TRACKING GLASS FIBER INTEGRITY THROUGH A NOVEL VAPOR-BASED SILANE DEPOSITION

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Introduction

- S-2 Glass is used in the fabrication of composites for armor applications by the U.S. Army.
- To develop improved structural and penetration properties, strong adhesion between the fiber and matrix must occur.
- The deposition of APS and GPS has been shown to increase interfacial shear strength of S-2 Glass Fibers.
- This experiment tracks the fiber strength of the selected fibers through a novel chemical vapor deposition (CVD) process to create thin silane coatings to explore how fiber strength is impacted during the cleaning and deposition phases of fiber preparation.

Fiber Selection and Conditioning

- 906 S-2 was selected for its removable glycerin sizing.

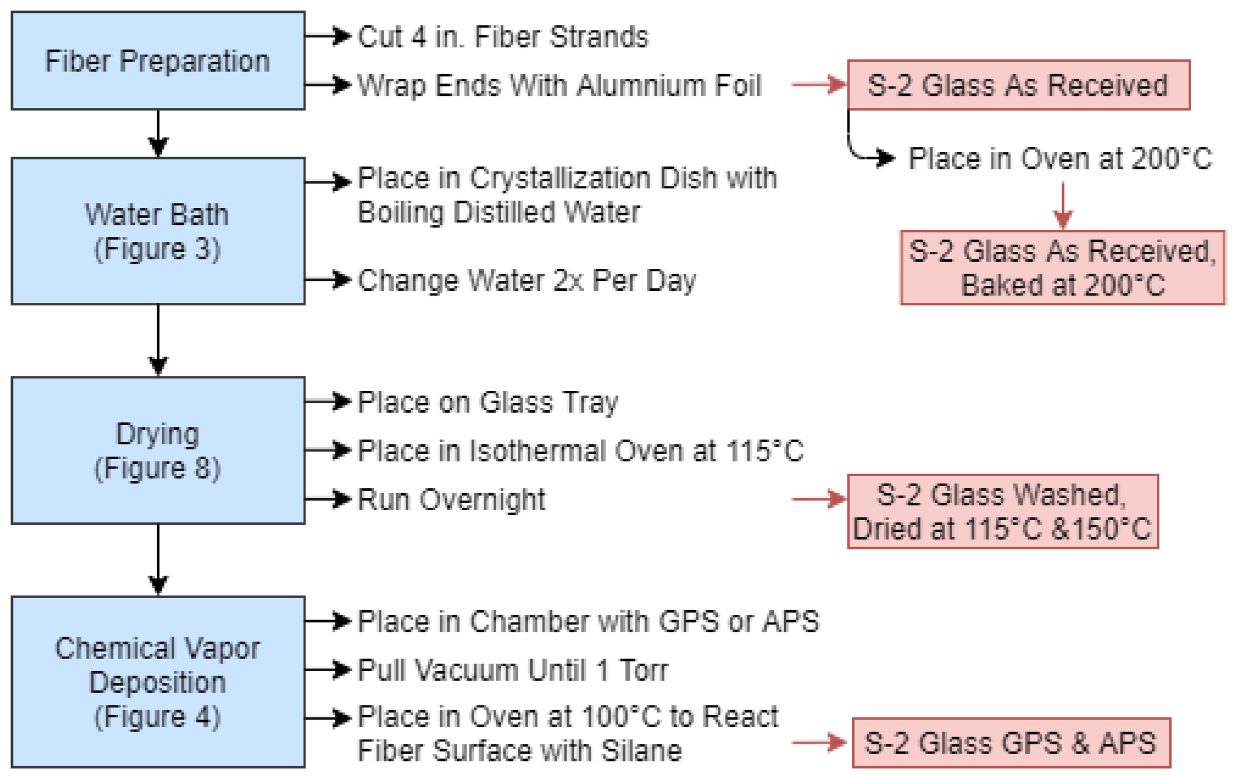
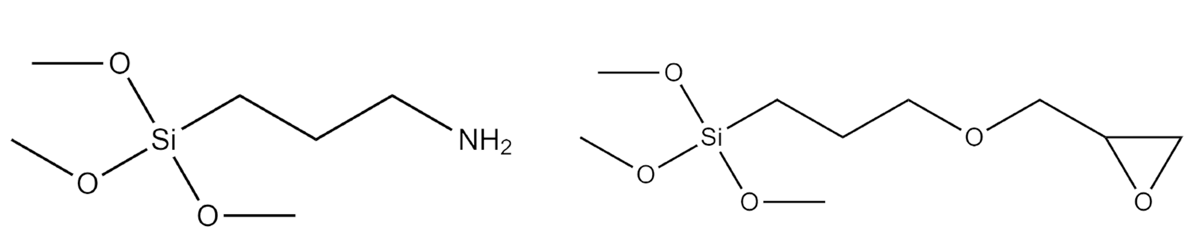


Figure 1. Fiber Preparation Process.

