3D Printing of Ceramic Composites for Aerospace and Biomedical Applications

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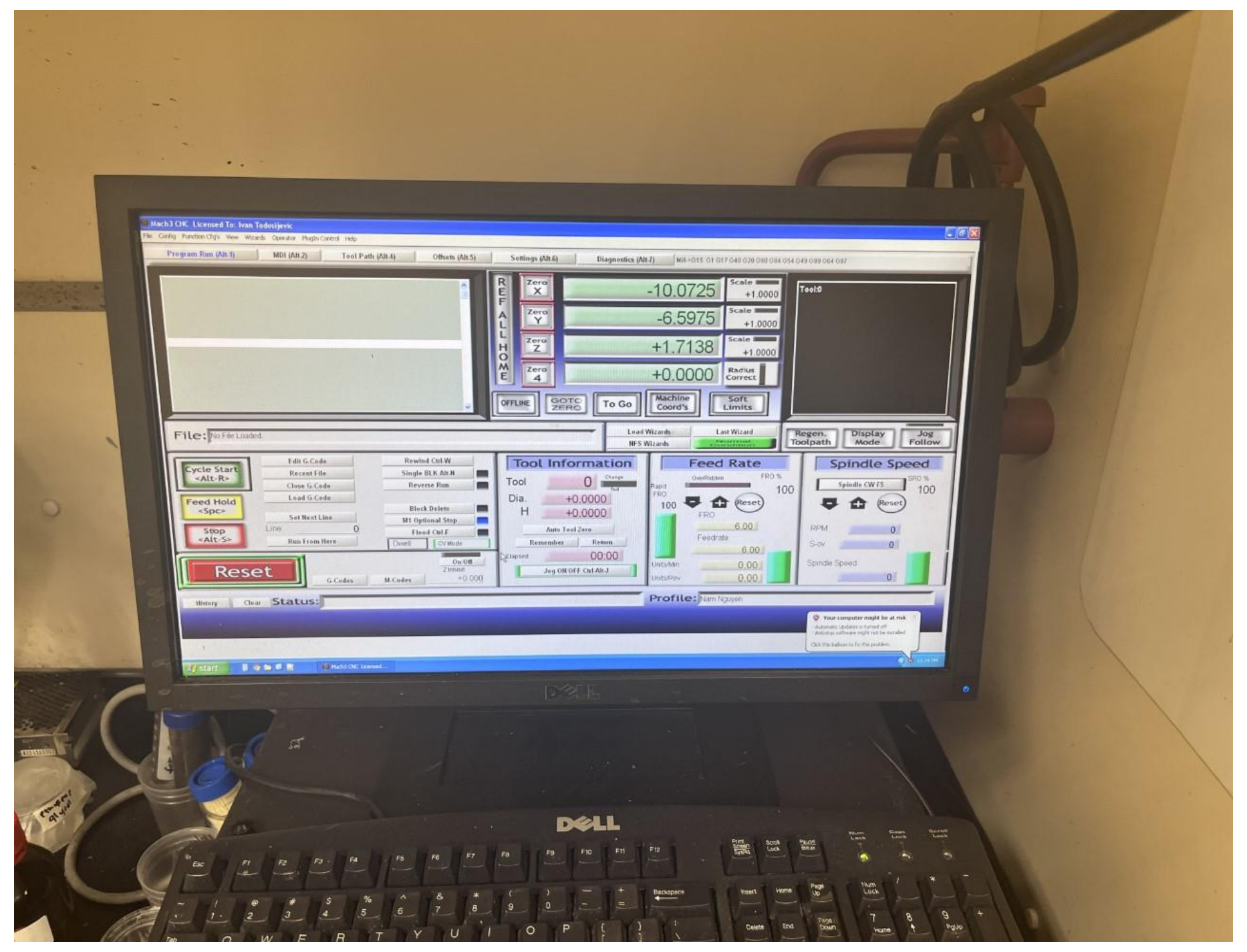
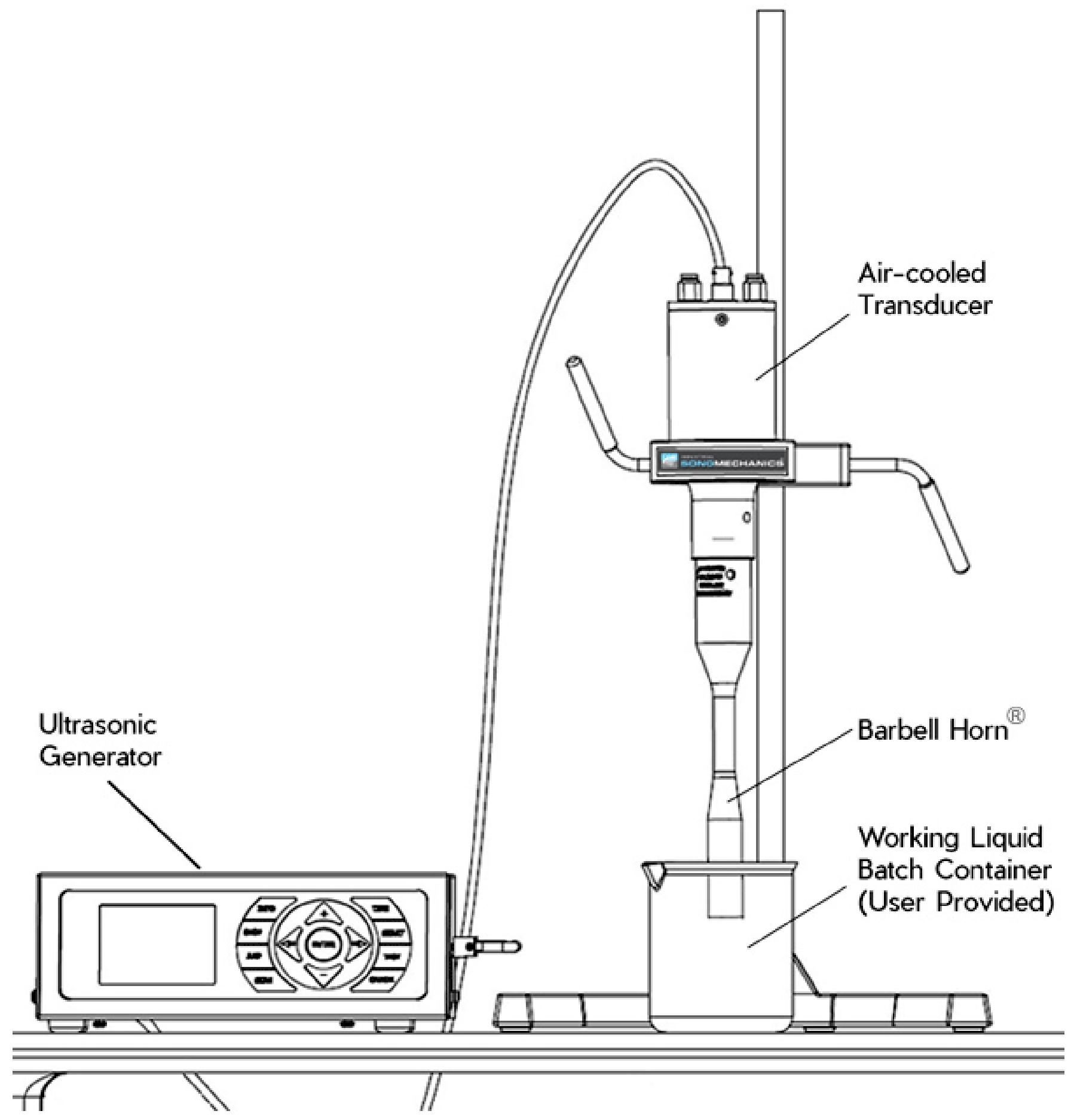
Background:

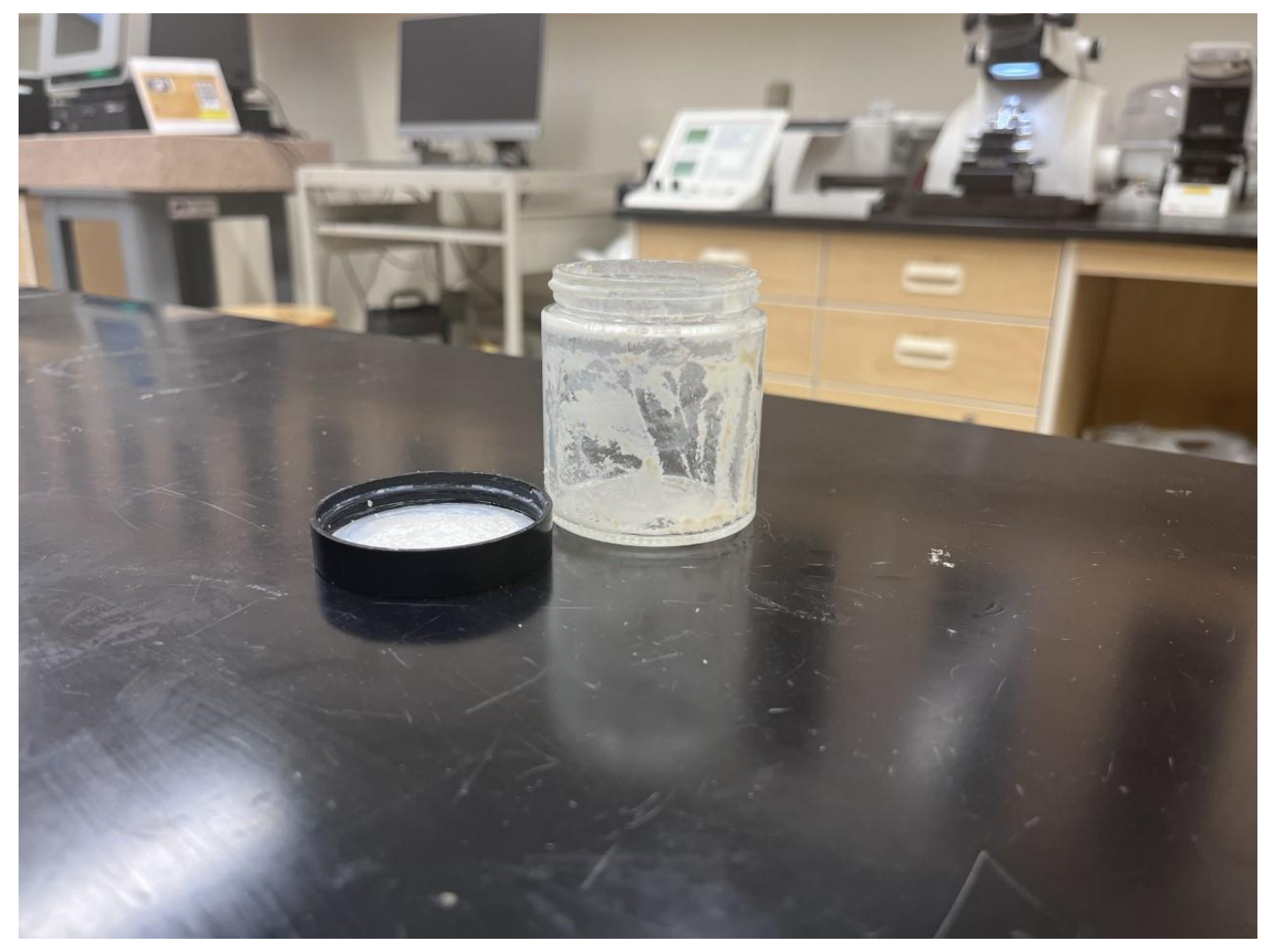
- Compared to other materials, ceramics have high tensile strength, high melting points, low electrical conductivity, low thermal expansion, and are chemically inert.
- Combing these properties with the tough and flexible properties of polymers creates a ceramic composite with surprisingly powerful properties making them ideal materials for aerospace and biomedical applications.
- Unfortunately, current manufacturing techniques like sintering powders make synthesizing ceramic composites inefficient and cause errors in the form of cracks due to the brittle nature of ceramics. Additionally, sintering prevents the printing of complex shapes.
- Over the past year, the Yu Group has aimed to harness the powerful abilities of composite ceramics by successfully 3D printing a composite material.
- Additionally, the Yu Group has aimed to improve the mechanical and physical properties of composite ceramics using SMP-10 ceramic precursor, toluene, and boron nitrate nanotubes (BNNT), with my main role being to ascertain the correct material ratios and printing settings.

