3D Printing of Piezoelectric Materials and Devices

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Abstract

The design goal of the project is to use a stock 3D printer to 3D print materials with piezoelectric properties by adding Barium Titanate nanoparticles to the UV resin. The result of the printed material will be a device that will produce a charge when subjected to vibrations or stress. This process will be achieved by modifying the 3D printer by changing the film in the resin vat of the printer with a conductive film. This will allow for applied voltage to create an electric field to align the nanoparticles, producing a manufactured piezoelectric structure. The current progress of the project has been developing a 3D model of the devices, modification of the off the shelf parts, and researching the most effective material ratios.

Background

The project utilizes a 3D printer to produce the piezoelectric material, utilizing UV (ultra-violet) light to polymerize resin containing barium titanate ($BaTiO_3$). The barium titanate allows the printed material to demonstrate the piezoelectric effect, allowing mechanical stress to create an electrical charge.

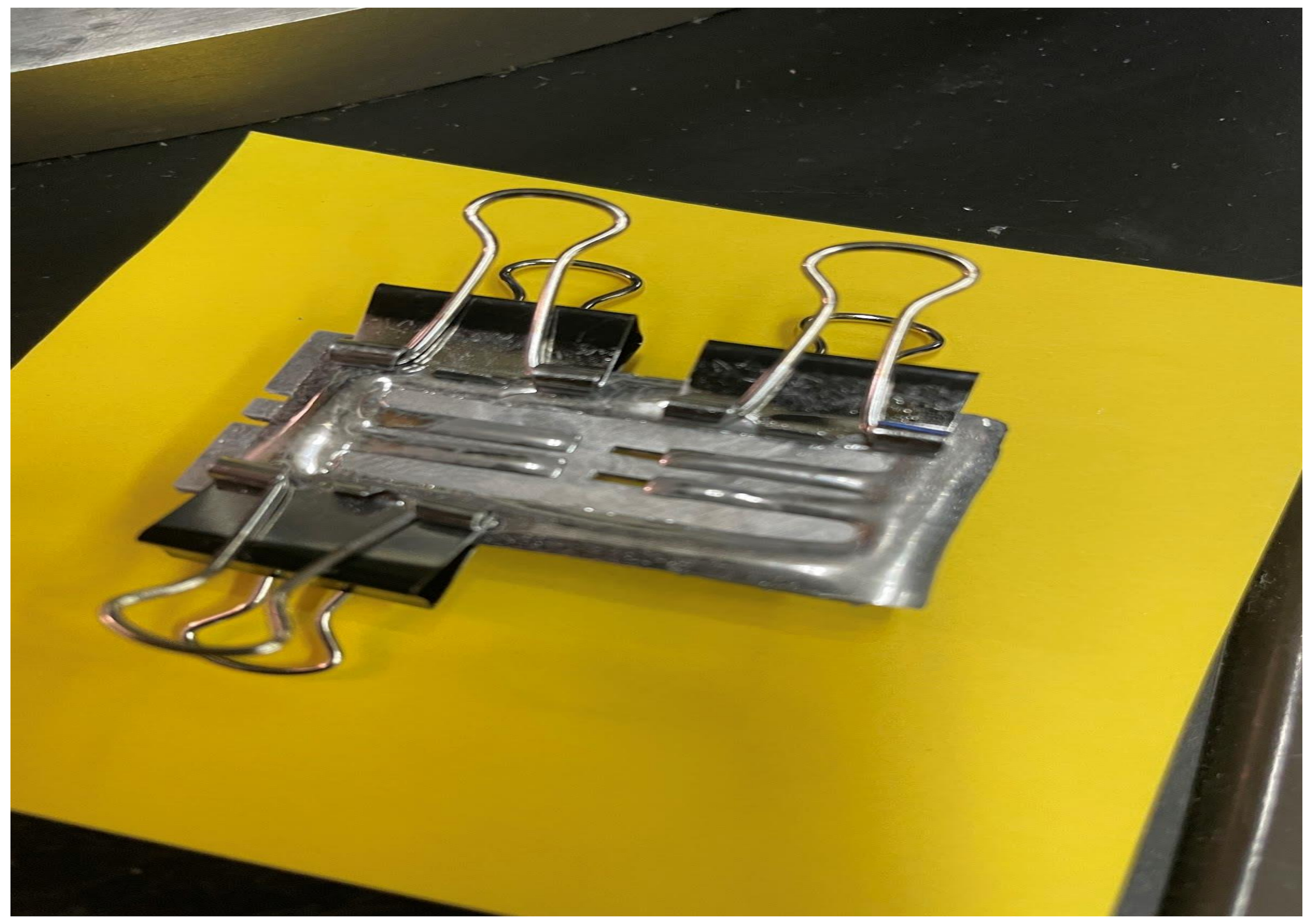

Figure 2. Printed device after undergoing metallization process

Methods

1. Prepare the resin vat for conductivity.
   a. Cut out clear conductive film to shape (leave extra length for connections).
   b. Replace clear FEP film in vat with the conductive film.
2. Prepare the resin for 3D printing,
   a. $BaTiO_3$ nanoparticles are measured to desired ratio and added to resin in container.
   b. Handheld resin mixer used until uniform consistency.
3. Resin added to resin vat.
4. Connect one power supply node to top of build plate, other to conductive film to create an electric field.
5. Turn on power supply.
6. Run 3D printer.
7. When product is finished, remove from build plate and add it to the washing machine for several minutes.
8. Use the curing machine for ~1 minute each side to solidify the device and minimize curling.
9. Insert in shadow mask to metallize the device.