S-2 Glass GPS & APS

- APS and GPS Silanes are selected because their functional groups can couple between glass and epoxy (Figure 2).



(APS) 3-aminopropyltrimethoxysilane (GPS) 3-glycidyloxypropyltrimethoxysilane

Figure 2. Molecular structures of APS & GPS.

Chemical Vapor Deposition Process

- GPS and APS are deposited on the bare fiber using a CVD chamber, pulling a vacuum until the chamber reaches 1 Torr.
- Placed in oven at 100°C to encourage the silane to react with the glass surface.

Figure 3. Hot Bath Setup

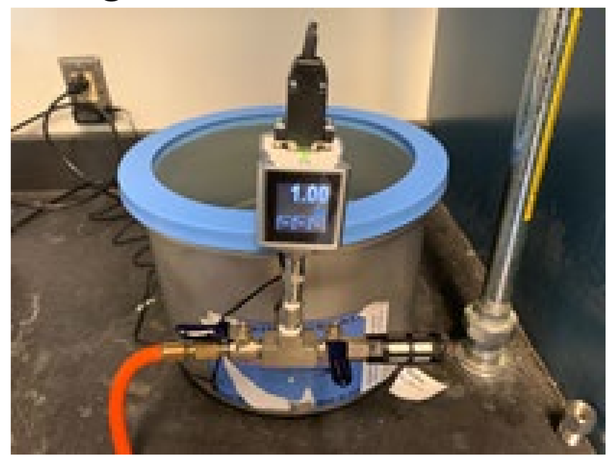


Figure 4. CVD Chamber Setup

Tensile Testing Sample Preparation

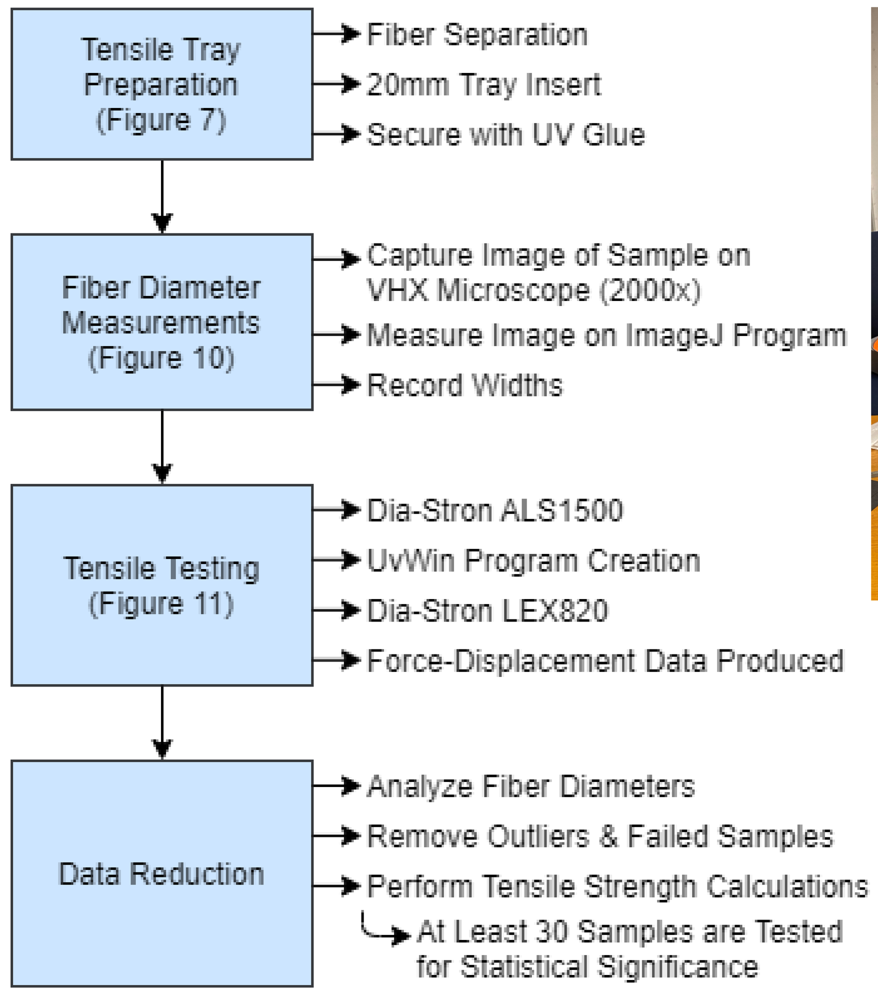


Figure 6. Tensile Testing Process.

