KANSAS STATE UNIVERSITY
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PIRE SYNTHESIS • NANOSTRUCTURE • PROPERTIES POLYMER-DERIVED CERAMIC FIBERS

Mechanical Property Assessment of Silicon Carbide Fiber-Reinforced Epoxy-Matrix Composites

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Abstract

Ceramic fibers present unique solutions for high-temperature, high-stress applications including thruster nozzles, nuclear reactors, and combustion gas turbine engines. Silicon carbide fibers exhibit excellent thermomechanical properties that allow them to maintain impressive Young's moduli at temperatures exceeding 1000°C, while still being lighter and less dense than metals with comparable mechanical properties. Three varieties of these fibers were compared to determine optimal performance within fiber-reinforced polymer matrix composites for future research involving the fabrication of ceramic matrix composites. Tensile testing was performed to review the Young's moduli and tensile strengths of both chopped fiber-filler and continuous fiber composites in order to fairly compare mechanical improvements made by each SiC fiber. The three types of SiC fibers tested were Hi-Nicalon Type S, Sylramic, and Tyranno SA3. The matrix for each composite was a 635 thin epoxy resin mixed with a 3:1 epoxy hardener.

General Procedure

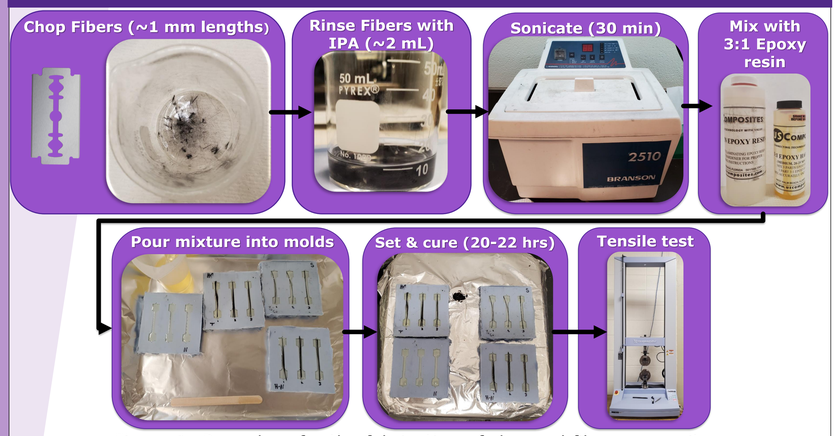


Figure 1: Procedure for the fabrication of chopped fiber composites.

SiC Fibers: Microscopy

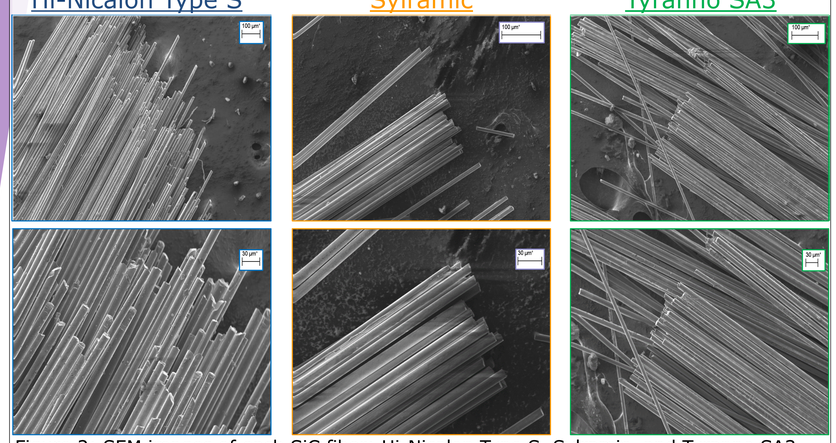
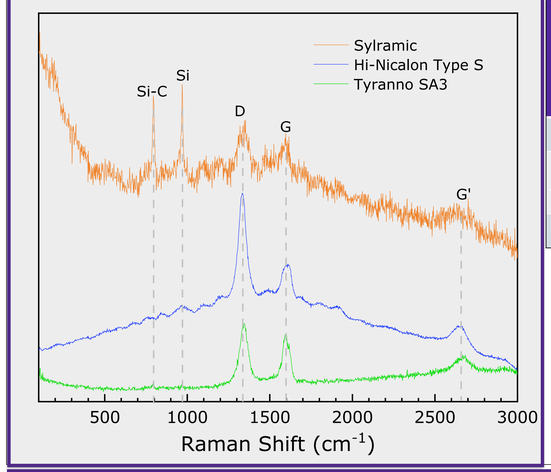


Figure 2: SEM images of each SiC fiber: Hi-Nicalon Type S, Sylramic, and Tyranno SA3, respectively.

SiC Fibers: Raman



SiC Fiber	I(D) / I(G) Ratio
Sylramic	1.049
Hi-Nicalon Type S	1.515
Tyranno SA3	1.154

Figure 3 (left): Raman spectroscopy data obtained for Sylramic, Hi-Nicalon Type S, and Tyranno SA3 SiC fibers using a Confocal Micro-Raman Microscope at the University of Kansas's Bioengineering Research Center Laboratories.

