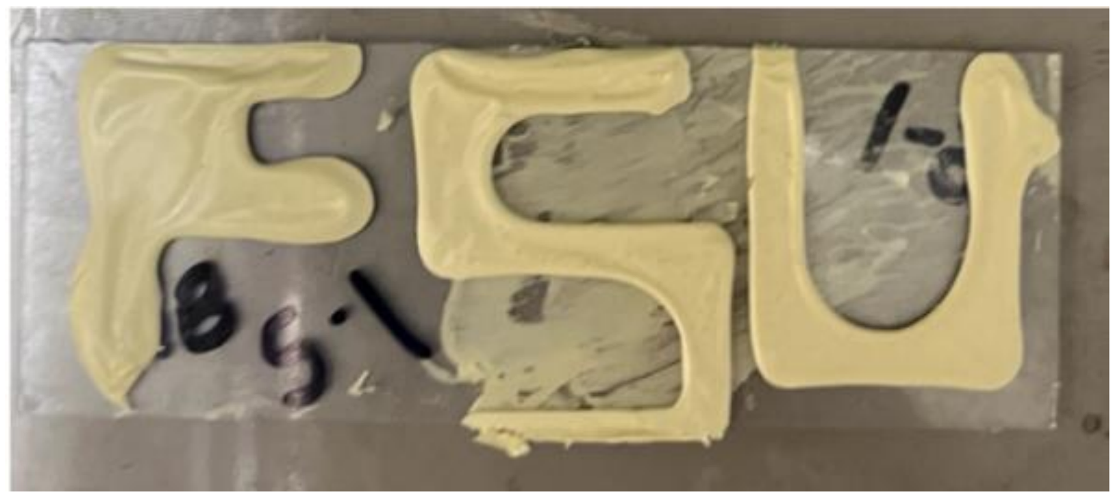
3D Printing of Ceramic Particle-Polymer Composites for Medical Radiation Shielding

FAMU-FSU College of Engineering

Kyla Booker, Vivienne Zacher, Dr. Zhibin Yu

Background:

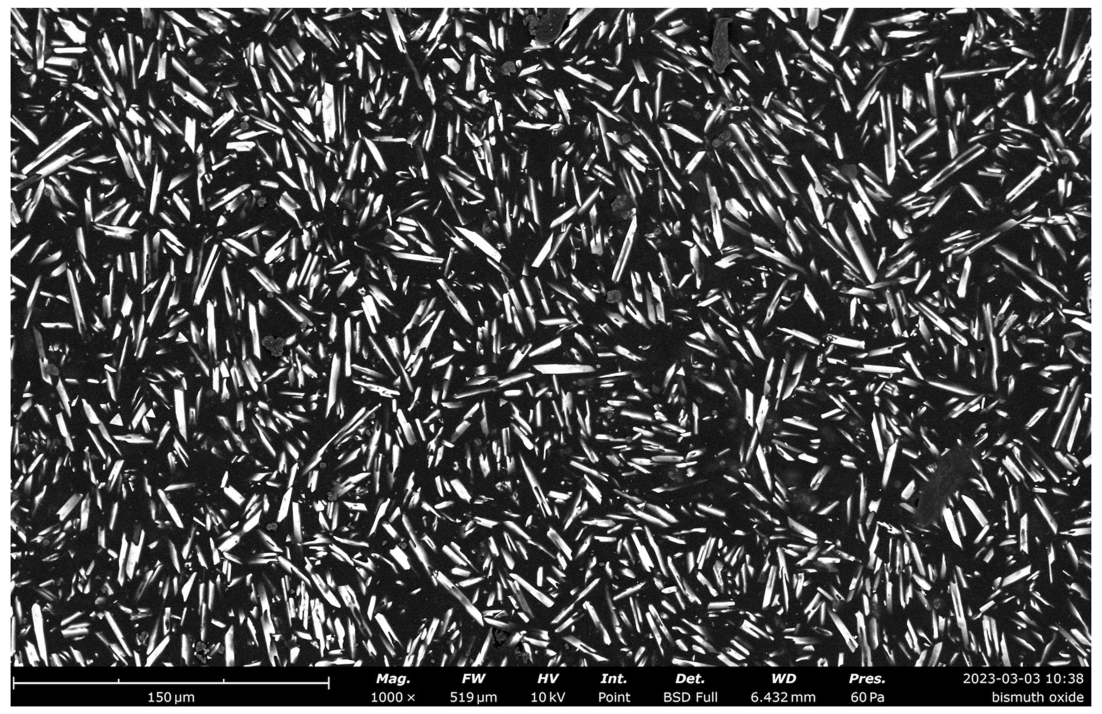
- Currently, lead is used as a radiation shield in the medical field. Lead is a heavy-weight harmful substance that the medical community is trying to astray from.
- Cardiac Device Implant procedures have been trying to implement a bismuth drape to protect patients as well as the surgical team. While performing cardiac device implants, fluoroscopy is used. The duration and complexity of this procedure leaves the surgeons at risk of exposure to radiation[1].
- Our research is centered around using a 3-D printing technique to create an inorganic radiation-shielding material to replace lead for X-ray protection. Using a 3D printer allows us to produce various viscosities of this material on a smaller scale to determine which biomechanical property will be best for radiation protection and flexibility of a glove.
- We specifically use a 3D printer to create ceramic particle-polymer composites using a standard weight of Polystyrene-block-polyisoprene-block-polystyrene (SIS) and various ratios of Bismuth (III) oxide. This mixture of SIS and bismuth oxide allows for both material's properties to be illustrated in the product. We are testing the radioactive efficiency of this polymer material to later produce a lightweight, flexible, and comfortable x-ray protective gloves.

