Fabricating a **ZnO Piezoelectric Pressure** Sensor

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Piezoelectric response CONFIRMED — April 21, 2026

- Our device has **confirmed piezoelectric response**
- Signal **passed three independent controls** (triboelectric, polarity, and mechanical-coupling null tests)

Motivation:

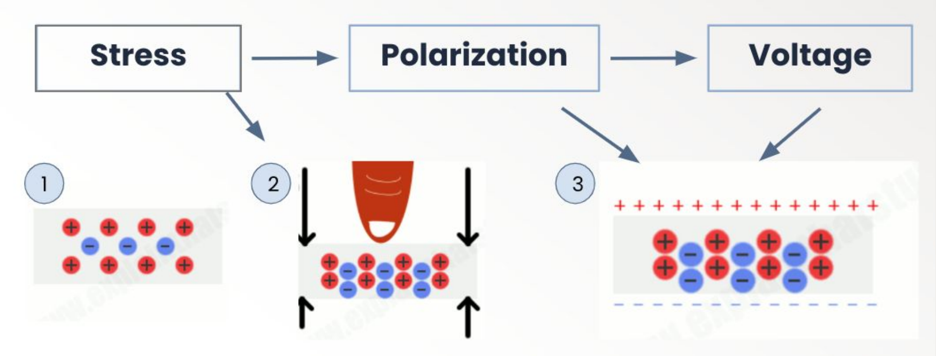
Why measure
pressure/impact?

Need: convert mechanical events (pressure changes/impact) into a measurable electric signals

Piezoelectric: converts applied stress into voltage/charge

Applications:

- concussion monitors (monitor pressure or mechanical contact)
- structural health (stress and damage)
- Robotics (touch sensing)



ZnO Thin Films

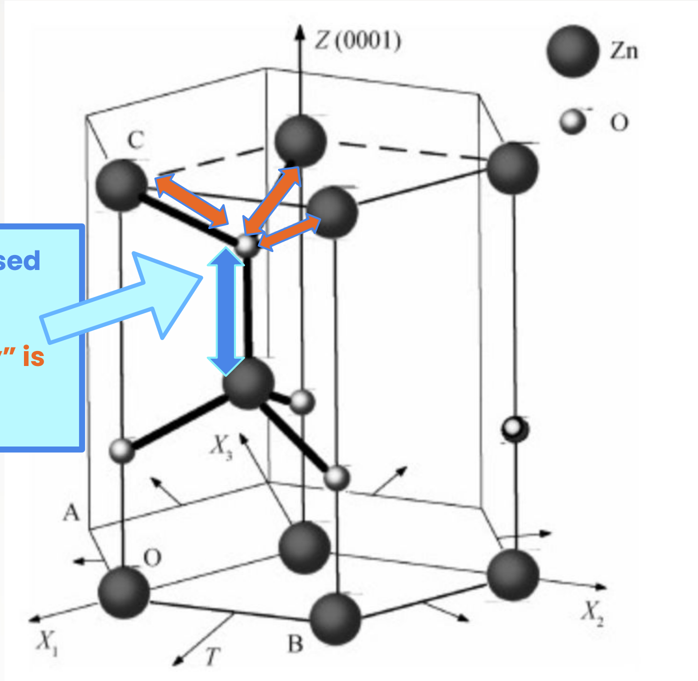
ZnO is **wurtzite and non-centrosymmetric**

Lacks inversion symmetry -> generates polarization
when stressed

Thin film **advantage**

Bottom electrode -> ZnO ac
Easy to interface with electronics

- Largest net polarization caused from applying pressure “vertically”
- Applying pressure “laterally” is less effective due to lattice spacing