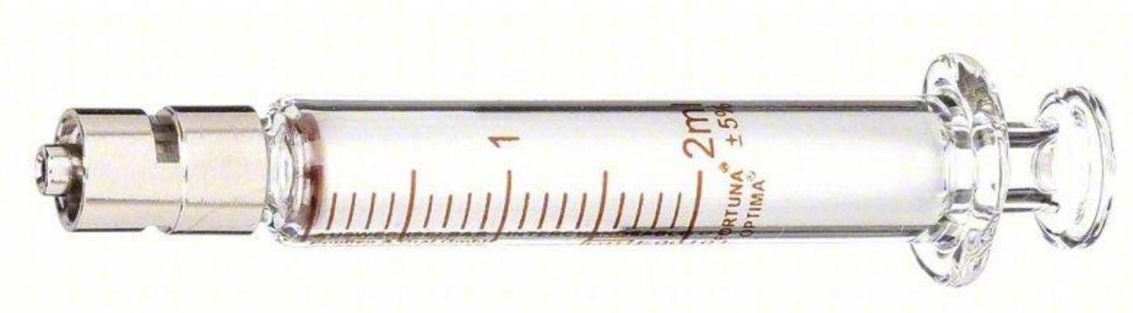
Experimental Question:

What is the ideal physical composition and 3D printing settings to successfully print a ceramic composite?







