Free-standing $PbZr_{0.2}Ti_{0.8}O_3$ top-gated two-dimensional MoS_2 photovotaics

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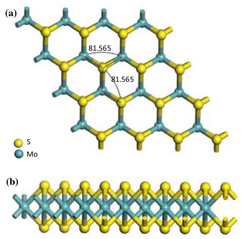
Abstract

Free-standing ferroelectric oxide membranes are promising materials for building flexible, wearable electronics. In our study, we will use the water-soluble $Sr_3Al_2O_6$ (SAO) as a sacrificial layer to prepare free-standing membranes of ferroelectric oxide $PbZr_{0.2}Ti_{0.8}O_3$ (PZT) and transfer it onto the MoS_2 channel as the top gate. Here, a scanning probe can be used to control the polarization of PZT to accomplish carrier injection and achieve n-type and p-type doping. The approach allows lateral p–n homojunctions to be arbitrarily formed and altered. Moreover, the ferroelectric domains are nonvolatile, reversible, and durable. By using a piezoresponse force microscopy (PFM) probe to precisely control the size and shape of the domain patterns, we could build optoelectronic and photovoltaic devices based on domain patterned 2D MoS_2 p–n junctions.

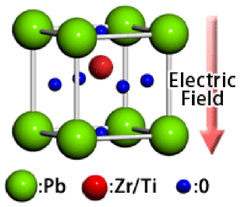
Motivation



Molybdenum Disulfide (MoS_2) can form Van der Waals heterostructures.

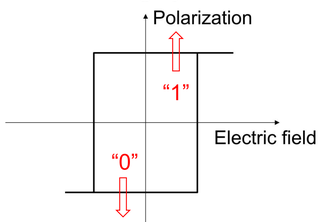
https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.researchgate.net%2Ffigure%2Fa-Top-view-b-front-view-of-MoS2-monolayer_fig1_351835275&psig=AOvVaw22DjXkILyRbiCtUUcQ4DJ&ust=1680021708983000&source=images&cd=vfe&ved=0CA8QjRxqFwoTCICvp9vG_P0CFQAAAAAdAAAAABAE

PZT crystal model

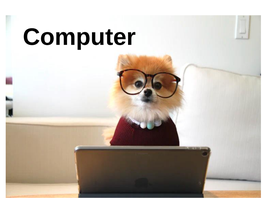


https://www.globalsino.com/EM/page1804.html

Switching hysteresis



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 and optoelectronics

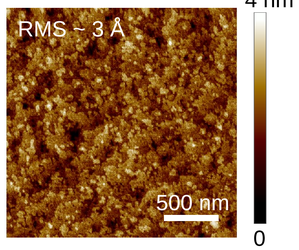
https://www.quytech.com/blog/the-future-of-modern-hologram-technology-for-every-industry/

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

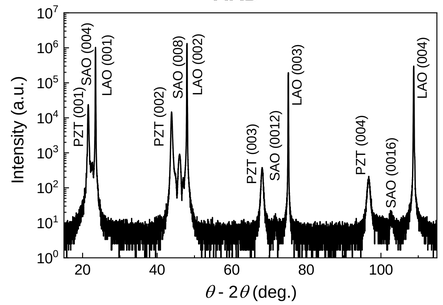
2. **Characterization of 50nm PZT/20 nm SAO/LAO (001)**