Strongest piezoelectric response when stress is aligned with **polar C-axis**

Project Goal

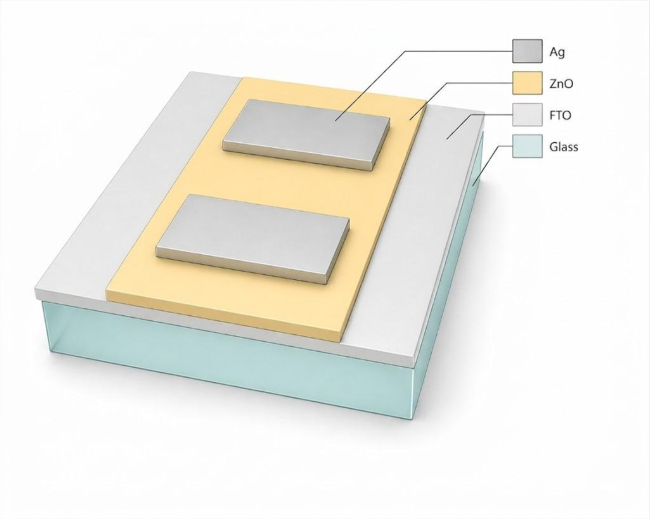
Fabricate and characterize a **ZnO thin-film piezoelectric pressure sensor** and **quantify** its **electrical output** under controlled loading.

Film Growth

Final Parameters:

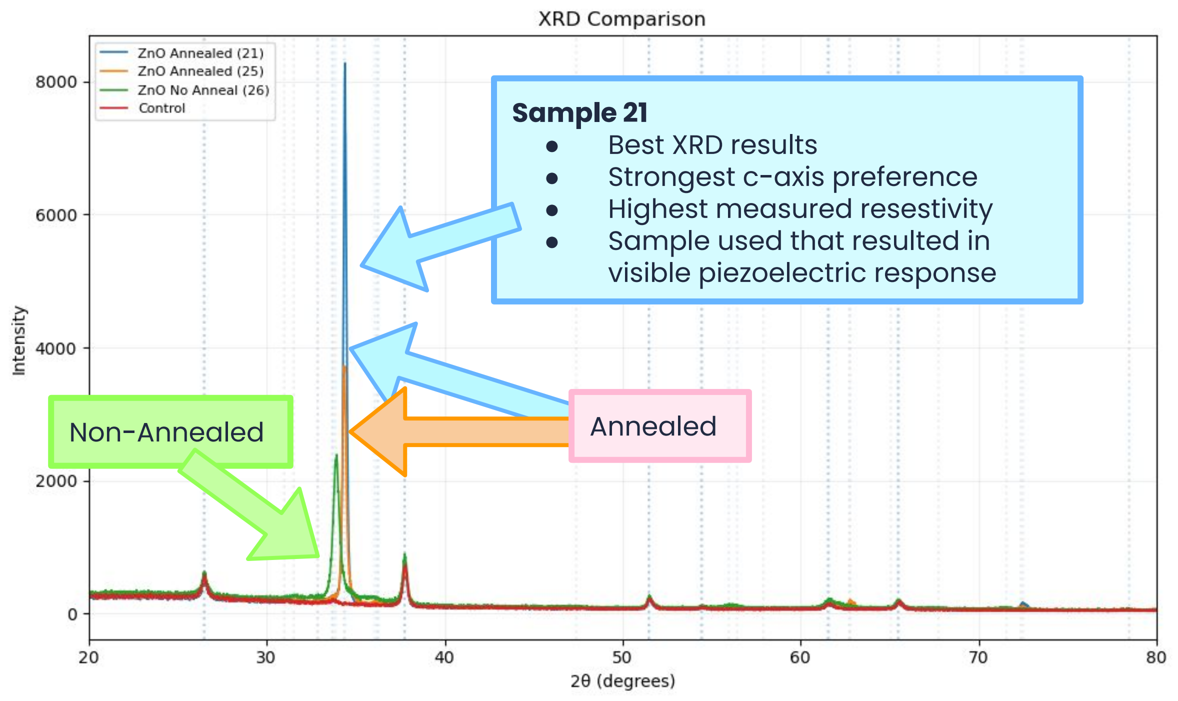
- FTO covered glass slab (25 mm x 25 mm) as substrate
- Cleaned each target for 2000 pulses
- ZnO grown in 5 mtorr O_2 on low for 20,000 pulses
- Annealed for 1 hour at 500 ℃ in heat oven
- Ag grown in vacuum for 10,000 pulses with a two rectangle cast
- Ag paint on some devices to improve probe contact

