MATECH

"The All American Composite"

Woven SiNC-1400X Ceramic Fiber Reinforced Ceramic Matrix Composites

April 9, 2012

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How is it "All American?"

Manufacture of SiNC(f)/PyC(i)/SiC(m) Ceramic Matrix Composites

- Domestic precursors converted into SiNC preceramic polymer for fiber manufacturing at MATECH.
- SiNC-1400X Ceramic Fiber Tow manufactured (in-house).
- Ceramic fiber tow woven into fabric (in-house).
- Fabric PyC interface coated by CVI (in-house).
- Composite lay-up and densification (by PIP) performed in-house.
- Entire manufacturing process performed "under one roof" in **Westlake Village, CA USA**!

Production Grade
Melt Spinning

500 Filament Tow

Diameter	12-14 μm
St. Deviation	0.59 μm
Tensile Strength*	2.75 GPa
St. Deviation	0.5 GPa
Young's Modulus	~150 GPa
St. Deviation	26 GPa
Density	2.48g/cc

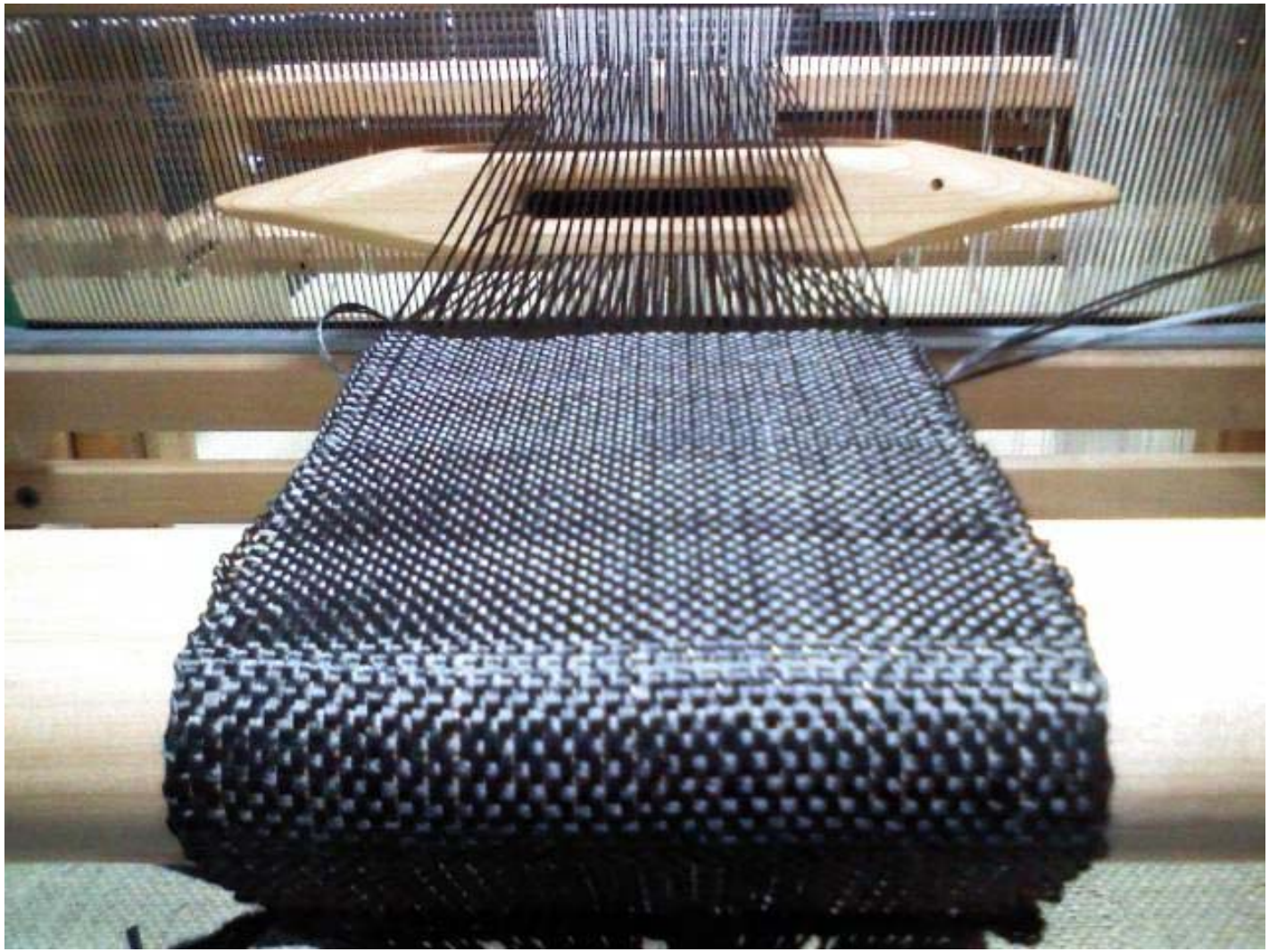
Manufacturing of SiNC-1400X at MATECH

SiNC-1400X 500 Filament Ceramic Fiber Tow and SiNC-1400X Chopped Fiber Staple

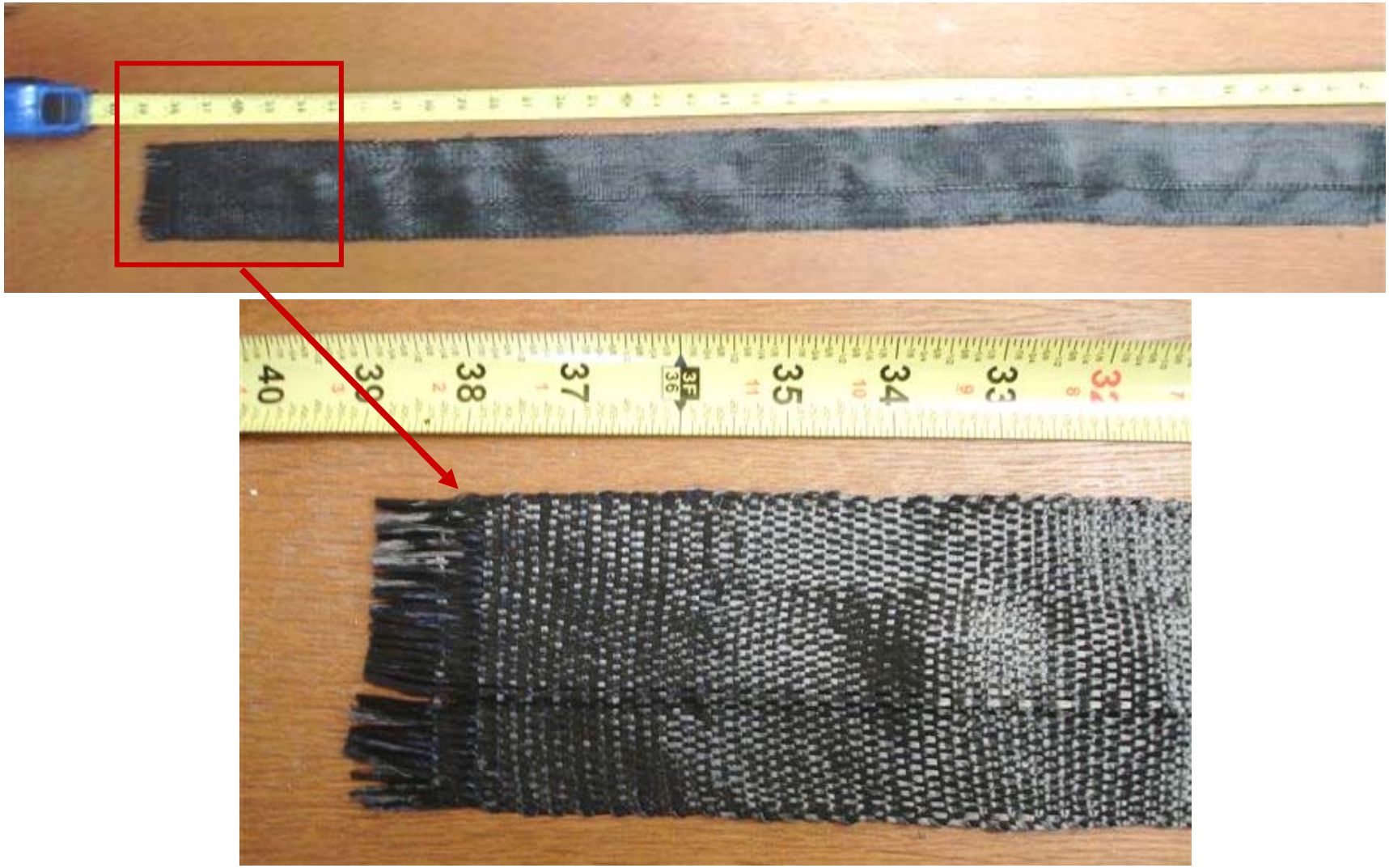
Developed with Continuous US NAVY
SBIR Support since 2000

MATECH Small Weaving Loom (3 – 12 inch fabric width)

