Fabrication of Silicon Carbide Nanocomposites for Extreme Environments

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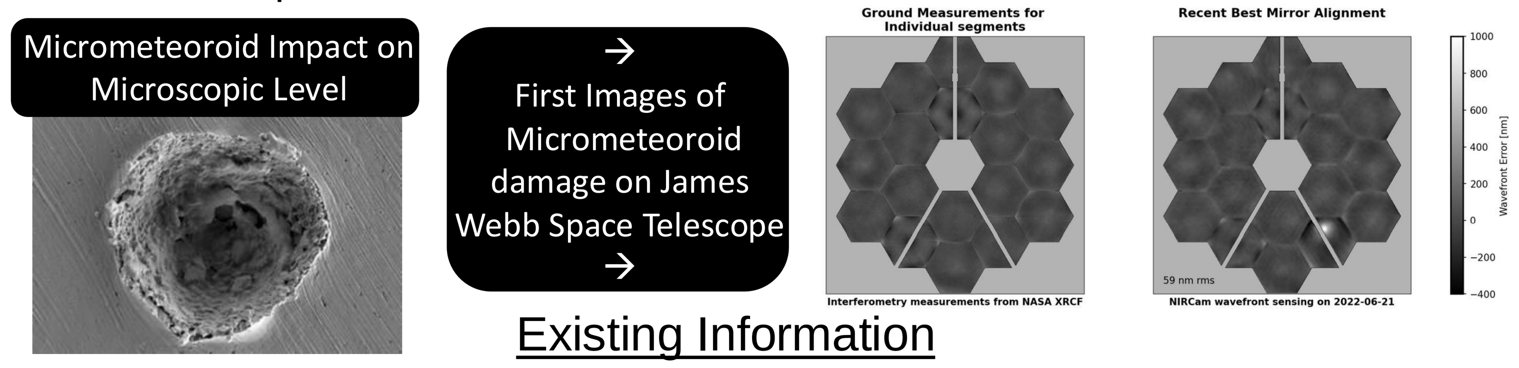
Background

- Interest in deep space exploration has spiked in recent years with the introduction and success of private space travel companies.
- Deeper space travel requires strong exterior lining to protect against a higher volume of microprojectile (micrometeoroid) impacts. These impacts were mostly overlooked in previous missions due to the shorter distance traveled.



Existing Information

- Research in ultra-light, ultra-thin coatings to protect against these impacts have resulted in the development of several polymer-based fibers which show some potential but perform poorly under cases of extreme temperatures.

Research Gap

- The potential of creating and using pre-ceramic polymers to be made into ceramic thin films for use instead of these fibers is the basis of this research.
- Can ceramic coatings be used instead of fibers to remain ultra light and thin while also adding extra rigidity and heat-resistance?

Methods

Materials

- Polymethylsilsesquioxane (SILRES MK Resin Powder)
- N-Dimethylformamide (DMF) (Sigma-Aldrich)
- Isopropyl Alcohol (Sigma-Aldrich)

Tools

- Analytical Scale and
- Three 100 mL beakers
- Magnetic based hot plate
- Stir rods
- Laurell Spin Coater (with CDA and Vacuum connections)

Procedure

- Using the scale and beakers, combine the Resin Powder (preceramic precursor) with DMF (Solvent) in proportions of 5%, 10% and 15% by mass pc.

8.868g (Solvent) + 0.468g (pc) = 9.3367g, (5.0190%)
10.845g (Solvent) + 1.206g (pc) = 12.051g, (10.0074%)
10.034g (Solvent) + 1.775g (pc) = 11.809g, (15.0300%)

- Insert stir rods and cover with protective lining.
- Place solution on hot plate to combine for five hours.
- Insert wafer onto spin coater and cover ¾ with each solution (one wafer per solution)
- Spin coat at 500 rpm for 10 seconds, 2,000 rpm for 15 seconds, and 4,000 rpm for 20 seconds.

