Research Experiences for Teachers and Young Scholars in Advanced Self-Powered Systems of Integrated Sensors and Technologies (ASSIST)

PZT Thin Films: Poling Study

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Motivation for Poling

Poling in this study (see Fig 2) was done in order to improve performance of samples provided by a sponsor. Optimized poling conditions need to be determined for each family of PZT samples. For example, different microstructures require differences in the amplitude of the electric field applied, the amount of time it is applied for, and the optimal temperature to hold a sample at during the poling process.

Piezoelectricity: Introduction

Piezoelectricity can be used to scavenge energy from motion of the human body. Piezoelectric ceramics and films are typically made of lead zirconium titanate (PZT). This material has a crystal structure, seen in figure one, which spontaneously polarizes, leading to a build up of electrical charge when the material is stressed, producing the piezoelectric effect.

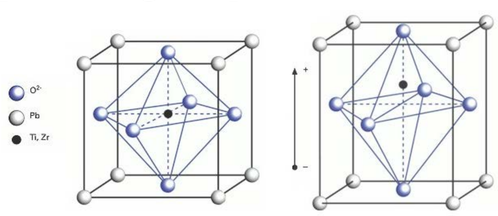
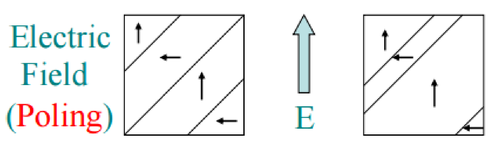


Fig. 1: The spontaneous polarization of the PZT crystal structure can be changed by movement of the charges either due to a mechanical deformation or by application of an electric field.

Dipoles in a PZT Sample

In order for the material to exhibit a new piezoelectric effect, the dipoles need to be aligned. The dipoles can be shifted into similar orientations through the poling process. To align the dipoles, the electroceramic material is exposed to heat and an electric field over time. This can be seen in figure 2; this process is referred to as poling of the material.

Fig. 2: Poling of the material moves the domain wall of the crystals, shifting the direction in which they polarize by causing their structure to flip polarization directions.



Acknowledgements

I would like to thank my mentors for taking the time to explain again and again for me and taking the time to break down the concepts so I could understand. They also took the time to go over the lab procedures slowly and made sure I understood what I was doing, not to mention letting me ask lots of questions. The other teachers in the RET and REUs helped with motivation, ideas, and laughs through my time here.

Resources

Figure 1: http://mainland.cctt.org/istf2009/images/Titanium.jpg

Other images from Xiaoli Tan lecture, Electroceramics by Moulson and Herbert, made by mentors, or taken in the lab by author of poster

Poling Process

The process for poling a sample is displayed below. Part of the process is allowing twenty minutes of high electric field exposure to align the dipoles.

1. Unpoled sample data collected (sponsor samples).
2. Sample connected on probe station (Fig. 3 and Fig. 4), heating of sample and electric field applied to shift the orientation of the dipoles.

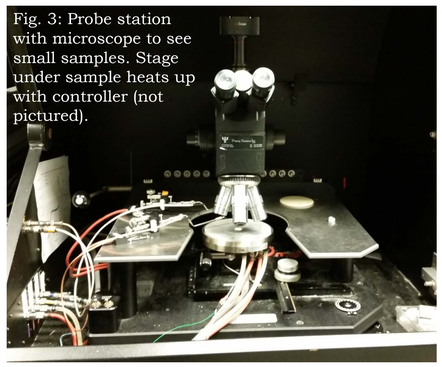


Fig. 3: Probe station with microscope to see small samples. Stage under sample heats up with controller (not pictured).

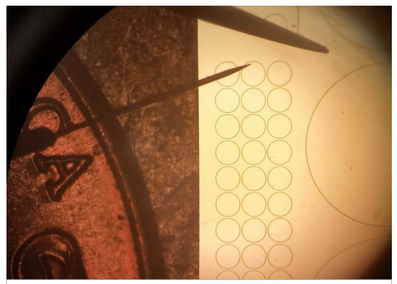


Fig. 4: Sample under microscope, penny for scale in image. Each small circle is a sample and top electrode to connect to and test. Bottom electrode is rest of sample.

3. Sample cooled and brought to DBLI (Fig. 5) for measurements.
4. Repeat process at another voltage on another sample (Fig. 4). Sometimes samples break down, like in figure 6. This helps to determine the maximum allowed field.