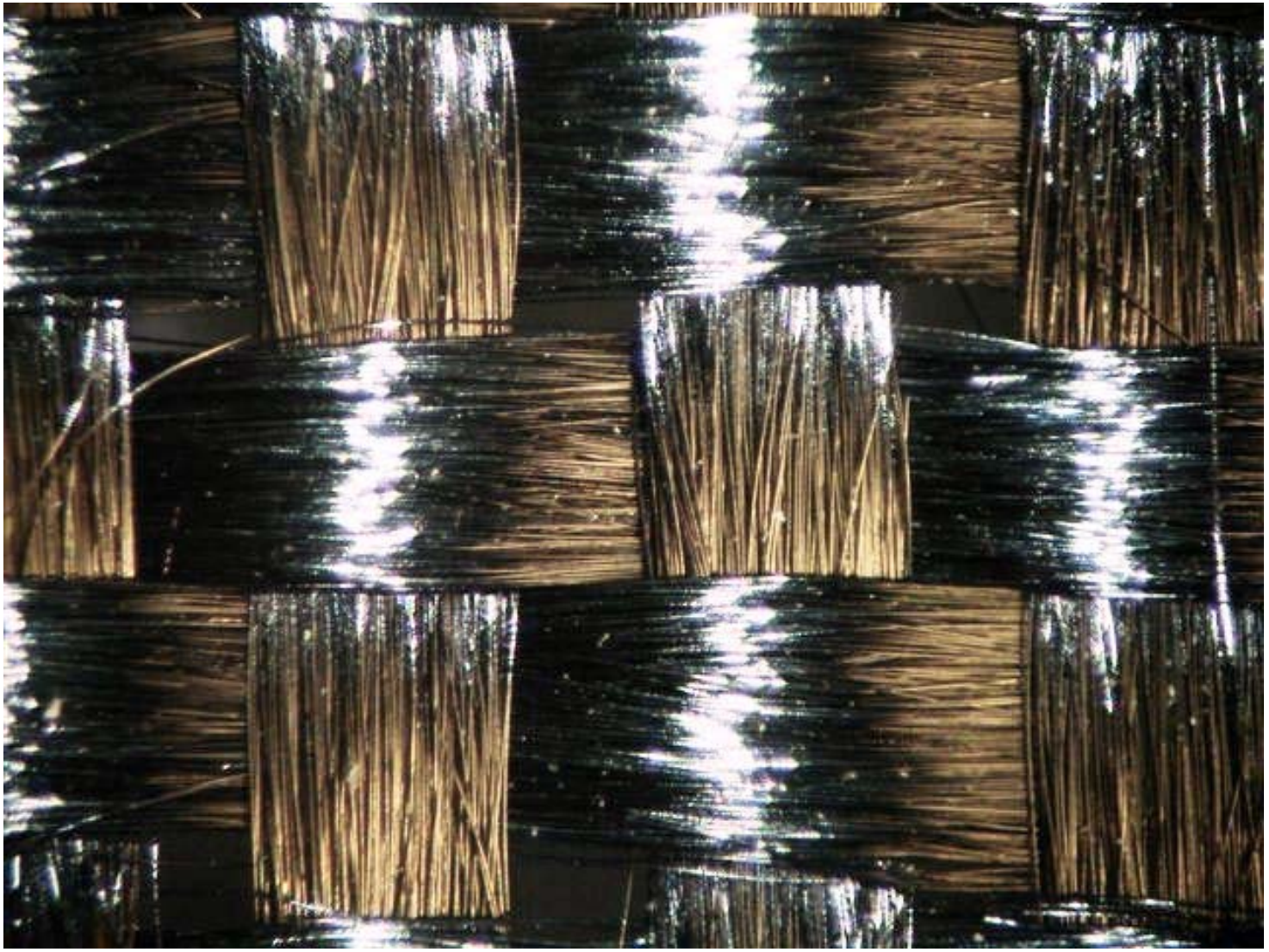
Plain Weave SiNC-1400X



Plain Weave SiNC-1400X (30 inch x 3 inch)