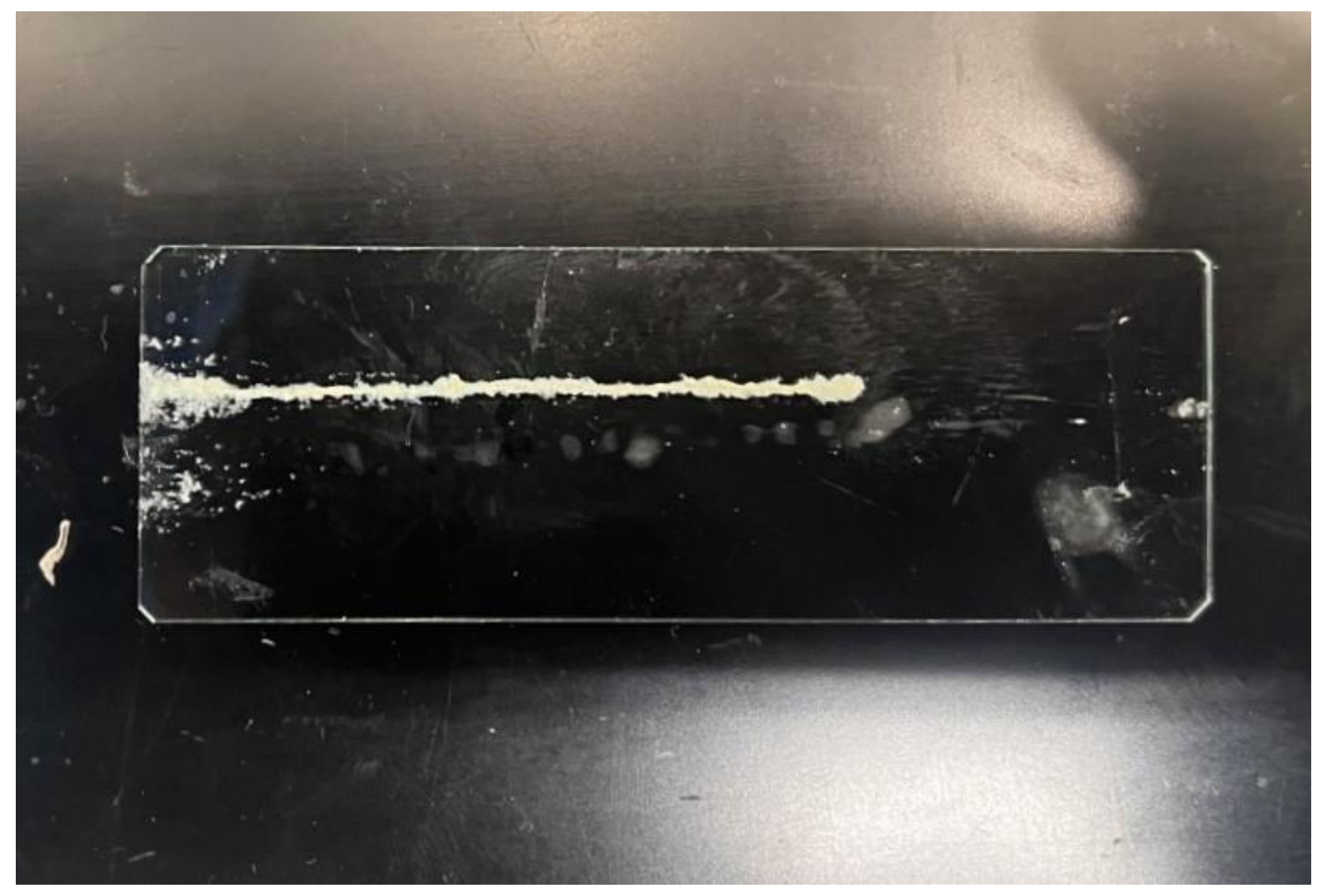


Methods:

- Initial testing for ideal chemical composition began with 181 mg BNNT, 50 mL Toluene, and 1.629 g SMP-10 precursor (10% weight percent). It was determined that this solution was too viscous but capable of stacking to form 3D structures.
- Successful composition for printing was achieved at 225.7 mg BNNT, 160 mL toluene, and 2.0313 g SMP-10.
- Toluene and BNNT added to a 400 mL beaker. The solution was then homogenized using a sonification machine at 80% power for 25, 5 second cycles until BNNT were uniformly distributed. SMP-10 ceramic precursor was then added to the solution after sonification and stirred until uniform distribution.
- Even amounts of solution were then poured into wide 100 mL uncapped containers and left under the fume hood for 18-20hrs to evaporate toluene until 45 mL of condensed solution remained. The concentrated solution was then homogenized using a sonification or vortex machine at the previous settings.
- The solution was then transferred to 10 mL glass syringes (originally plastic) lubricated with silicon and hooked to an air compressor. The syringe was then inserted into a holster on the 3D printer. The solution would be printed directly onto a slide on top of a hot plate set to room temperature. The printer was then manually controlled to print the solution at 100% printer speed, and 7 psi, approximately 1-2 millimeters above the slide.

Results:

- After several trials the correct chemical composition, and printing settings allowed us to create some samples with ideal texture for layering and printing complex 3D shapes.
- Successful composition and printing were achieved at 225.7 mg BNNT, 160 mL toluene, and 2.0313 g SMP-10.
- Because of the correct composite's "paste like properties" (a result from suspending the ceramic in solution- rather than draining the toluene and readding it) the composite had enough viscosity to retain its surface tension when printing on the glass while being able to flow from the syringe.
- Printings of 0.5 mm were achieved with the needle; further testing is required to see the consistency and "smoothness" of samples after printing as well as the materials physical and chemical properties.



Conclusion:

- Though successful printing of toluene-BNNT based ceramics have been achieve the consistency of said results must be improved. Currently errors in printing due to syringe malfunctions and air pressure issues are common.
- As a result, the Yu group is currently trying to improve the consistency of 3D printed ceramics by using silicone lubricants to prevent syringe stoppage.
- Overall, this is good data necessary for the widescale application and improved production of ceramic composites for aerospace and biomedical applications.

References:

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