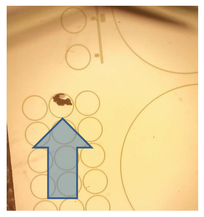
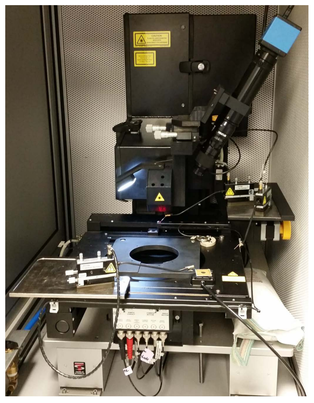


Fig 5 (at right): The DBLI shown, the stage with loading spot for wafers at the bottom right, with contact and microscope like probe station.

Fig 6 (at left): A sample that has undergone dielectric breakdown. This can happen if there are defects within a sample or if the poling stresses the material and provokes failure.



Driving the Samples

During poling: the top electrode of the sample was used as the ground and a positive voltage was applied to the bottom electrode.

During DBLI measurement: the bottom electrode was used as the ground and a negative voltage was applied to the top electrode.

Doing this ensured imprinting in the direction requested by the sponsor, the opposite of the original imprint to test durability.

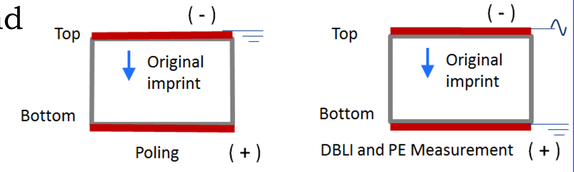
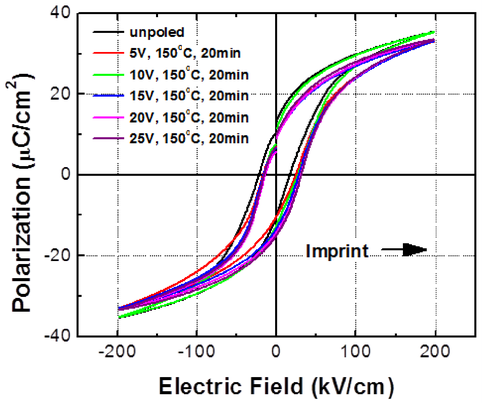
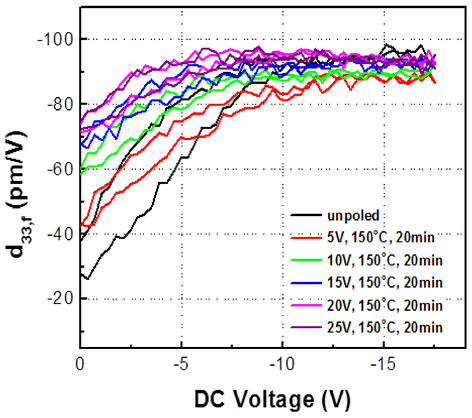


Fig. 7: The direction of the field during poling and measurements for this study.

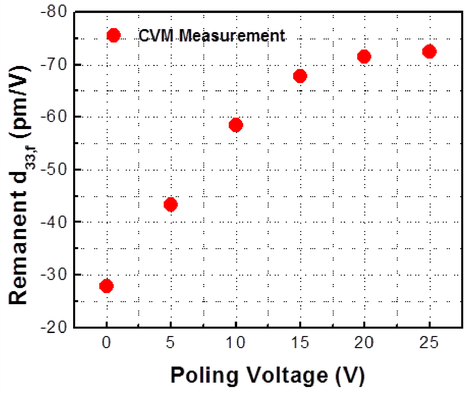
Poling Data and Results

The graph on the right shows a PE loop measurement which shows the imprint developed during poling. With increased poling voltage, the imprint increased as shown by shifting to the right.





The CVM measurements at the left show less hysteresis with increasing poling voltage. This results in flatter curves with higher starting values and less space between starting and ending values for a set. The space between where a data set starts and ends is a function of how unaligned the domains are within a sample. The remanent d_{33} values at left show that the poling made the sample perform better by displacing in larger amounts.



Continuing to Pole

While there are more samples to pole, so far the study has shown an increase in the piezoelectric d_{33} value on the unpatterned PZT films with increasing poling voltage. The patterned PZT was poled but the data and images of it showed the samples to have many defects. The study will continue with changes to other poling values to optimize the process.

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