Composites: Chopped Fiber

Initial comparison of 0.60 mg/mL chopped commerical SiC fiber-reinforced Epoxy polymer-matrix composites

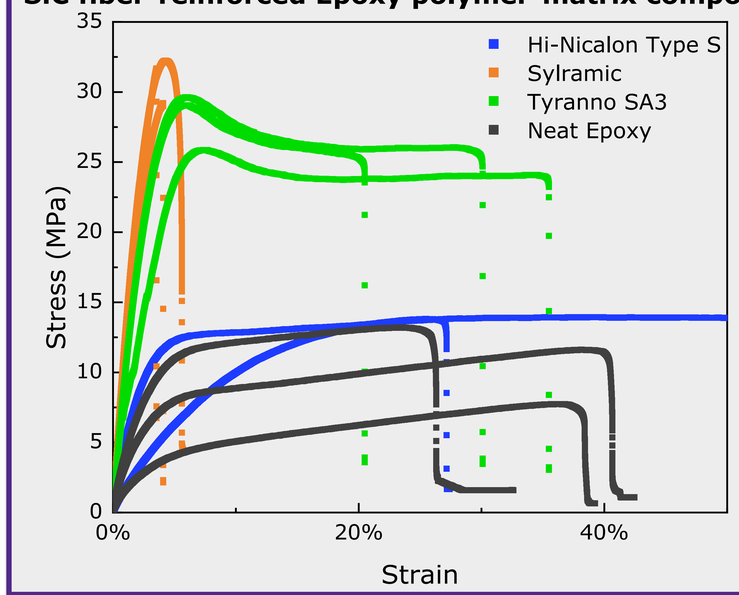


Figure 4: Stress-strain comparison of the three SiC fiber types using a 0.60 mg/mL ratio of fibers to epoxy resin.

Reinforcement	E (GPa)	σ_{max} (MPa)
Hi-Nicalon Type S Composite	0.57	11.24
Sylramic Composite	1.45	31.05
Tyranno SA3 Composite	1.14	28.19
Neat Epoxy	0.38	10.86

Composites: Continuous Fiber

Tensile test data from continuous commercial SiC fiber-reinforced epoxy composites

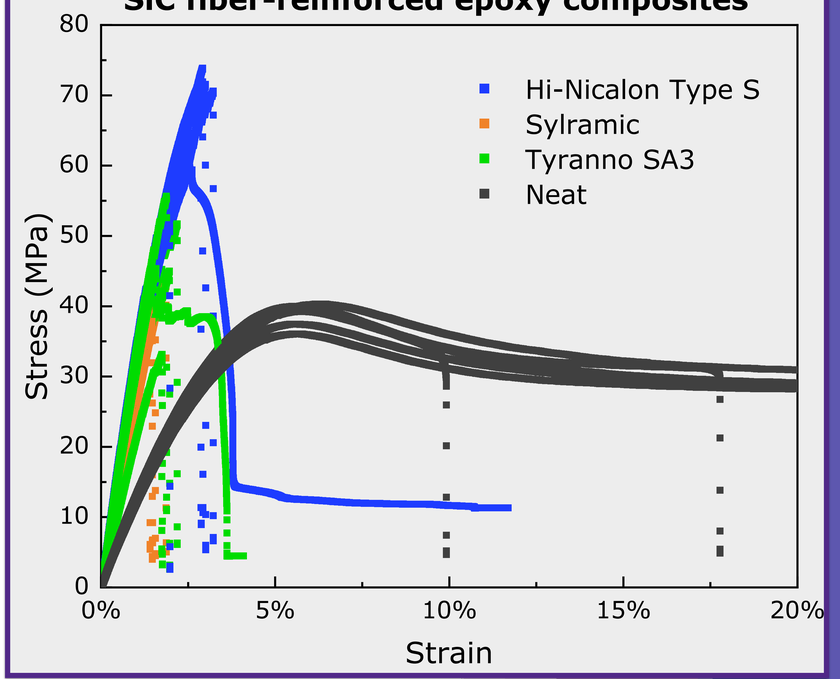


Figure 5: Stress-strain comparison of the three SiC fiber types using two-inch tow bundles of each fiber.

Reinforcement	E (GPa)	σ_{max} (MPa)
Hi-Nicalon Type S Composite	3.49	67.22
Sylramic Composite	3.01	40.89
Tyranno SA3 Composite	3.09	46.03
Neat Epoxy	1.25	38.82

Conclusions & Future Work

Third-generation SiC fiber types were used as fiber-reinforcement for an epoxy polymer matrix for the purpose of comparison using tensile testing. Fiber reinforcement was tried as both chopped- and continuous-fiber along the gage length of ASTM D638V tensile test specimens. Experiments with chopped fibers imply that Sylramic and Tyranno SA3 fibers show significant improvement on a neat matrix. In the instance of the continuous fiber-reinforcement, Hi-Nicalon Type S showed the highest strength and modulus of the three fiber types tested followed closely by Tyranno SA3 and Sylramic respectively. This data is supported by the manufacturers' data for the SiC fibers. Further testing of the fibers as reinforcement following exposure to temperatures >1000 °C would prove useful for establishing knowledge of temperature effects on the elastic modulus and tensile strength of each fiber type. Additionally, increasing the concentration of SiC fibers to epoxy resin in the chopped fiber mixtures or changing the lengths of the chopped fibers might show different effects on the mechanical properties of chopped fiber polymer composites. Future work will also involve using a SiC fiber as filler for a SiC photoreactive matrix to produce 3D-printed SiC/SiC ceramic matrix composites.

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