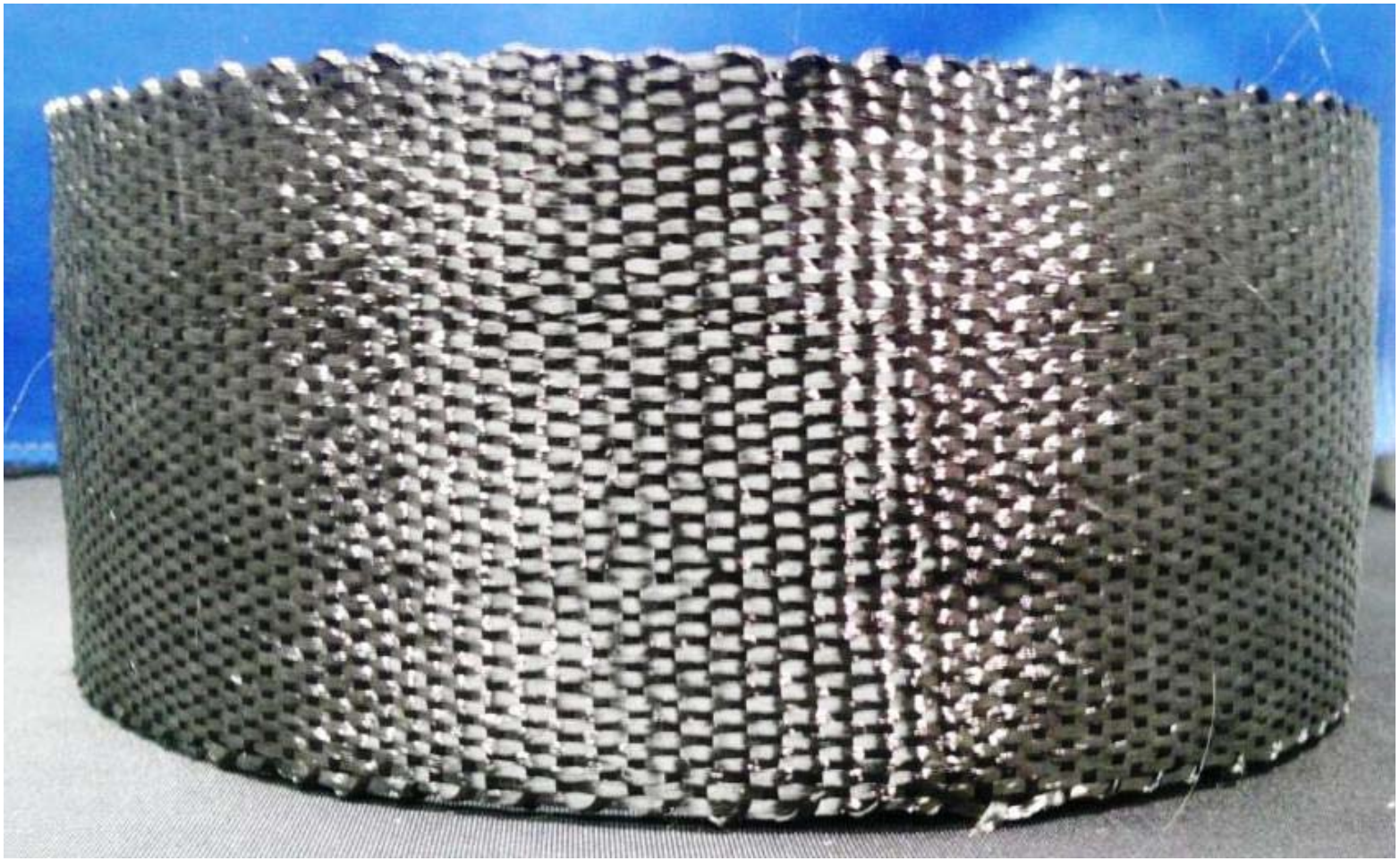


Plain Weave 500 Filament Tow SiNC-1400X

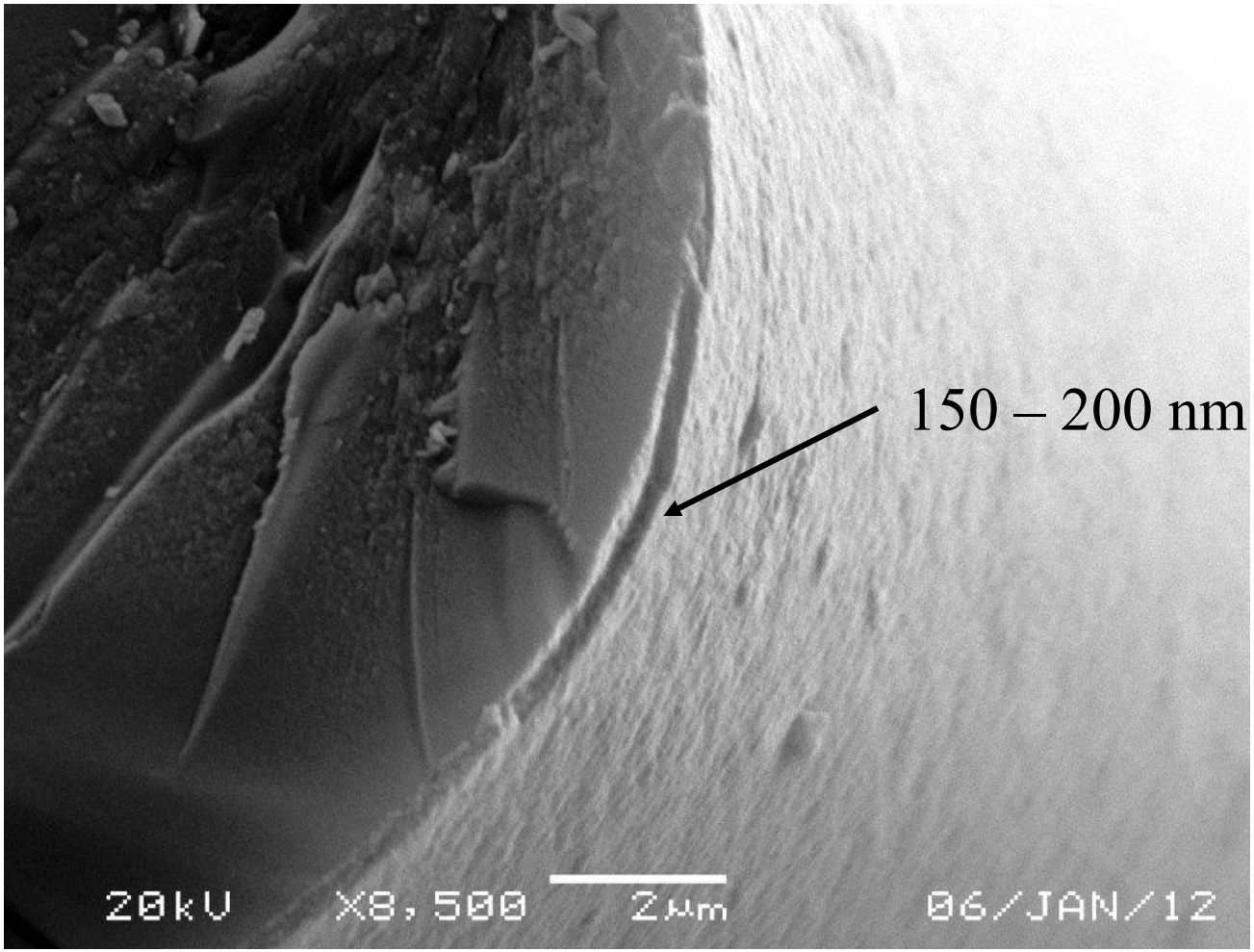


SiNC-1400X Plain Weave Fabric Roll (before CVI PyC)

CVI PyC Coated SiNC-1400X Plain Weave Fabric Roll



PyC Interface Coated SiNC-1400X Woven Cloth



Post PyC Interface Coated SiNC-1400X Fiber Strength (monofilament test of 30 filaments per ASTM)

	Tensile strength [GPa]	**Modulus [GPa]**
Maximum	3.54	245
Mean	2.19	190
Minimum	1.23	157
Standard deviation	0.53	21.

Plain Weave 6 Ply Laminate
SiNC-1400X Fiber / PyC Interface / PIP SiC Matrix CMC

6.25” L x 3.125” W x 0.11” T

Translating fiber properties into CMC properties!

- SiNC(f)/PyC(i)/SiC(m) CMC Machining.
- Archimedes Method:
  - Apparent density
  - Bulk density
  - Porosity
- MOR (Flex Strength) Testing
- Compression Testing.
- FE-SEM Microscopy/Fractography.