Scanning and Analysis of Thin Films

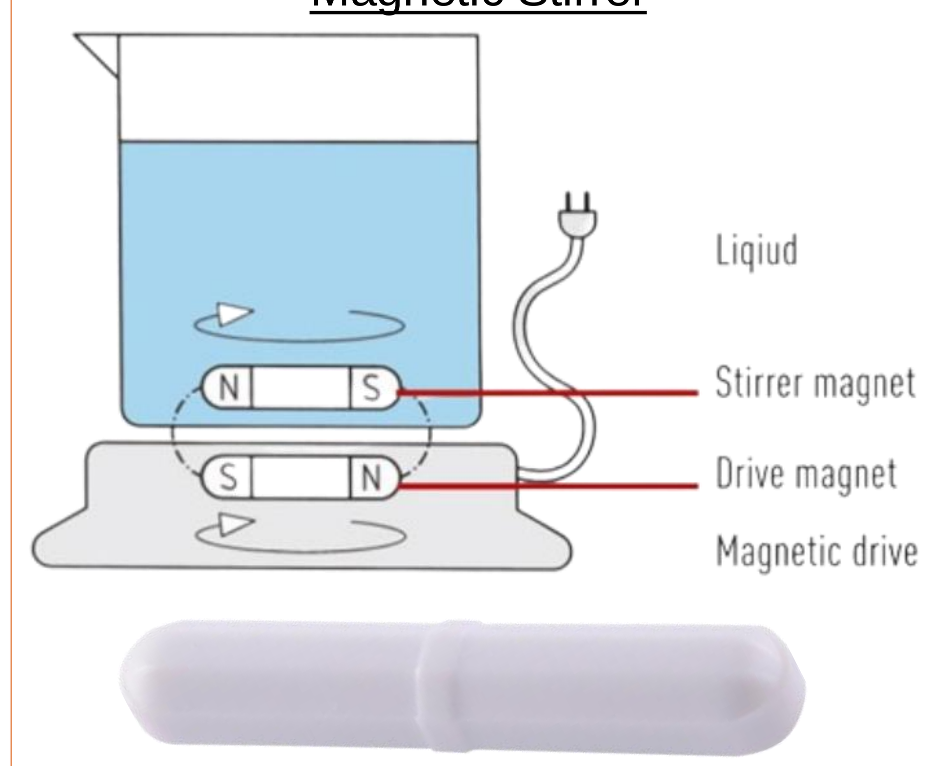
- Thin films (in petri dishes) along with beakers containing solution were placed inside an airtight contained post spin coating for storage.
- After two days of storage, another three samples were created using the already described procedure and placed alongside original samples in the airtight container.
- These six samples were placed on a Scanning Electron Microscope (SEM) tray mountain flat and placed against a hex bolt to serve as a ground.
- The SEM allowed for imaging of both the original wafer surface and the raised film surface.
- Readings and images of the raised surface was taken and used for results.

Removal of Thin Film from Wafer

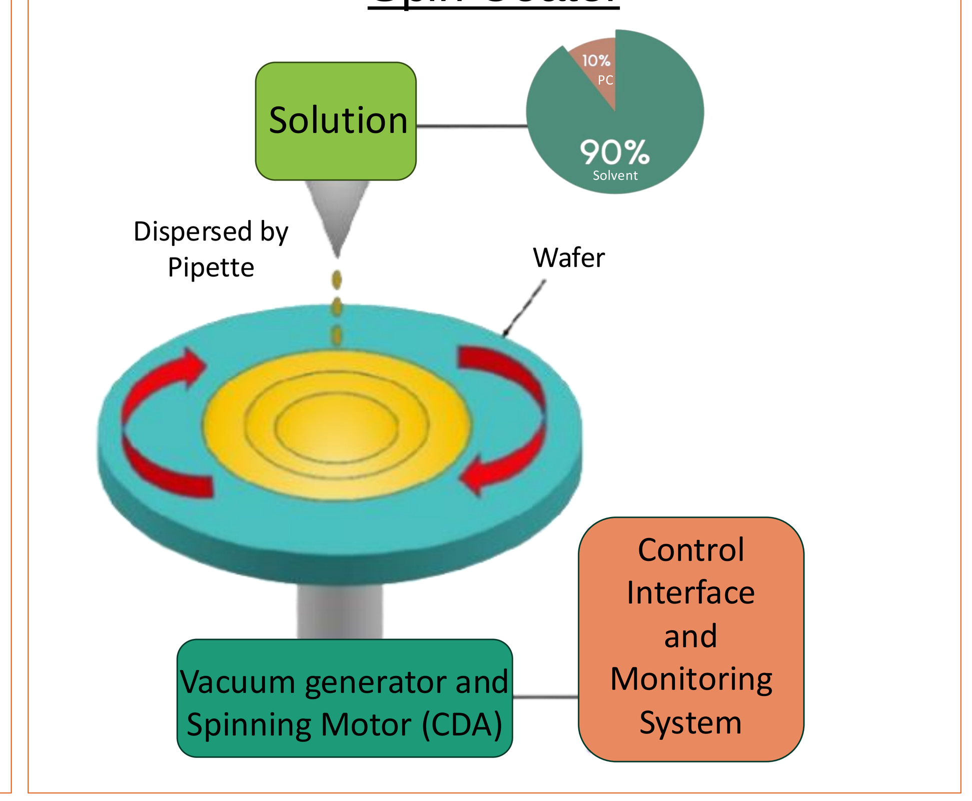
- Thin film was scored against the wafer using a razorblade and placed in a water bath.
- Using tweezers, the film is removed and placed in a petri dish.

