally accounts for these observations and harmonizes a large body of experimental results.

Fig. 1: Sketch of the geometric profile of the wave-function at oxides interfaces.



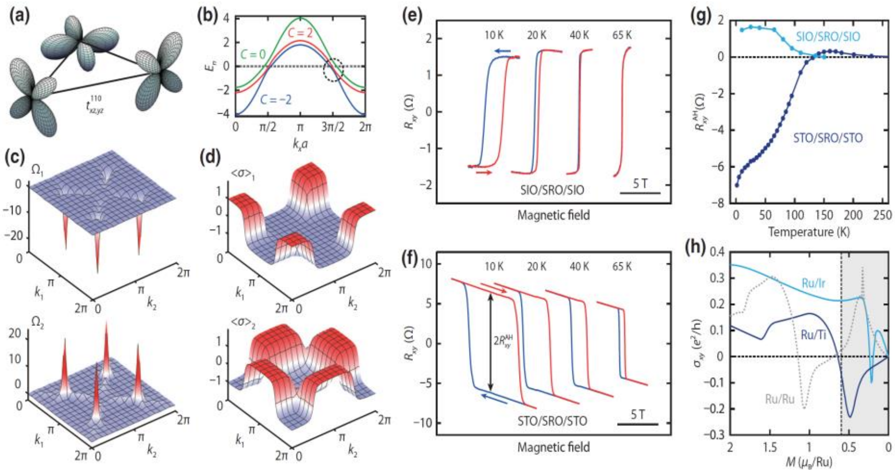


Fig. 2: (a) Next-nearest-neighbor hopping amplitude. Dispersion of Ru t_{2g} bands. (c) Berry curvature associated with topologically nontrivial Ru t_{2g} bands. (d) Spin polarizations for the corresponding bands. (e) and (f) Hall resistance of symmetric heterostructures as a function of temperature. (g) Temperature evolution of the amplitude of the AHE. (h) Evolution of the intrinsic contribution to the Hall conductance for various bilayers configurations as a function of the average Ru magnetization.