Ferroelectric domain studies on free-standing $PbZr_{0.2}Ti_{0.8}O_3$ membranes

Qiuchen Wu, Alyssa Simpson, Kun Wang, Xia Hong

Department of Physics and Astronomy & Nebraska Center for Materials and Nanoscience, University of Nebraska-Lincoln

Abstract

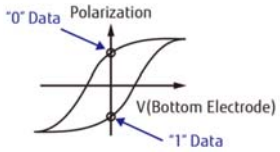
Free-standing ferroelectric oxide membranes are promising materials for building flexible, wearable electronics. For exploiting ferroelectric domain structures to represent the binary logic for information storage, it requires fundamental understanding of the static configuration and dynamic response of the ferroelectric domain walls (DW). In this study, we report the fabrication of nanoscale free-standing ferroelectric $PbZr_{0.2}Ti_{0.8}O_3$ (PZT) membranes, and scanning probe microscopy studies of DW in these samples. We deposit 10 to 50 nm epitaxial single crystalline PZT thin films on $Sr_3Al_2O_6$ (SAO) buffered $SrTiO_3$ (STO) substrates using off-axis RF magnetron sputtering. By water etching of the SAO buffer layer, we achieve suspended PZT membranes, and transfer the samples onto Au and LSMO/STO substrates. Piezo-response force microscopy (PFM) measurements reveal a uniform polarization down state for the as-prepared samples, We also systematically examine the DW roughness and creep behavior of the PZT membranes. Our study provides critical material information for the domain properties of PZT membranes for data storage applications.

Motivation

PZT crystal model

https://www.fujitsu.com/jp/group/fsm/en/products/fram/overview/

Hysteresis Loop



Ferroelectric domains can be used for information storage

Computer

www.istockphoto.com/vector/modern-computer-cartoon-gm862739386-143196107

Cellphone

www.gizbot.com/mobile/features/why-mobile-manufacturers-choose-metal-over-other-build-materials-036856.html

Free standing PZT membranes can lead to flexible wearable electronics

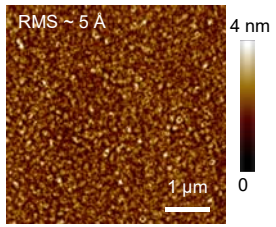
phys.org/news/2015-12-graphene-wearable-devices.html

- ✓ DW roughness ⇨ higher device memory density
- ✓ DW creep ⇨ higher speed

Fabrication Method

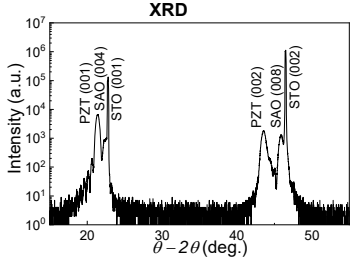
1. **Thin film growth** 50 nm PZT thin films were deposited on SAO buffered STO substrates using off-axis radio frequency (RF) magnetron sputtering method
2. **Characterization of 50nm PZT/20 nm SAO/STO (001)**

AFM



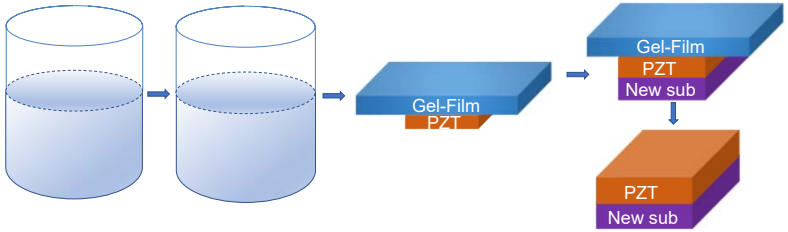
Smooth surface

XRD

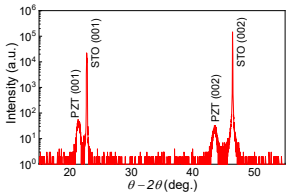


Single crystalline with no impurity phase

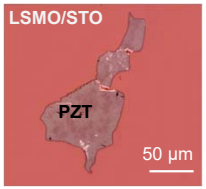
3. **Fabrication of free-standing PZT membranes**

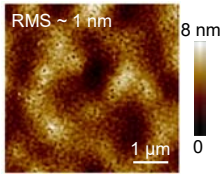


- XRD after etching SAO



- PZT transferred on LSMO/STO

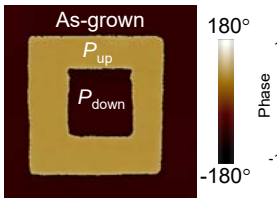


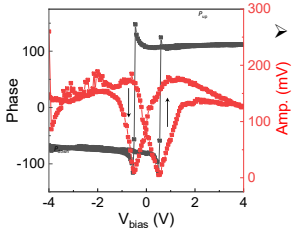


- **PZT phase retains after water etching SAO buffer layer**
- **The free-standing PZT membranes are rougher after transfer.**

PFM Characterization

PFM switching hysteresis

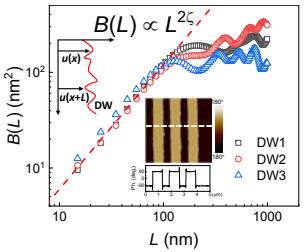


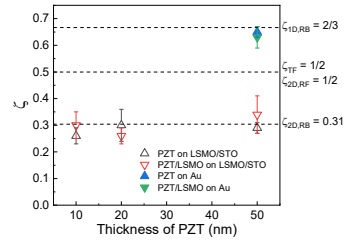


- PZT/LSMO on LSMO/STO
- Coercive voltages
  - +0.5 V for P_{up}
  - -0.5 V for P_{down}
- Nonvolatile bistable states
- Robust switching

DW Roughness

- PZT transferred on Au/SiO_2

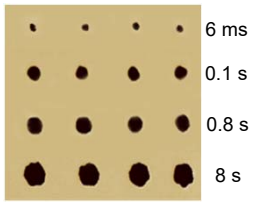


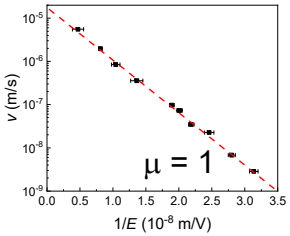


- **ζ is independent of PZT thickness**
- **Dominated by random bond disorder**
- **PZT and PZT/LSMO membranes show similar ζ**

DW Creep Behavior

- PZT transferred on LSMO/STO





DW creep suggests the random bond disorder is long ranged.

$$\nu(r_0) \propto \exp\left\{-\frac{\Delta}{k_B T}\left(E_0/E\right)^{\mu}\right\}$$

Conclusion

- We have successfully fabricated single-crystalline free-standing PZT and PZT/LSMO membranes and transferred the flakes on LSMO and Au substrates.
- We have studied the DW roughness and creep behavior in the PZT Membranes, which reveal long range Random Bond disorder dominated behavior.
- This study provides important information for implementing the PZT membranes for information storage applications.

Acknowledgement

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