Figure 5. VHX Microscope.

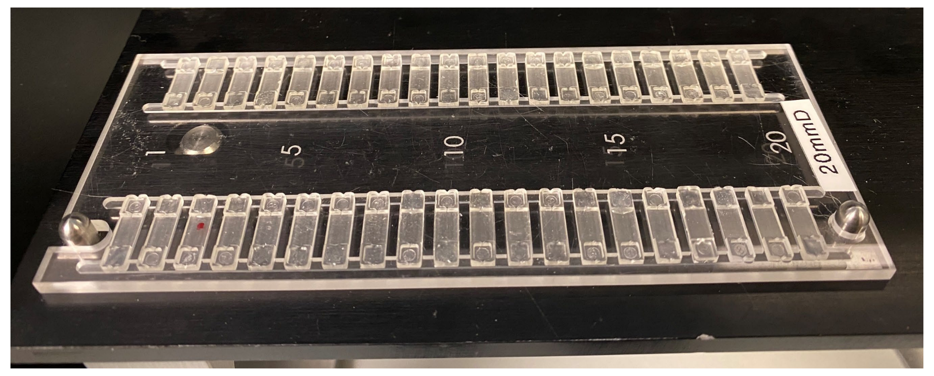


Figure 7. 20mm Tensile Sample Tray.

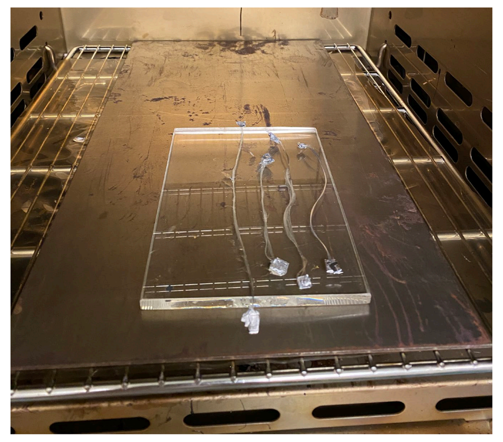


Figure 8. Water Bath Fibers Drying in Isothermal Oven.

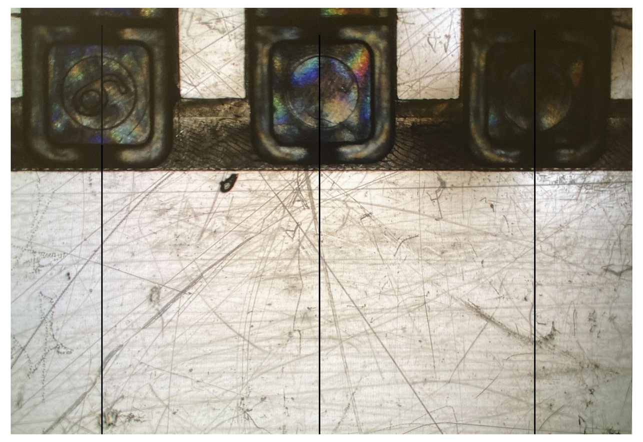


Figure 9. Individual S-2 Glass Fibers at 20x Magnification.

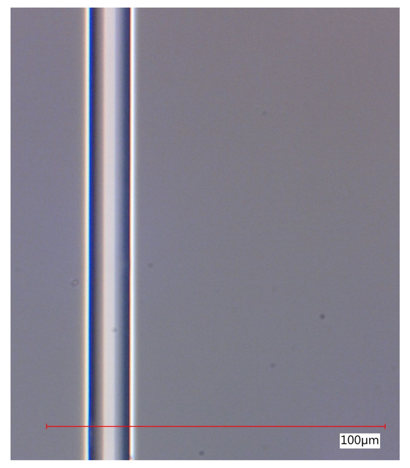


Figure 10. S-2 Glass at 2000x Magnification.