Device Diagram:



XRD Results:

Summary:
Annealed ZnO samples had more consistent and more intense peaks at desired c-axis orientation [0,0,2]



Results

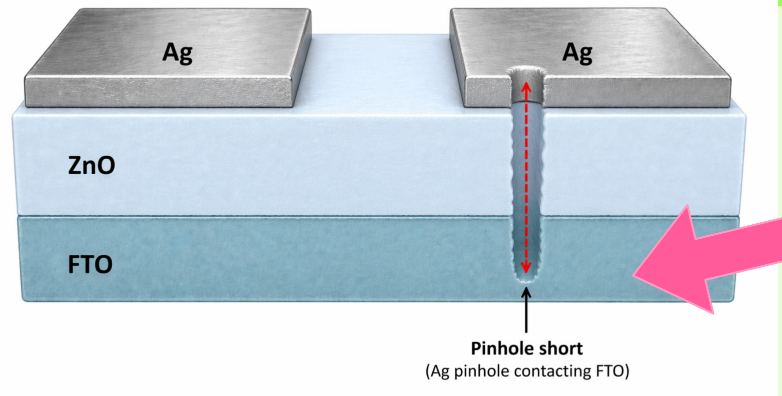
Resistivity

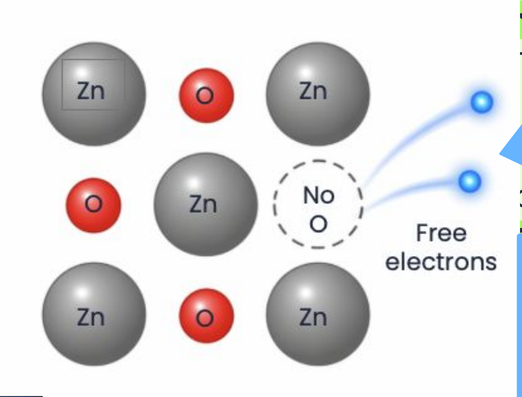
Meth

-

Obse

-
-
-



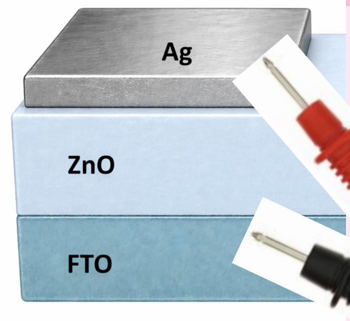


ner resistance
1 = 107k ohms
ystal quality,
onnection, etc.

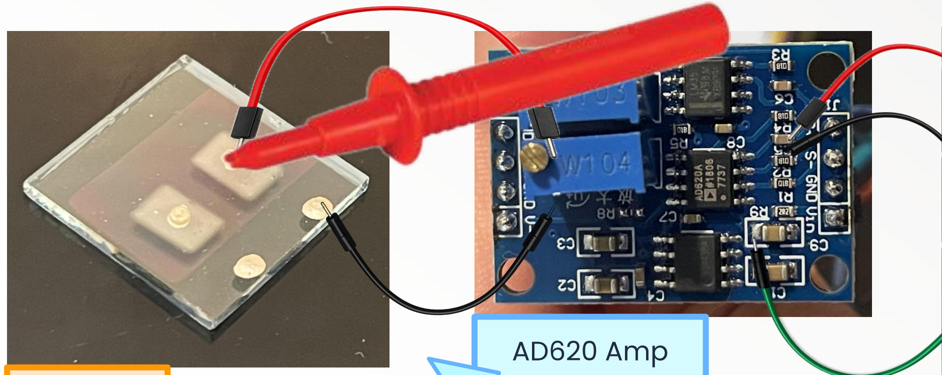
Oxygen Vacancy →
Free electrons →
n-type semiconductor →
lower resistivity