AFM



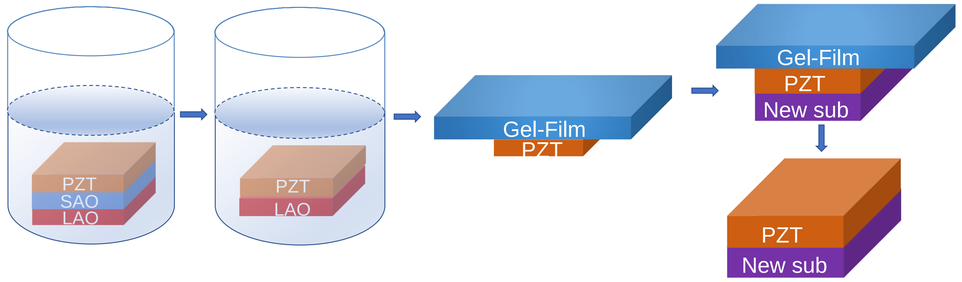
Smooth surface

XRD

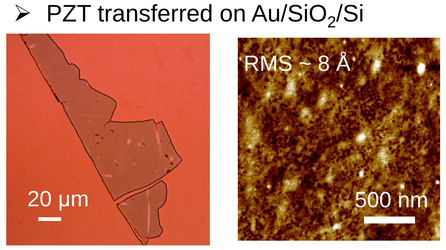


Single crystalline with no impurity phase

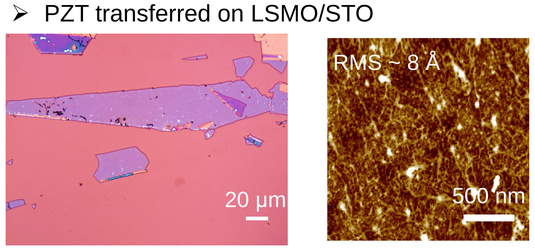
3. **Fabrication of free-standing PZT membranes**



➢ PZT transferred on $Au/SiO_2/Si$



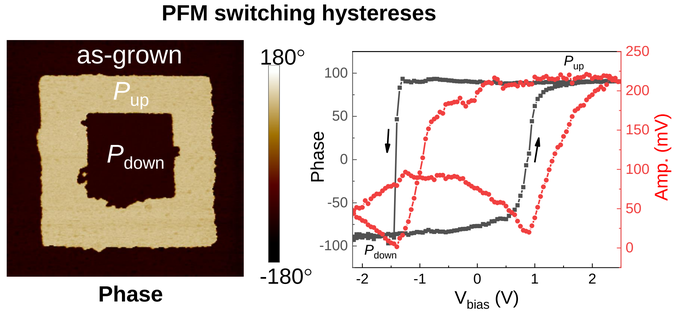
➢ PZT transferred on LSMO/STO



The free-standing PZT membranes are rougher after transfer.

PFM Characterization

PFM switching hystereses



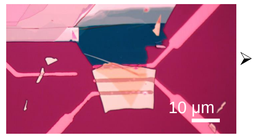
➢ PZT on $Au/SiO_2/Si$

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

- Nonvolatile bistable states
- Robust switching

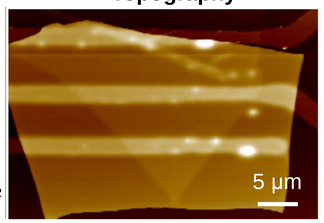
PZT/MoS_2 optoelectronic device

➢ 5L MoS_2 on pre-patterned Au electrode.

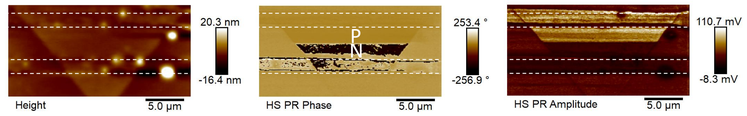


➢ 50 nm PZT/MoS_2 device

Topography

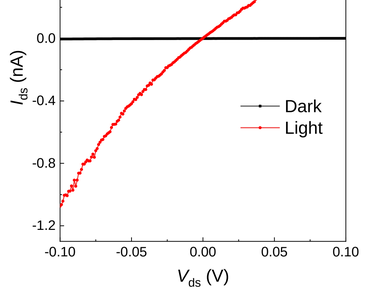


Creation of P-N junction

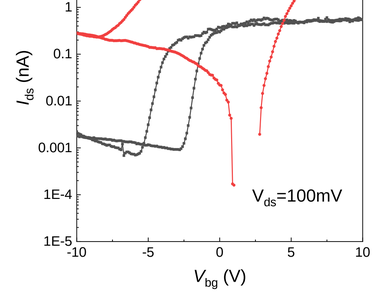


Optoelectronic behavior

Output characteristics



Transfer characteristics



Current on/off ratio of ~ 10^3 between dark and light

The emission of light has lifted the transfer curve and broadened the memory window

Conclusion

- We have successfully fabricated single-crystalline free-standing PZT membranes and transferred the flakes onto MoS_2 flakes.
- We have successfully polarized the PZT top gate into a P-N junction and characterized the device under dark/light environment, which gives an on/off ratio of ~ 1000, which is promising for application of optoelectronics.

Acknowledgement

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