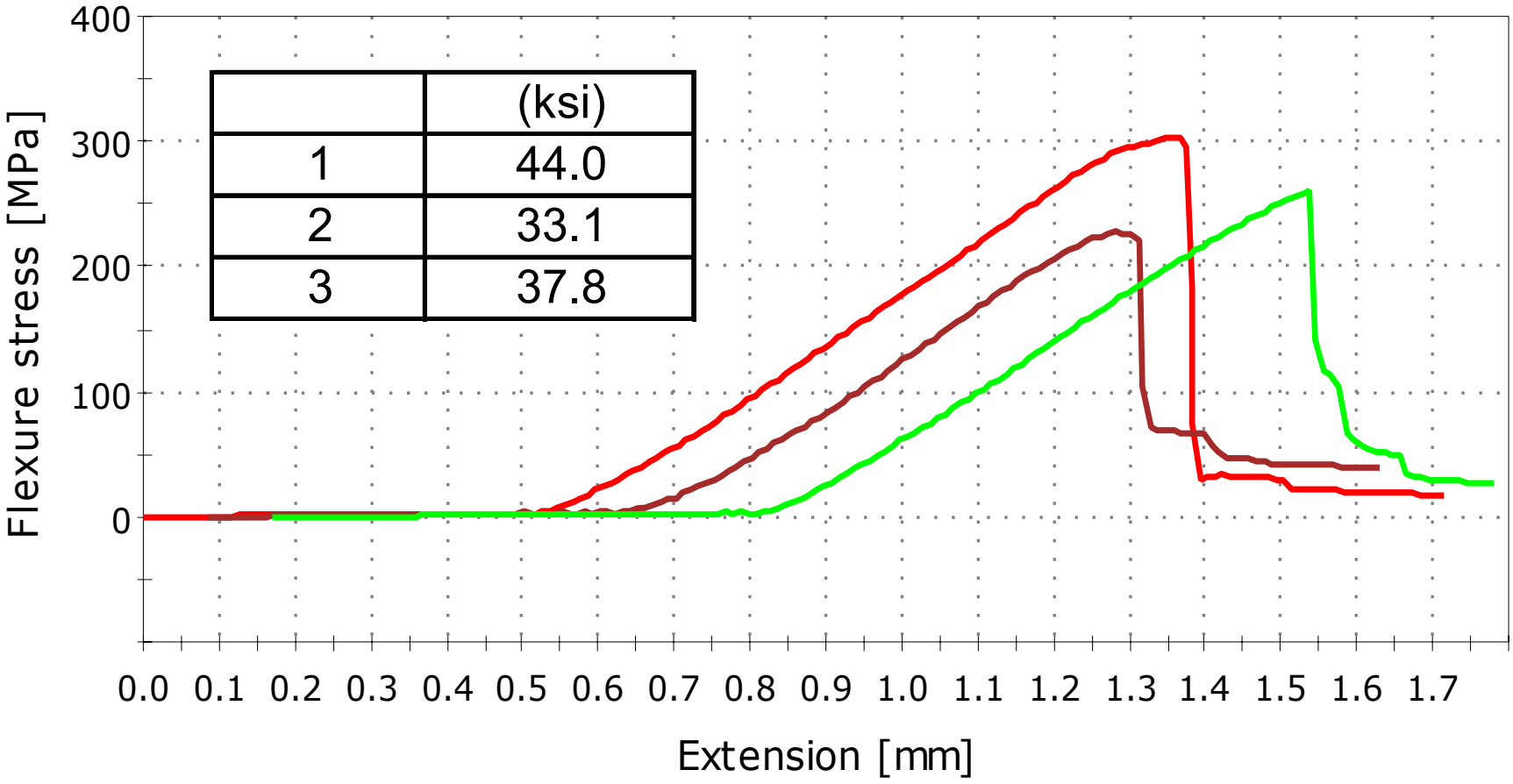
SiNC(f)/PyC(i)/SiC(m) CMC Panel Physical Properties & Flex Strength

Sample	W_d	W_{ss}	W_s	Apparent Density	Bulk Density	% Pa
1	5.3693	3.5699	5.5241	2.354	2.168	7.92
2	4.5447	3.0292	4.7215	2.366	2.119	10.45
3	4.4521	2.9642	4.638	2.361	2.099	11.11
Average				**2.360**	**2.128**	**9.825**

	Specimen	Thickness (mm)	Width (mm)	Load (lbf)	Flexure strength (MPa)	Flexure strain (%)
	1	2.13	7.76	79.07	**303.48**	0.76%
	2	2.04	7.79	54.77	**228.15**	0.65%
	3	2.04	7.76	62.34	**260.52**	0.74%
Maximum		2.13	7.79	79.07	303.48	0.76%
Mean		2.07	7.77	65.39	**264.05**	0.71%
Minimum		2.04	7.76	54.77	228.15	0.65%
Standard deviation		0.05	0.01	12.43	37.79	0.06%

Flexural (MOR) Strength (MPa)