Tools

Magnetic Stirrer

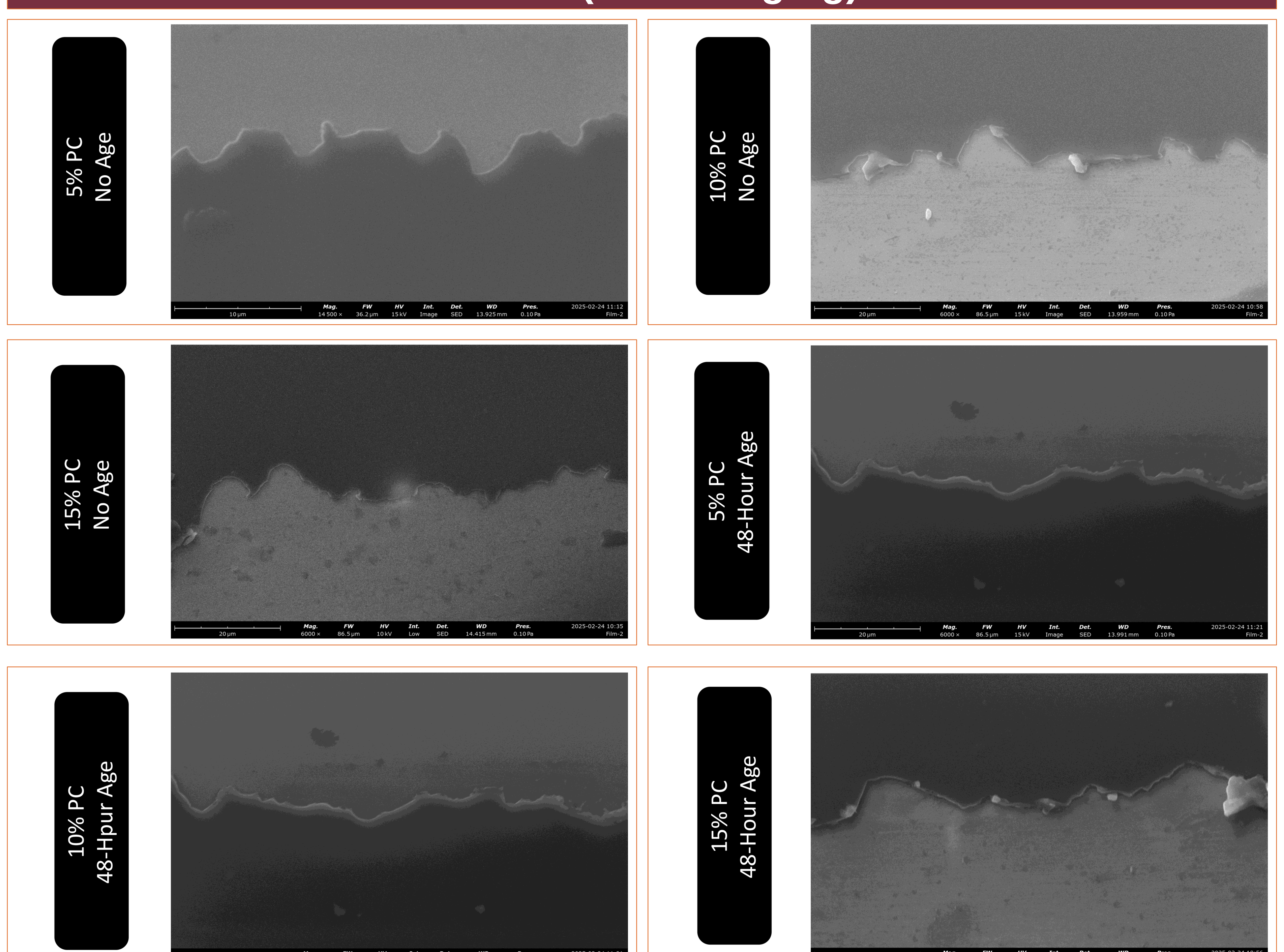


Spin Coater

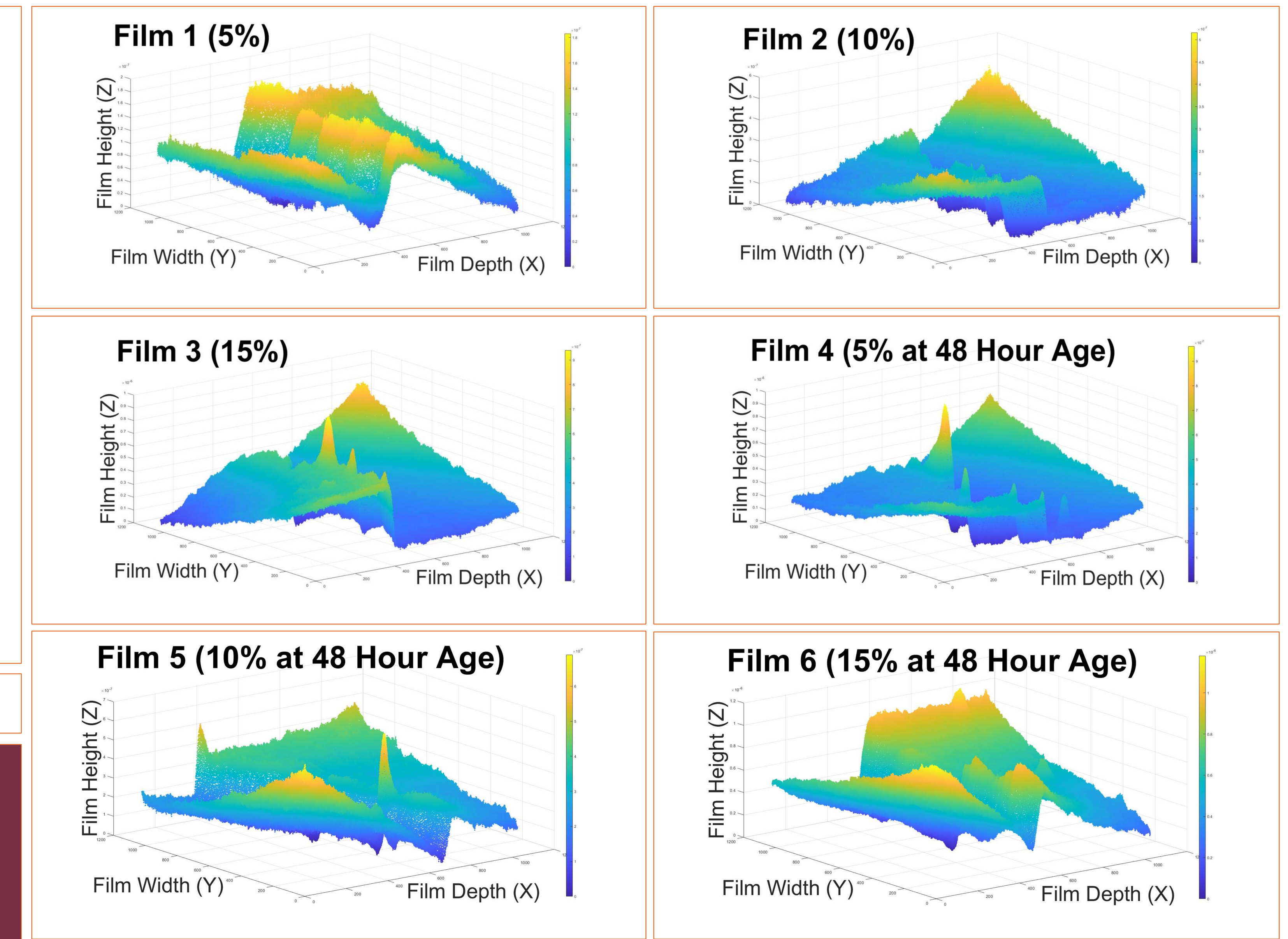


Laurell Brand Spin Coater

Results (SEM Imaging)



Results (3D Rendering)

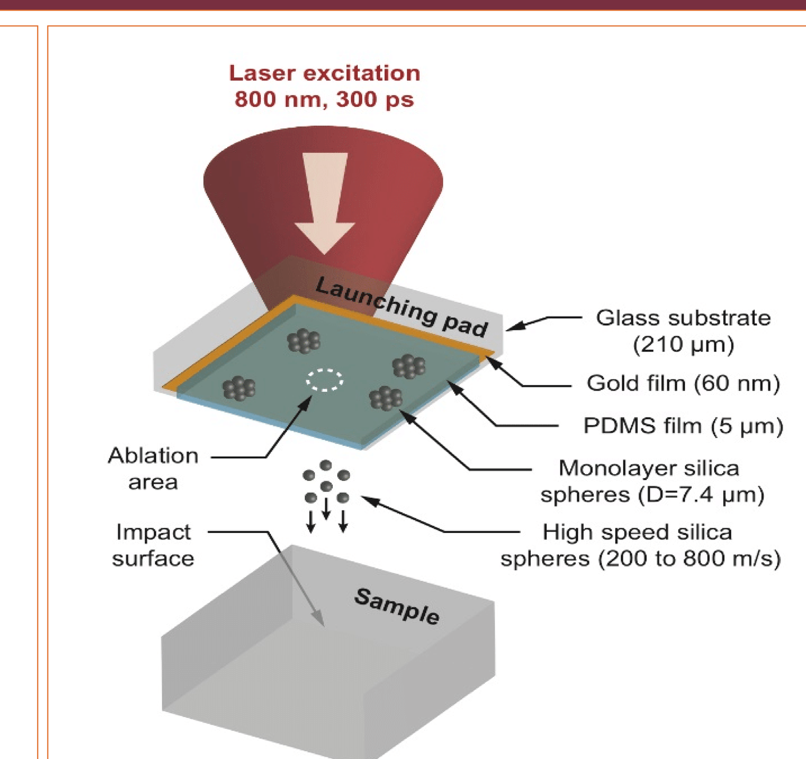


Analysis and Conclusion

- Depth measurements from lowest to highest position showed films from solutions of lesser preceramic precursor by mass were overall thinner.
- Depth measurements also displayed that aged solutions had a greater thickness at each concentration level than their unaged counterparts.
- Linear increase in percent precursor by mass of solution showed increase by factor of two in thickness of film (5-10-15% = 114.6-209.4-458.2nm).
- Each 3D rendering is slightly tilted on its axis to show a surface that is not level with the horizontal – this is due to microscopic imperfections on the observation tray of the SEM which does not allow the wafer to sit completely flat on the surface when scanned.
- Removal of film from the wafer using a water bath and tweezers was made difficult due to the lack of structure found within the makeup of the film itself.
- In order to create a stronger and more versatile film which can be removed from the wafer, an additive for density is recommended.

Future Research

- Once refined, each film will be baked to be made into a ceramic.
- Ceramics will be placed in a Laser Induced Particle Impact Testing machine where performance under stress can be observed.
- This machine will use a laser to rapidly heat a substrate with microparticles lodged underneath and another laser to photograph.
- The rapid heating will cause expansion of the substrate and the 'firing' of a microparticle onto the ceramic film beneath it.



References

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