3D Printable Flexible Piezoelectric Materials

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3D PRINTABLE FLEXIBLE PIEZOELECTRIC MATERIALS

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OBJECTIVES

The original intent of this experiment was to develop a work flow for the 3D printing of flexible piezoelectric materials using DLP type 3D printing - by way of doping photosensitive resin with piezoelectric nanoparticles (PENPs). The circumstance has required a refocusing of the project to what can be done remotely, namely successfully creating the final material, but without 3D printing.

Our general goals are to:

1. Verify the validity of using 3D printing for flexible piezoelectric materials
2. Find effective ratios of resin to piezoelectric nano-particles
3. Identify the physical characteristic and electrical response.

MATERIALS & METHODS

The following materials and equipment were required to complete the research:

- UV Flexible Resin from Photocentric3D
- Barium Titanate Nanoparticles, cubic
- Conductive Paste (silver)
- Clear Indium-Tin-Oxide coated film
- High Power UV light
- Variable DC Power Supply
- Oscilloscope
- Various glassware
- Magnetic Stirrer

Note: a 50W UV LED array was used - remember to use the proper eye wear before engaging in any use of high power UV lights.

The methods used in this project were created by the author, so the references included are supplementary.

REFERENCES

[1] V. Bansal et al. *Journal of the American Chemical Society*, 128(36):11958–11963, 2006.

[2] E. Fantino et. al. *Materials*, 9(7):589, 2016.

INTRODUCTION/PROCEDURE

Flexible piezoelectric materials promise to take all fronts of technology to new heights, from use as cheap audio/vibration sensors, to perhaps even synthetic muscle fibers. The two main challenges that we currently face are:

- the formulation of such materials, and
- the forming of such materials into the needed geometries

In this stage of the project, we focus on formulation and testing of physical characteristics:

Formulating and testing the material:

Due to the high-viscosity of the resin, the PENP doping of the resin was done with a magnetic stirrer, and allowed to stir for 15 minutes. The mixture is then cooled in a refrigerator for an hour. A parallel plate capacitor is created using two small sheets of ITO film and the PENP mixture. The capacitor is set to a voltage of 30 V, allowed to sit for several minutes, and then exposed to high-intensity UV light for 2 minutes. The material is than peeled from betwixt the films and probes are attached to either side for testing.

Printing the material:

The printer to be used in this stage of the experiment was designed and constructed by previous USM students. This poses a large challenge as one must learn and tune this printer with no community to draw from. The coming steps will include focusing on rapid fire printing experiments to find the desired outcome.

OBSERVATIONS

- prolonged exposure to intense UV light increased brittleness in the material
- thicknesses of about 500 μm produced little to no response to audio frequencies, but significant responses at low frequency

