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Electrical Control of Inversion Symmetry

R. Ramesh (UC Berkeley), M. Fiebig, N.A. Spaldin (ETH Zurich), D.A. Muller, D.G. Schlom (Cornell)

Symmetry in crystalline materials largely dictates their properties and new functionalities can arise when inversion symmetry is broken and disappear when it is restored. **PARADIM users** have made a new material in which by applying a voltage they can "turn off" and "turn on" the inversion symmetry of the atomic arrangement. Inversion symmetry is what happens when you turn an object inside out. Turning a plain balloon inside out results in no change; it is indistinguishable from the starting object. In contrast, turning a glove inside out is distinguishable because at first the glove only fits on your right hand whereas after turning it inside out it fits only on your left hand. Being able to turn inversion symmetry on and off by applying a voltage has never been seen before. Voltages almost always break or remove symmetry; it's unprecedented to find a material where it can also "turn on" symmetry. This new ability allows the control of electronic, optical, and other properties by factors of one thousand to one hundred thousand, all at the same time, with reversibility and nonvolatility.

The new material is a superlattice of alternating 14-unit-cell-thick $BiFeO_3$ layers and 10-unit-cell-thick $TbScO_3$ layers on a $GdScO_3$ substrate in which a coexistence of centrosymmetric and non-centrosymmetric $BiFeO_3$ phases is stabilized at room temperature with antipolar, insulating and polar semiconducting behavior, respectively. Both phases are identified and characterized using a combination of **high-resolution and four-dimensional (4D) scanning transmission electron microscopy (STEM) at PARADIM**, piezoforce microscopy (PFM), and confocal second harmonic generation (SHG) over atomic and mesoscopic length scales.

L. Caretta, *et al.* *Nature Materials* **22**, 207–215 (2023).

(**right**) A cross-sectional electron microscope image showing the spatial distribution of polar and antipolar $BiFeO_3$ in the superlattice. Scale bars 10 nm.

(**below**) Mapping the polarization reveals a pattern (sale bar 5 nm) akin to the main character of a popular children's book.