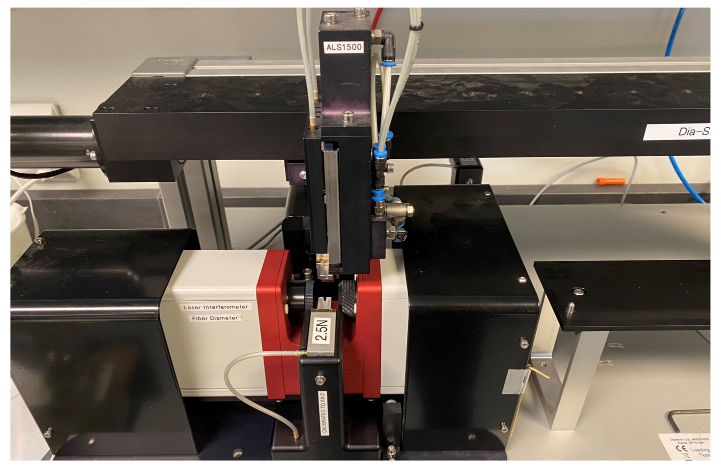


Figure 11. Dia-Stron Tensile Tester.

Data Analysis

- Dia-Stron records the force and displacement of a fiber when testing.
- The maximum force is taken as the break force (Figure 12).

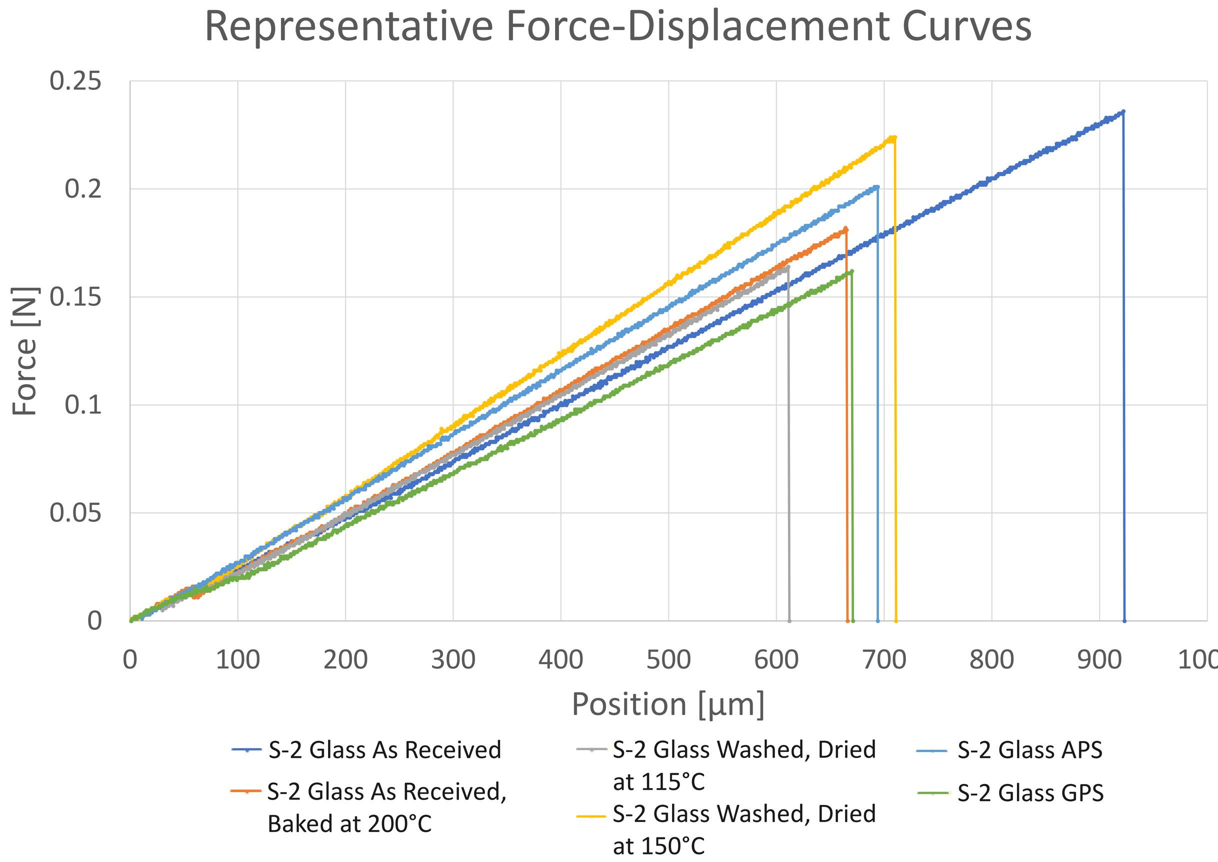


Figure 12. Representative Force-Displacement Curves.