Potential

- **Pin**
  -
- Not
  imp
  shorts:
  - **Candidates**: grain-b
    oxygen-vacancy, par
    defects (ex. density v
  - **Future:**
    - anneal for **longer** than one hour so that it has more time to fill oxygen-vacancys
    - PLD at **higher** oxygen levels so oxygen-vacancies are less likely to form

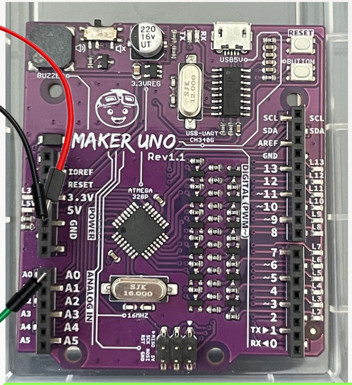


Voltage Measurement Method



Sample

AD620 Amp



Arduino Uno (10-bit ADC)

Computer

Used our 107k ohm sample. (Sample **21**)

- multiplies our signal by **62x** before measurement
- differential input **rejects** 60 Hz **ambient noise** by a factor of 100,000.

An oscilloscope scope does neither

Noise Floor:

- 200-500 μV at sensor input
- Note: minimum in oscilloscope is 1mV

Pressing down:

- Plastic insulating tip is used to apply pressure on the order of 10^2 Pa - 10^3 Pa
- **Signal**: 100-500 μV at sensor input

Signal and Mechanical Force Application

Single Tap :

- Creates a signal of around ~100-500 µV
- Well below noise floor for multi-meter and oscilloscope, within the noise of the AD620 setup
- Does not indicate non-piezoelectric behavior but measurement gets lost in the noise

Rythmic/Cyclical Taps:

- Same signal amplitude as a single tap
- Rhythmic tapping at ~2Hz
- Pressure applied in a cyclic fashion does yield **coinciding changes in voltage**
- Cyclical spikes can be differentiated from random noise fluctuations
- Signal is still close to threshold so quantitative results were not made yet

Discussion

Initial Project Goal: Fabricate and characterize a **ZnO thin-film piezoelectric pressure sensor** and **quantify** its **electrical output** under controlled loading.

Success:

- Established ideal growth conditions using PLD and annealing to grow ZnO with the ideal crystal orientation (002)
- Created thin film devices where resistance measurements provided early insight into device quality
- Measured potential differences across thin film electrodes associated with applied pressure = visible piezoelectric response

Long-Term Goals

Post ZnO Sensor Film Growth:

- Most Piezoelectric sensors used today are **lead-based**. There are new regulations to phase these out and ZnO is the leading **lead-free** alternative
    - More infrastructure and money is backing ZnO pressure sensors

- Growing ZnO films using PLD offers a cheap method of manufacturing many pressure sensing devices

- Affordable pressure sensors have many applications including
    - ➔ Robotics
    - ➔ Wearable Health Devices
    - ➔ Altitude measurements

Future Timeline
(how we will continue with **your** funding)

01 **Reduce shorts + leakage** (minimize pinhole conduction paths)

02 **Increase ZnO resistivity (MΩ)**

03 **Refine annealing/PLD growth**

04 **Use calibrated loading** (use indentors)

05 **Lower measurement noise** (shielding or amplification)

06 **Quantify voltage + pressure** (linearity and repeatibility)

RESOURCES

- Thank you: Dr. Rene Lopez, Dr. Shane Brogan, David Stilwell

Sikarwar, S., Satyendra, Singh, S. *et al.* Review on pressure sensors for structural health monitoring. *Photonic Sens* 7, 294–304 (2017). https://doi.org/10.1007/s13320-017-0419-z

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Almassri, Ahmed & Wan Hasan, W. & Ahmad, Siti & Ishak, Asnor & Mohamad Ghazali, Aina Mardhiyah. (2015). Pressure Sensor: State of the Art, Design, and Application for Robotic Hand. Journal of Sensors. 2015. 12. 10.1155/2015/846487.

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Questions?