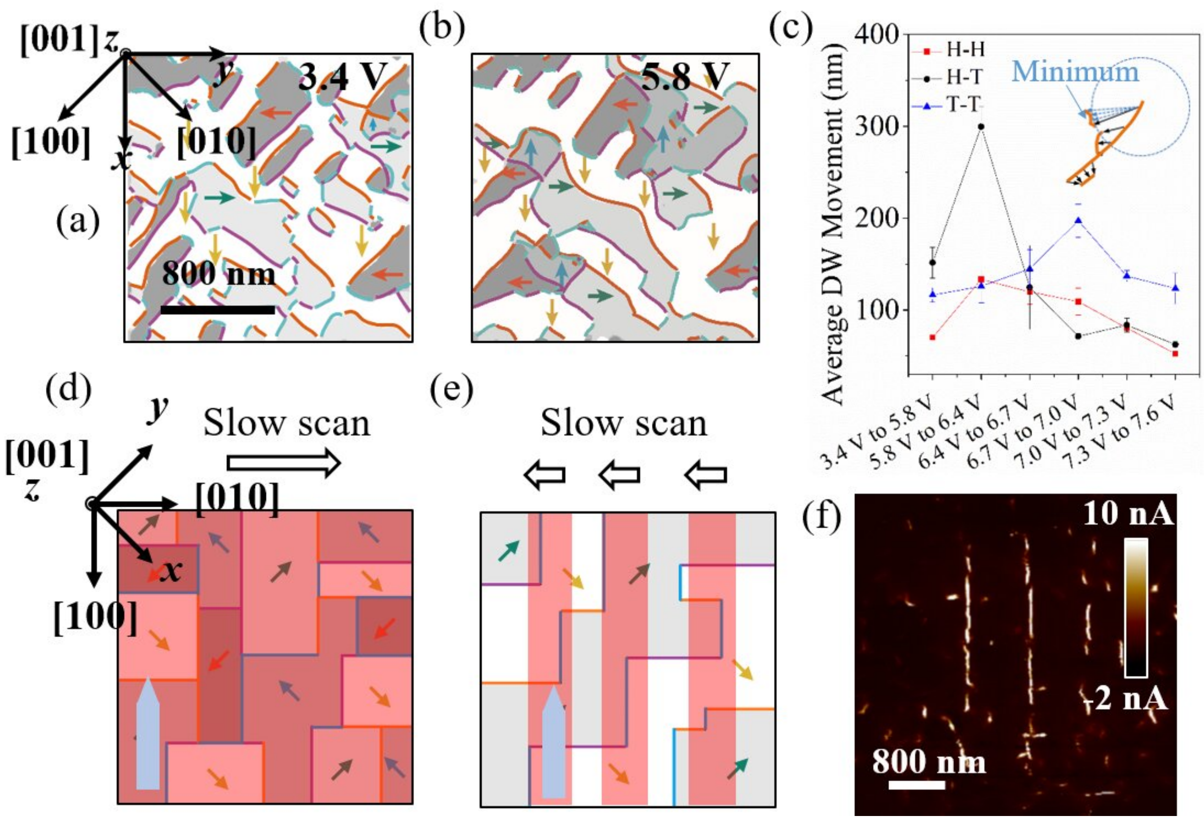
Controllable functional ferroelectric domain walls under piezoresponse microscope

February 6 2020



Domain patterns after (a) 3.4 V and (b) 5.8 V poling. Dark, white, light gray, and dark gray area represent domains with polarizations along [111], [111], [111], and [111], respectively. Head-head, head-tail and tail-tail DWs are colored by orange, light blue and purple, respectively. (c) Average DW movement during each poling process. Sketch of two-step poling process including scan poling by (d) lower and (e) higher electric field. (f) Well-aligned conductive tail-tail DWs are successfully produced. Credit: ©Science China Press

Ferroelectric materials possessing high photoelectric, piezoelectric and dielectric response are widely applied in industrial products, such as transducers, capacitors and memory devices. However, as the development of technology, miniaturization, integration and flexibility are of great importance, which could hardly be fulfilled by traditional bulk ferroelectric materials. Hence, nanoscale ferroelectric domain walls (DWs), with recently found dramatic mechanical, electrical, optical and magnetic properties aside from ferroelectric domains, have become a hot topic.

Despite the intriguing properties ferroelectric domain walls have, to put them into use better understanding of DW dynamics and developing DW manipulation approaches are urgently needed. It is known that external stimuli, such as electric field, mechanical strain and temperatures could influence DW morphology and stability. DW movement could also be affected by inertial properties of the sample as well as intrinsic characteristics of DWs. However, the impact of bound charges, which is one of the foremost characteristics of DWs, is mostly studied theoretically.

In a new research article published in the Beijing-based *National Science Review*, scientists at the Nanjing University in Nanjing, China, Rutgers University in New Jersy, USA and at Chinese Academy of Sciences in Shenzhen, China provide direct experimental insight into DW dynamics of differently charged DWs under electric fields. It is found via atomic force microscopy that the mobility of differently charged DWs in bismuth ferrite films varies with the electric field.

Under lower voltages, head-to-tail DWs are more mobile than other DWs, while under higher voltages, tail-to-tail DWs become active and possess relatively long average length. This is attributed to the high nucleation energy and relative low growth energy for charged DWs. Based on these results, researchers designed a two-step poling approach.

They polarize ferroelectric thin films with lower and higher electric fields by scanning the surface of the sample with the atomic force microscopy tip. Arrays of well-aligned stripe tail-to-tail DWs are successfully produced as conductive paths, while the orientation of DWs may be changed by varying the scanning direction of the tip. In this way, they achieved the oriented growth and configuration control of ferroelectric DWs.

"Our work unveils the remarkable impact of charge accumulation around DWs on DW mobility, providing a generalizable approach for DW dynamic studies in ferroic materials. The methodology proposed here for the advanced tunability of conductive DWs makes significant progress towards their applications in functional nano-devices," they claim.

More information: Shuyu Xiao et al, Dynamics and manipulation of ferroelectric domain walls in bismuth ferrite thin films, *National Science Review* (2019). DOI: 10.1093/nsr/nwz176

Provided by Science China Press