- With the diameters measured from microscopy, the following formula can be used to calculate the fiber strength:

$$\sigma = \frac{F_{Max}}{Cross\ Sectional\ Area} = \frac{F_{Max}}{\pi \frac{d^2}{4}}$$

Figure 12. Strength Formula.

Strength Results

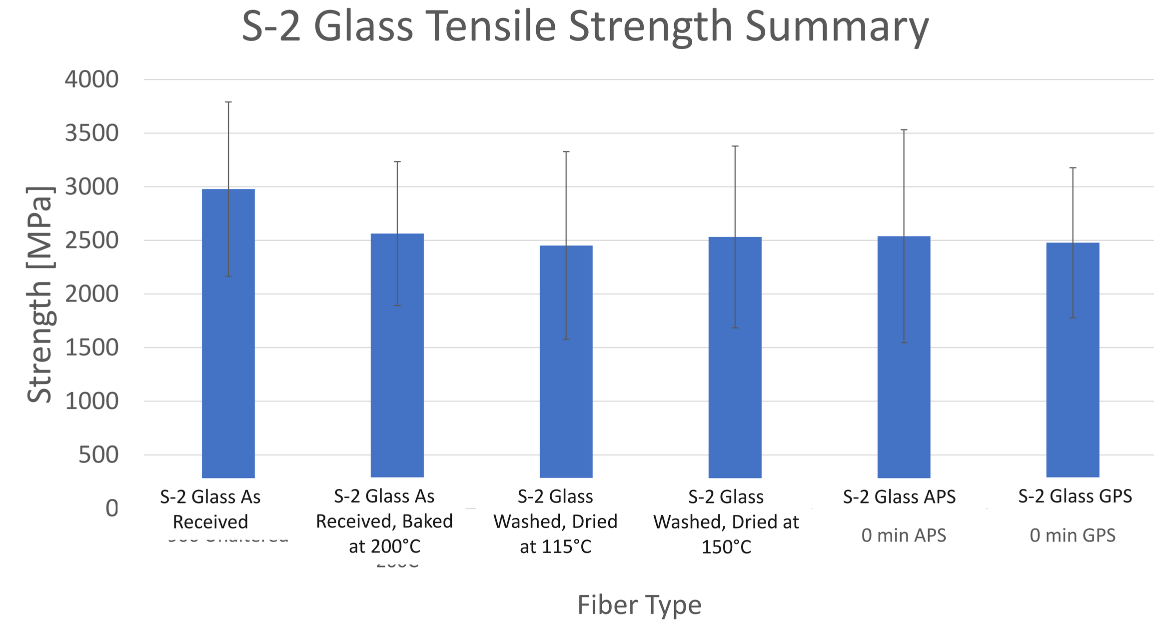


Figure 14. S-2 Glass Tensile Strength Summary.

- T-tests determine if the difference between the means of two data sets are statistically significant ($P < 5\%$) by calculating the probability of the data sets being observed randomly.
- T-test analyses were conducted amongst the as received and conditioned fibers, showing a statistically significant reduction in strength of approximately 15%.
- According to the t-test, there is no statistical significance between the strength of the as received and the APS coated fibers (Table 1).

Comparing S-2 Glass As Received to	P-Value
S-2 Glass As Received, Baked at 200°C	1.67%
S-2 Glass Washed, Dried at 115°C	1.01%
S-2 Glass Washed, Dried at 150°C	3.08%
S-2 Glass APS	5.49%
S-2 Glass GPS	0.87%

Table 1. Comparing Conditions T-Test Summary.

Conclusions

- The heat and turbulence generated by the washing process exacerbates existing flaws on the S-2 Glass surface, causing a reduction in tensile strength.
- The thin depositions of APS and GPS do not seem to further reduce the tensile strength of the S-2 Glass Fiber. The CVD process does not damage fibers because fiber strength reduction can be found in the cleaning phase.

Future Work

To expand upon the research conducted, the following routes can be explored:

- Consider alternate cleaning procedures to retain fiber strength.
- Conduct an analysis of the surface morphology and flaws through atomic force microscopy.

Acknowledgements

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