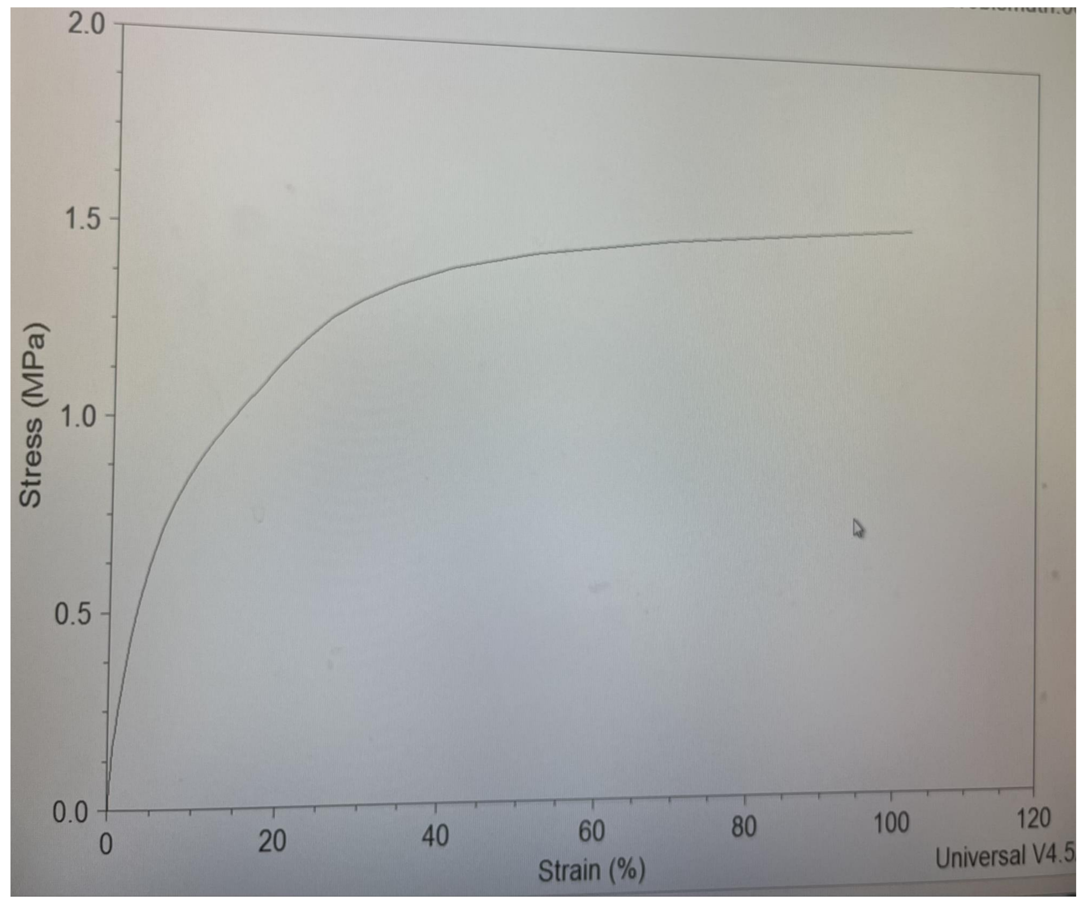


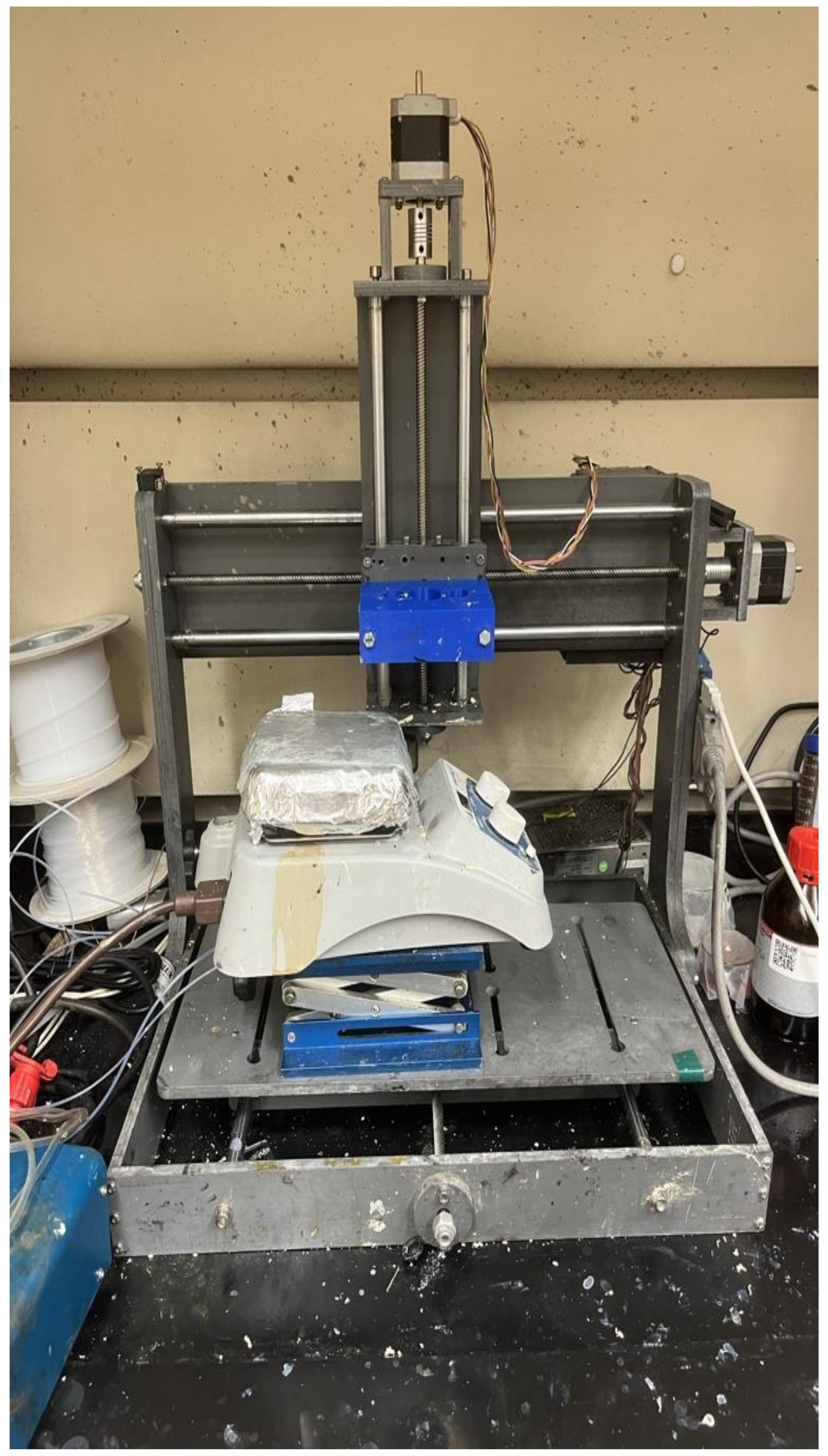
Methods:

- We dissolve polystyrene-block-poly-isoprene-block-polystyrene in toluene.
- We add bismuth oxide to this solution, varying the ratio of bismuth oxide to poly-SIS in each solution and mix.
- The solution gets put in a syringe that is attached to an air dispenser and a 3D printer.
- We adjust the hot plate temperature to around 100 degrees Celsius and 15 psi, depending on which ratio we are using.
- We go over the shape multiple times for the 3D effect.
- Using the DMA Q800, we tested the flexibility of each ratio of bismuth oxide to poly-SIS ratio sample.
- We then collected a strain vs. stress plot for each sample that was tested.
- A SEM machine allowed us to have a microscopic view of the material.

Results:







Conclusion:

- The different ratios of bismuth oxide produced solutions with varying viscosity levels. The 7:1 ratio produced the highest viscosity, which led to a thicker print, while the 3:1 produced a very thin print due to its low viscosity.
- The Strain vs Stress plot produced by the DMA 800 machine, allowed us to see the flexibility of the varying ratios of bismuth oxide to poly-SIS. We compared these results to a basic medical blue nitrile glove which has a strain ranging from 85 to 90 percent.
- The stress vs strain plots displayed a visual representation of how the varying ratios behaved in the presence of tension.
- Additionally, we found that the elastic behavior of the 7:1 ratio was the highest, as it reached 100% at a strength of 1.3MPa.
- Using an SEM machine, we were able to look at the composite on a microscopic level. The light part of the image is the Bismuth Oxide, while the darker spots are the poly-SIS.

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References:

[1] Jones, M. A., Cocker, M., Khiani, R., Foley, P., Qureshi, N., Wong, K. C., Rajappan, K., & Betts, T. R. (2014). The benefits of using a bismuth-containing, radiation-absorbing drape in cardiac resynchronization implant procedures. *Pacing and clinical electrophysiology : PACE*, *37*(7), 828–833. https://doi.org/10.1111/pace.12349