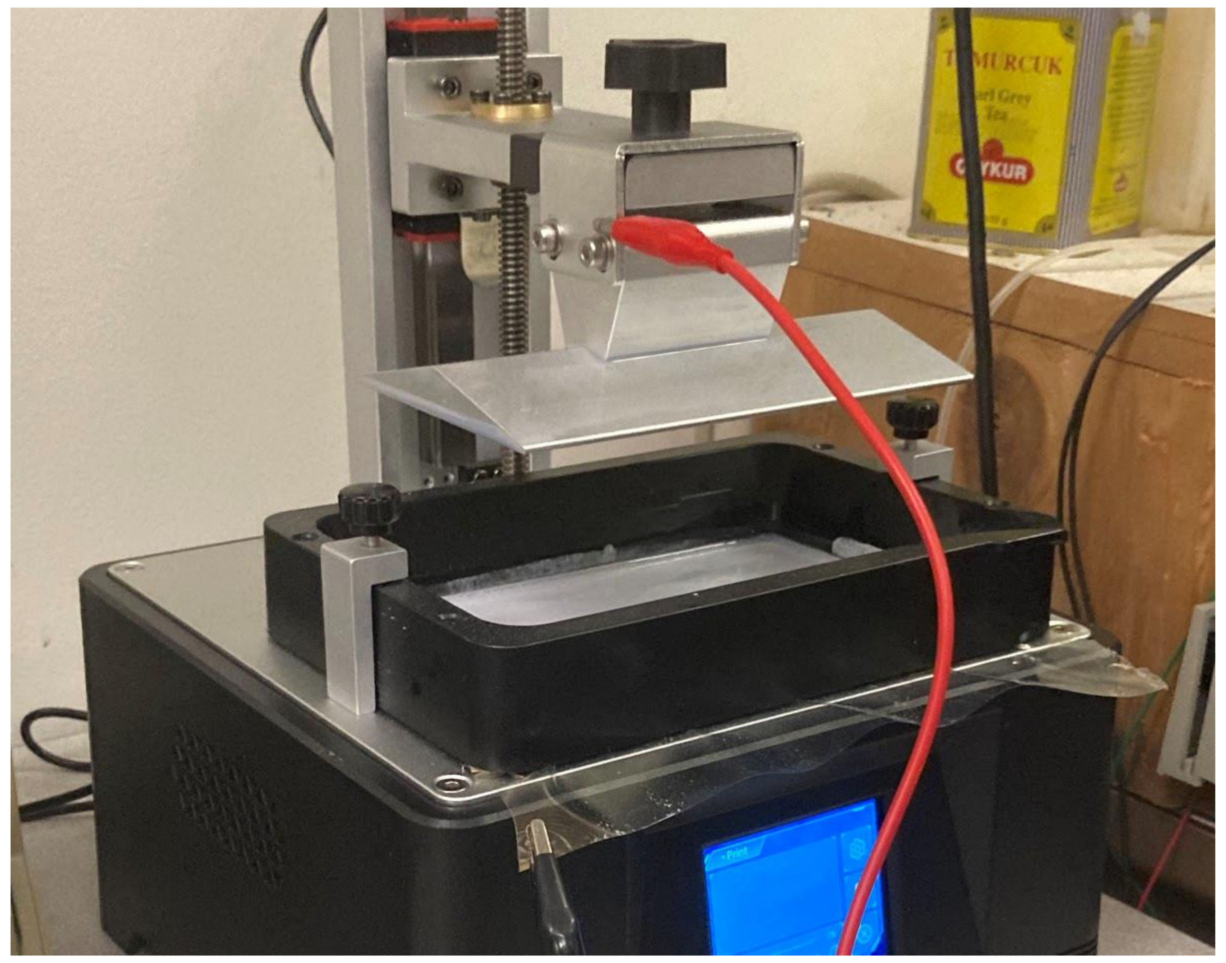

Figure 1. Modified 3D printer mid-print cycle

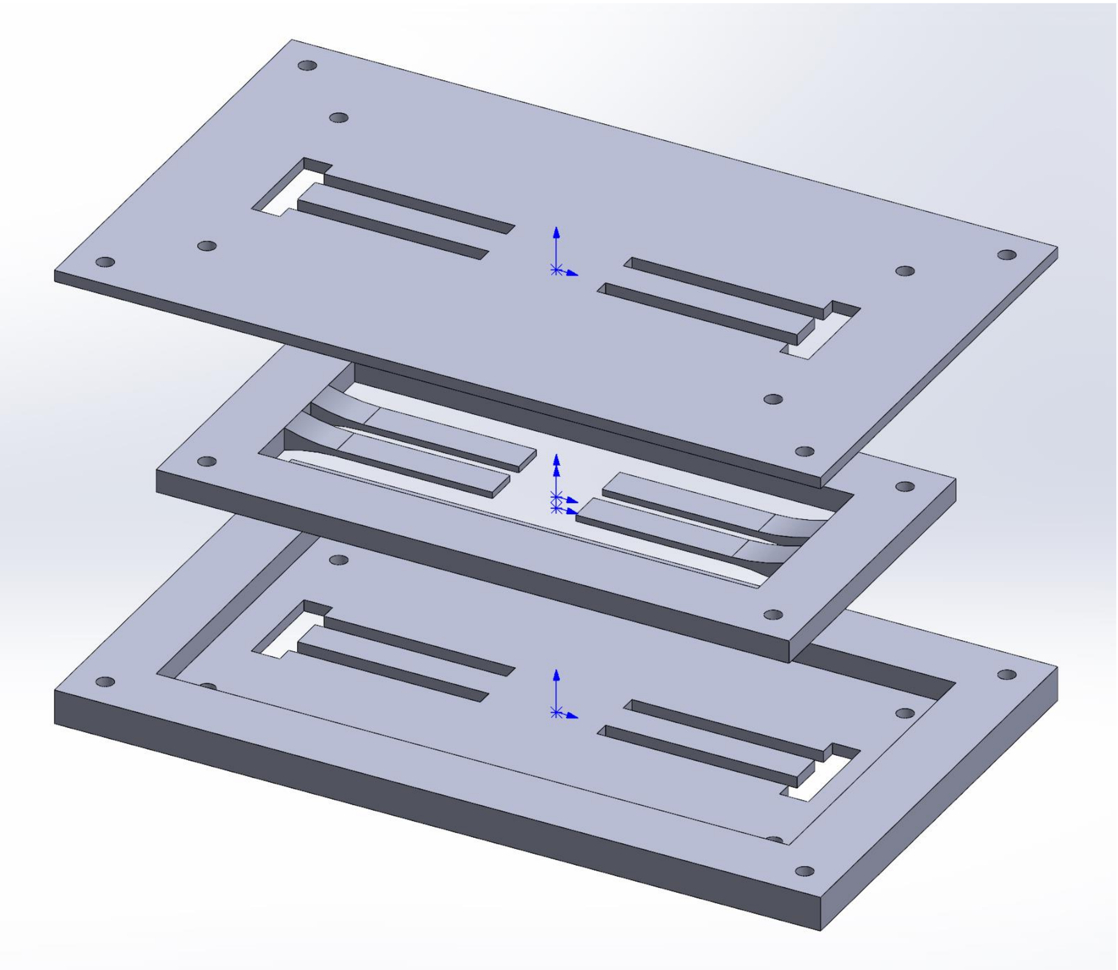

Figure 3. CAD files for printed device and metallization shadow mask

Results

There were four different made: 50:50 resin to 400nm $BaTiO_3$, 75:25 resin to 400nm $BaTiO_3$, 50:50 resin to 100nm $BaTiO_3$, and 20:1 resin to 400nm $BaTiO_3$. The 50:50 ratios created a very thick resin that resulted in very low-quality prints. Instead of printing the full device, only a 10-micron thick layer would print. On top of that, the 50:50 ratio with the 100nm $BaTiO_3$ created extremely brittle device. Decreasing the concentration to 5%, which had success with a previous student working on this project, resulted in a fully printed device. However, the quality of the print was too low to have any function as a device.

Next Steps

Due to the quality of the prints rendering them unusable, the focus of the project shifted towards improving the quality of produced material. The process can be refined by altering the prints to make components further from each other and varying printing parameters, such as layer size, curing time, bottom layers, resolution, or adding supports to the product. A user manual is being created to detail steps to every aspect of the project we have completed to ensure that future students will be able to continue the project with ease.

References

Cholleti, E. R. (2018). A Review on 3D printing of piezoelectric materials. *IOP Conference Series: Materials Science and Engineering*, *455*, 012046. doi:10.1088/1757-899x/455/1/012046

Acknowledgements

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