Ferroelectric domain studies of free-standing $PbZr_{0.2}Ti_{0.8}O_3$ (PZT) membranes

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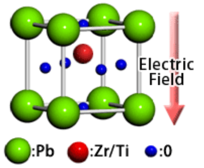
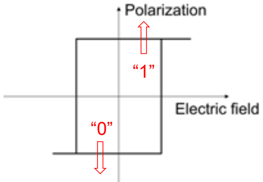
Abstract

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 50 nm epitaxial single crystalline PZT thin films on $Sr_3Al_2O_6$ (SAO) buffered $LaAlO_3$ (LAO) 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


Switching hysteresis

https://www.globalsino.com/EM/page1804.html

Ferroelectric domains can be used for information storage

https://unsplash.com/photos/gySMaocSdqs

https://unsplash.com/photos/y67dwfB2AiM.

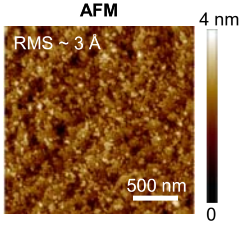
Free standing PZT membranes can lead to flexible wearable electronics

https://www.quytech.com/blog/the-future-of-modern-hologram-technology-for-every-industry/

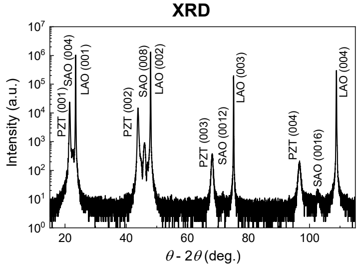
- ✓ DW roughness ⇨ higher device memory density
- ✓ DW creep ⇨ higher speed

Fabrication Method

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

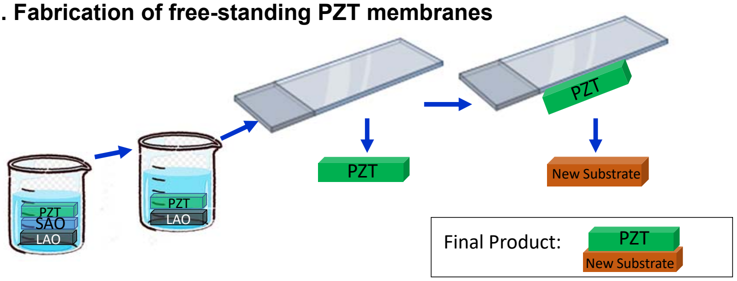

AFM

Smooth surface

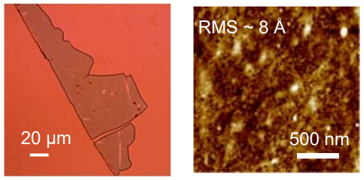

XRD

Single crystalline with no impurity phase

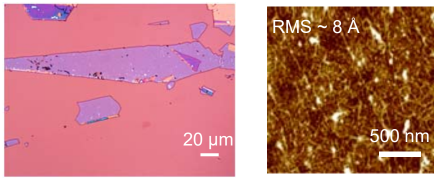
3. Fabrication of free-standing PZT membranes



- ➢ PZT transferred on Au/SiO_2/Si



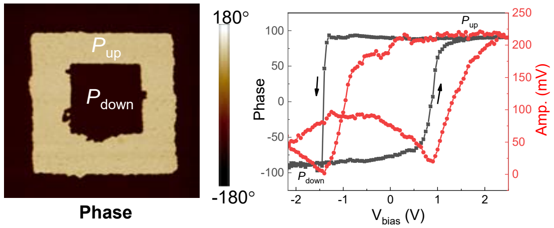
- ➢ PZT transferred on LSMO/STO



The free-standing PZT membranes are rougher after transfer.

PFM Characterization

PFM switching hystereses



- ➢ PZT on Au/SiO_2/Si

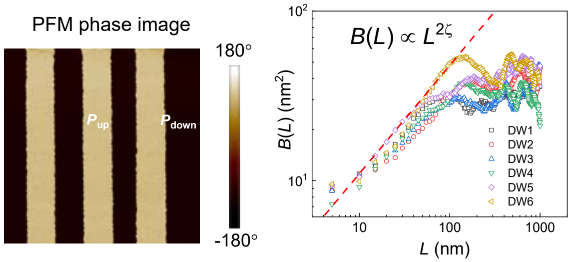
Coercive voltages

- +0.87 V for P_{up}
- -1.42 V for P_{down}

- Nonvolatile bistable states
- Robust switching

DW Roughness

- ➢ PZT transferred on LSMO/STO

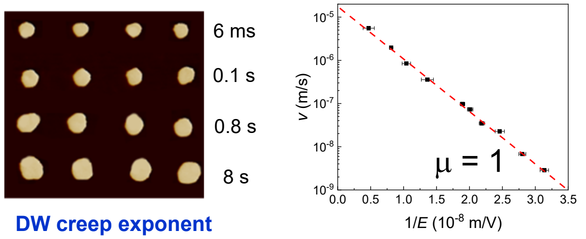


$\zeta_{Ave} = 0.29 \pm 0.04$

DW roughness dominated by 2D random bond disorder

DW Creep Behavior

- ➢ PZT transferred on LSMO/STO



DW creep exponent disagrees with 2D random bond disorder.

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

Flexoelectric effect?

Conclusion

- ➢ We have successfully fabricated single-crystalline free-standing PZT membranes and transferred the flakes on LSMO and Au substrates.
- ➢ DW roughness exponent agrees with 2D RB disorder
- ➢ DW creep exponent is larger than theoretical value for 2D RB disorder might be due to flexoelectric effect
- ➢ This study provides important information for implementing the PZT membranes for information storage applications.

Acknowledgement

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