Domain structures in ferroelectric epitaxial WO3 thin films

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Background incl. aims

Tungsten oxides (WO3-δ) have in the past received attention for their gas sensing, catalytic and electrochromic properties. Recently, ferro- and piezoelectric properties123 coupled to local mechanical strain and even supercondutivity45 have been reported in tungsten (tri)oxide as well, inspiring interest in the electronic properties of these materials. However, this behavior is not yet fully understood and investigations of epitaxial films of tungsten oxides are particularly scarce. In this work, we aim to provide some insight into the nature and formation of ferroelectric domains and domain walls and their structural and electronic properties.

Methods

Epitaxial films of tungsten (tri)oxide were grown by pulsed laser deposition at different thicknesses on a number of different substrates to reveal the effects of (epitaxial) strain. The substrates used are yttrium aluminate, lanthanum aluminate and strontium titanate. Atomic force microscopy and piezoresponse force microscopy were used to visualize the surface topography of the resulting films and to image the ferroelectric domain structures, respectively. In addition, conducting atomic force microscopy was utilized to show local electrical conductivity. The nanoscale structure of the films was probed using aberration-corrected scanning transmission electron microscopy (STEM). Differential phase contrast imaging enables the imaging of the lighter oxygen anions. Real-space analysis of the STEM images using an in-house developed software tool provides a sensitive means for visualizing local strain gradients and polarization.

Results

Our results suggest an intricate coupling between the epitaxial strain imposed by the substrate, film thickness and the ferroelectric domain structure in the film. Low-strain films grown on yttrium aluminate show a fairly traditional domain structure consisting of a combination of purely polar, non-ferroelastic and ferroelastic domain walls, distinct from the type of domain structure reported for thicker films on the same substrate1 in which the polar nature of the film is localized to the domain walls, as well as those reported for bulk tungsten trioxide based on theory2. Electrical conductivity is found to be enhanced in the vicinity of the domain walls. In contrast, a higher degree of epitaxial tensile strain suppresses the formation of domains altogether, favoring strain accommodation through an extended planar defect.

Conclusion

We provide some new insights into the formation of polar domain walls and strain accommodation in epitaxial thin films of tungsten trioxide under different conditions of epitaxial strain and show that there is potential for the functionalization of domain walls therein.

Keywords:

ferroelectrics, strain, STEM, PFM, epitaxy https://doi.org/10.1051/bioconf/202412929023

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