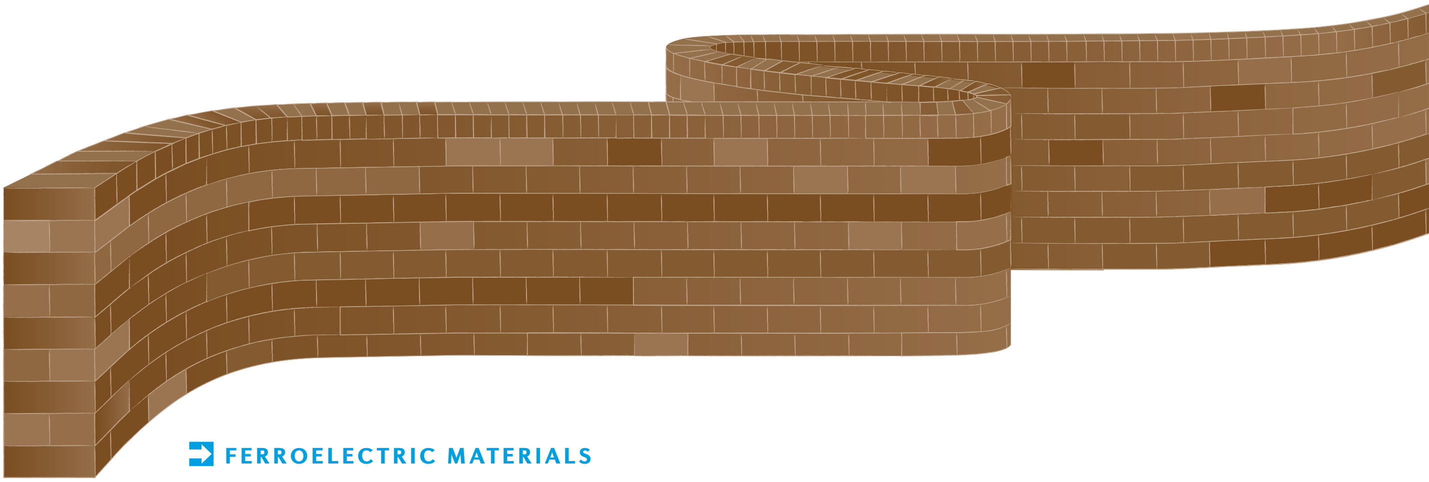

L.Robinson/NPG

FERROELECTRIC MATERIALS

Another bend in the wall

> As the domain walls deviate from their neutral position, they become partially charged and electrically conducting.

Ferroelectric domain walls that behave as erasable and rewritable metallic-like channels and show good stability are now a reality. “This finding is part of our quest for ‘domain-wall nanoelectronics’ — an approach in which the boundaries between ferroelectric domains constitute the functional elements of an electronic circuit,” explains Igor Stolichnov, first author of the study published in *Nano Letters*.

Ferroelectric materials are typically insulators, but the boundaries that separate regions of differing orientations of spontaneous polarization — namely, domain walls — can act as metallic conductors. The conducting walls are usually charged domain walls that can be reconfigured, erased and recreated by electric pulses, but are thermodynamically unfavourable and, hence, suffer from stability issues. In this new study, the research group led by Nava Setter, at the Ecole polytechnique fédérale de Lausanne (EPFL), demonstrates non-thermally activated, metallic conductivity in bent, stable domain walls. “We adopted an approach that permits us to combine the high conductivity of charged walls and the stability of conventional, neutral walls”, says Stolichnov. “This possibility exists when ferroelectric domain walls are forced to bend off their neutral position: they inevitably become partly charged and thus may display metallic-like conductivity.”

Setter and colleagues grew a titanium-rich film of a common ferroelectric material, lead zirconate titanate, on a substrate of $DyScO_3$. The lattice mismatch between the film and substrate produces a peculiar domain pattern. The pattern consists of so-called c-domains, in which polarization is oriented perpendicular to the substrate, and extremely narrow a-domains, with polarization parallel to the surface. To minimize the mechanical energy in the film, the a-domains are heavily strained, resulting in domain-wall distortion and bending. As the domain walls deviate from their neutral position, they become partially charged and electrically conducting.

Interestingly, the conduction shows very weak temperature dependence from 300 K down to 4 K. “This shows that the conductivity is metallic and not related to ionic defects,” says Setter. “This is important for reconfigurability because the movement of ions is much slower than that of electrons.”

The patterns of the domain boundaries can be engineered electrically with voltage pulses, or by applying a mechanical force using an atomic force microscope (AFM) tip. Using the latter method, the domains can be manipulated with high spatial precision — for example, two neighbouring channels can be connected with a transverse bridge. These new bridging domains can be created at 4 K and conduct in the same way as the native domain walls in the material. This high degree of control is a desirable feature for applications in nanoelectronics. In particular, this kind of system is promising for use in ultra-dense circuitry because the domains form extremely narrow conductive channels (less than 3–4 nm in width) and can be very close to each other (10 nm).

“We hope to demonstrate a sensor based on this technology in the near future,” says Setter. “However, the broader challenge in this research area is the development of domain-wall nanoelectronics combining the various functionalities of domain walls.” This integration of domain walls into circuits requires the development of good contacts and interconnections. “Connecting domain walls is not straightforward because the metallic conductivity disappears close to the surface,” adds Stolichnov. Another future research goal is the implementation of single domain walls in devices, such as memristors and field-effect transistors.

Giulia Pacchioni

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