RESULTS

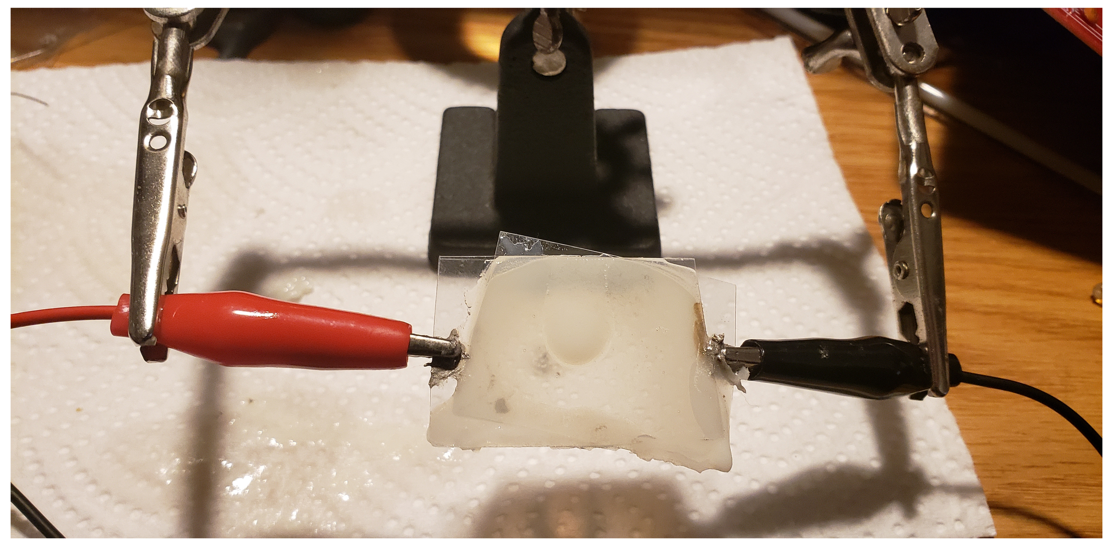

Figure 1: The parallel plate capacitor with cured resin

The conductive paste was found to be required in order to ensure constant contact during the curing process - otherwise, polarization was inconsistent. Figure 1 shows the apparatus used to hold the capacitor during the polarization and curing steps. It was found to be crucial to allow the material several minutes of polarizing before beginning the curing process. It was also found that cooling the doped material before the polarization step not only made it easier to work with, but also improved the final electrical response characteristic, likely due to a reduction in the thermalization of the inherent PENP dipoles.

Currently, the most successful trial has consisted of a PENP doping of 5 wt% at 500 μm thickness; refer to Figure 2. With these pieces, a small impulse from a finger is enough to illicit an electrical response, upwards of several millivolts in amplitude. This would likely be significantly smaller at higher frequencies, but with proper amplification this would be no matter.

Further considerations/next steps:

- How thin could this material be made before its structural integrity is nill?
- How might we streamline the process of polarization and curing of simple shapes?
- Can we simulate this particular material using a tool like solidworks, to improve our design potential?
- Will the prolonged UV exposure in the process of 3D printing prove to be an obstacle in obtaining excellent material characteristics?

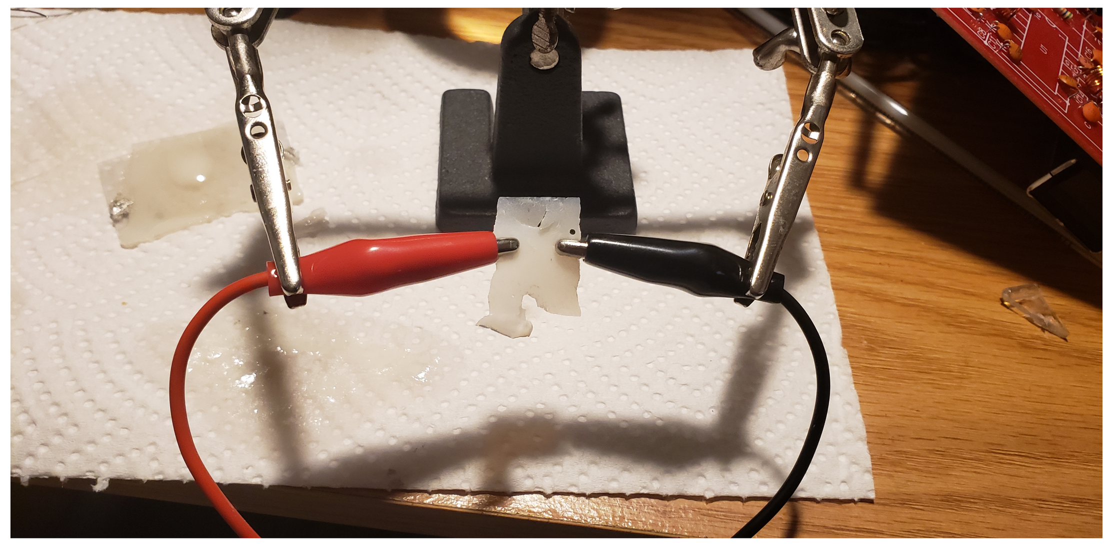

Figure 2: A piece of FPEM in testing, notice the tearing

CONCLUSION

- Working sheets were created - and showed obvious electrical response to physical stress - but are more easily torn than the pure cured resin, suggesting that the amount of PENPs can be optimized to allow for both good signal response and good strength.
- ITO sheets work excellent for polarizing the PENPs
- The resin may need to be colored when using DLP printing, to avoid over curing of the resin

FUTURE RESEARCH

- continue tuning recipe to optimize performance, collect abundance of data
- successfully implement DLP or SLA printing for advance geometries
- test other commercially available PENP, such as PZT
- test other, potentially unprintable resins for comparison of viability

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