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Partial Ferroelastic Domain Mediated Ferroelectric Domain Switching

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The fundamental understanding of domain switching in ferroelectric thin films is critical for the development of ferroelectric devices. In ferroelectric $PbZr_{0.2}Ti_{0.8}O_3$ (PZT) thin films, full ferroelastic *a*-domains extending to the film surface are frequently observed. These *a*-domains can significantly affect the ferroelectric switching behaviors in the local nanoregions surrounding them. For example, it has been observed that full *a*-domains in tetragonal PZT thin films can hinder the motion of 180° domain walls by forming charged ferroelastic domain walls, leading to incomplete domain switching [1]. On the other hand, partial *a*-domain terminating beneath the film surface can also exist in PZT films. However, the domain switching behaviors mediated by these partial *a*-domain areas are not elucidated yet.

In this work, ferroelectric domain switching in a PZT thin film with a partial *a*-domain is studied by *in-situ* TEM, in which the voltage is applied to the film by a movable tungsten tip (Figure 1). We find that the ferroelectric switching dynamics is related to the position of the tungsten tip with respect to the partial *a*-domain (Figure 1). A weak hindering effect on ferroelectric switching by the partial *a*-domain is observed when the tungsten tip is right above center of the *a*-domain (position 1 in Figure 2). It is surprising that ferroelectric domain switching can be enhanced by the partial *a*-domain. When the tip is offseted (position 2), however, the ferroelectric domain switching is strongly hindered by the partial *a*-domain.

Figure 2a-f shows the evolution of a ferroelectric *c*-domain in the film with the tip located at “position 1”. At the forward switching process, the *c*-domain grow gradually with the increasing voltage. A weak pinning effect is observed when the *c*-domain passes through the partial ferroelastic *a*-domain, which is different from the strong hindering effect at a full ferroelastic *a*-domain (Figure 2g). When the positive voltage was applied again after this cycle, the domain switching mostly occurred within the bottom part of *c*-domain (Figure 3) indicating, that the ferroelectric *c*-domain switching is promoted by the partial ferroelastic *a*-domain. The observed phenomenon can be explained by the asymmetrical electrical filed distribution around the partial *a*-domain [2]. When the tungsten tip is moved to “position 2”, a strong hindering effect was observed (Figure 4). In this case, the tip of partial *a*-domain is an electrically activated nanoregion that can strongly hinder the growth of the *c*-domain.

In conclusion, both hindering and promoting effects of a partial ferroelastic domain on ferroelectric switching by have been observed. These results will be useful not only for understanding the dynamics of ferroelectric domain switching but also for the development of practical ferroelectric devices [3].

References:

[1] Gao, P. *et al*., Nat. Commun. **5** (2014), p. 3801.
[2] J. Britson, *et al*., Acta Materialia **75** (2014), p. 188.

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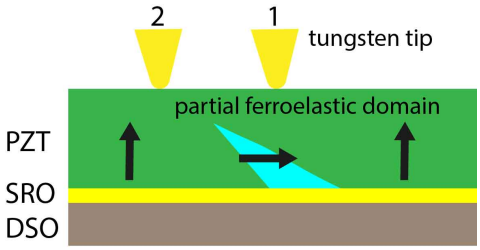

Figure 1. Schematic of PZT domain structure with a partial *a*-domain. The movable tungsten tip positions (1 and 2) are marked in the sketch. Note: SRO: $SrRuO_3$, DSO: $DbScO_3$.

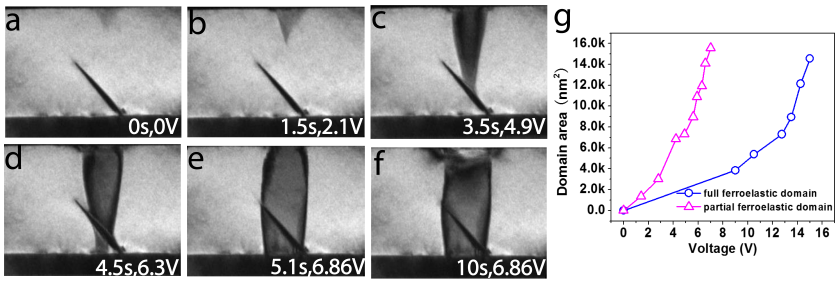

Figure 2. Weak hindering effect by a partial *a*-domain**.** a-f, Sequential images showing the ferroelectric domain evolution at a local region with a partial ferroelastic domainunder an positive applied voltage (0-7V). Elapsed time and voltage are indicated on the bottom center of each image. g, A comparison of the domain switching around full and partial ferroelastic domains, *i.e.*, a plot of the switched ferroelectric *c*-domain area (extracted from movies) as a function of applied bias.

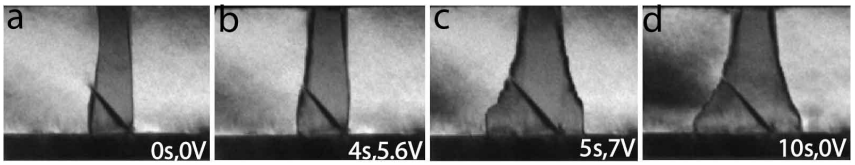

Figure 3. Domain switching promoted by the partial *a*-domain. Sequential images showing the ferroelectric c-domain evolution at a local region with a partial ferroelastic a-domain under positive applied voltage (0-7V-0V). Elapsed time and voltage are indicated on the bottom center of each image.

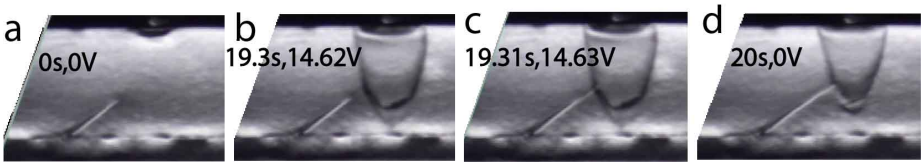

Figure 4. Strong hindering effect by the tip of a partial *a*-domain. Sequential images showing the ferroelectric domain evolution at at a local region with a partial ferroelastic a-domain under positive applied voltage (0-15V). Elapsed time and voltage are indicated on the bottom center of each image.

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