	(ksi)
1	44.0
2	33.1
3	37.8



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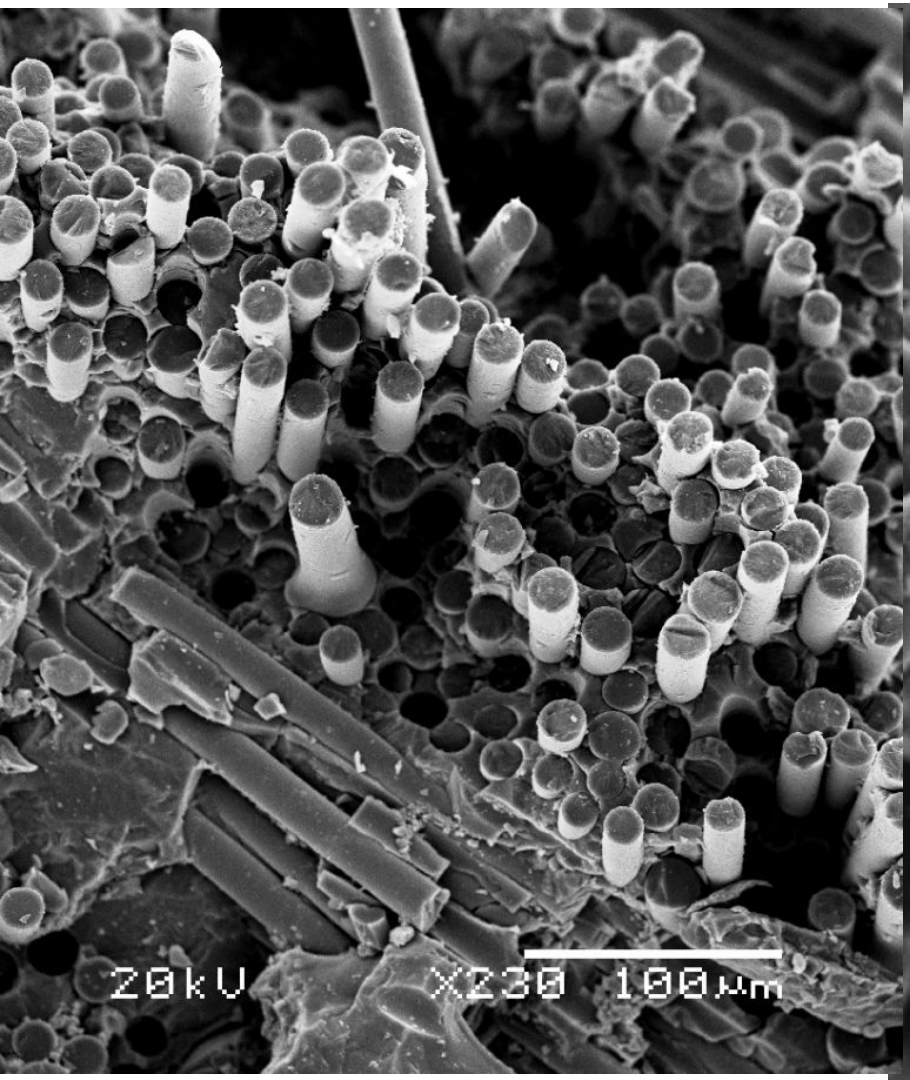
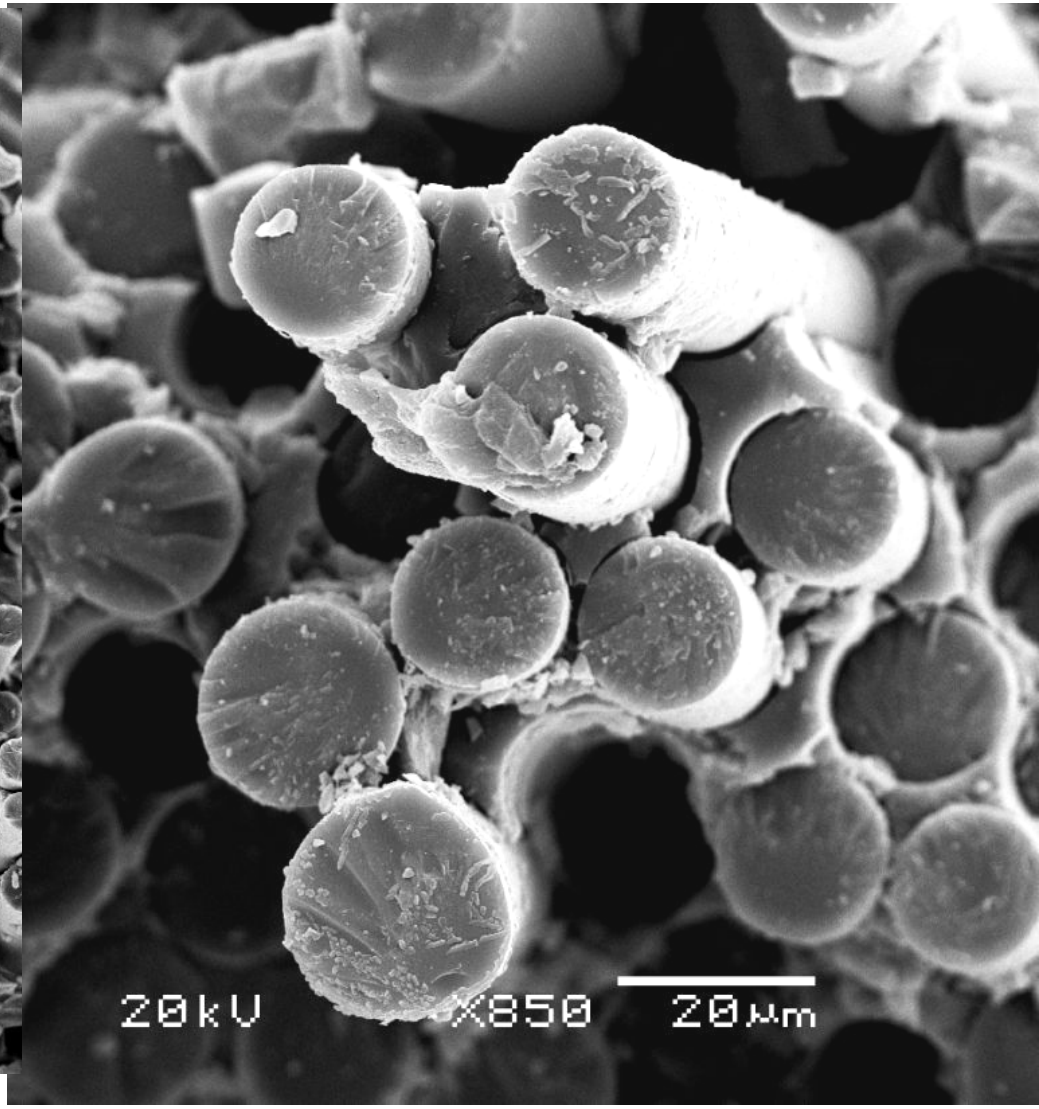
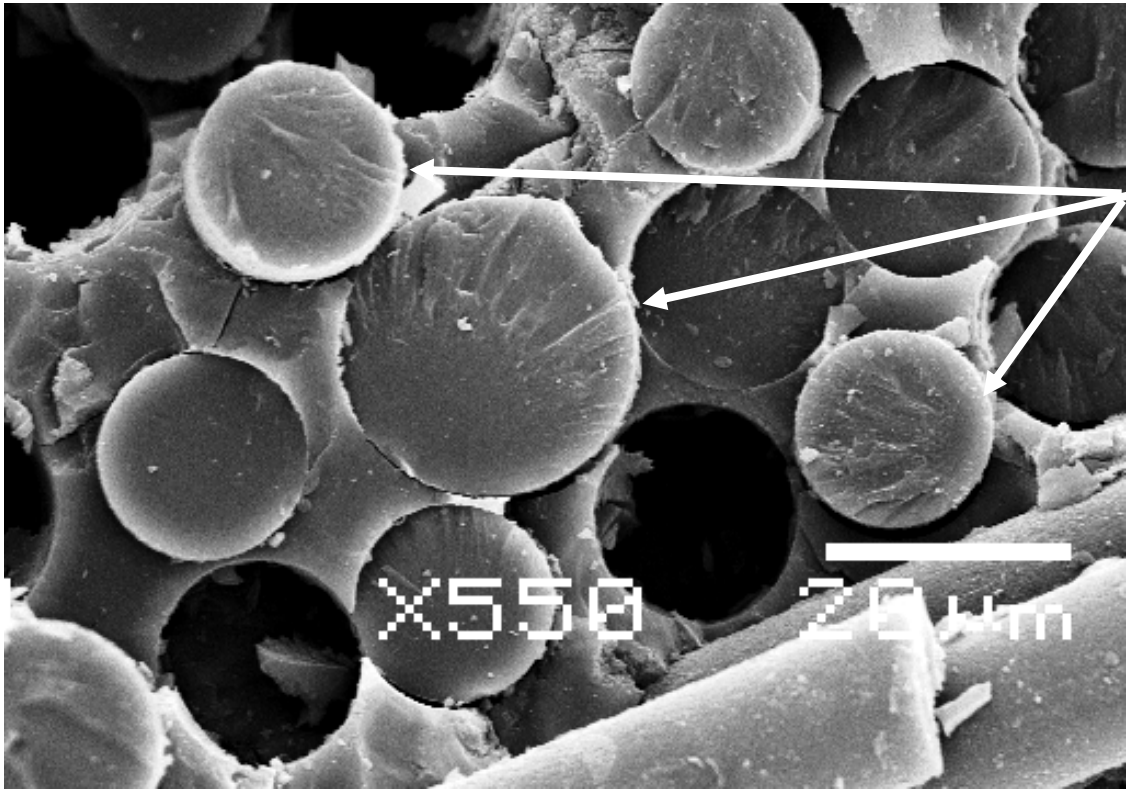
Fractography: *Extensive Fiber Pull-Out Evident*





Examples of Mirror and Hackle Fracture of SiNC-1400X Fibers



Mirror/Hackle Zones

SiNC(f)/PyC(i)/SiC(m) CMC Compression Strength

	Specimen	Thickness [mm]	Width [mm]	Compressive strength [MPa]	Strain [%]
	1	2.12	7.77	271.62	0.98
	2	2.12	11.54	211.10	0.74
	3	2.08	11.87	238.41	1.10
	4	2.03	12.31	244.71	0.99
	5	2.04	11.68	262.87	1.36
	6	2.08	11.43	258.46	0.64
Maximum		2.12	12.31	271.62	1.36
Minimum		2.03	7.77	211.10	0.64
Mean		2.08	11.10	**247.86**	**0.97**

	(psi)
1	39,395
2	30,618
3	34,578
4	35,493
5	38,126
6	37,486
AVE	35,949

Summary

- Starting with domestic raw materials, complex ceramic matrix composites were fabricated entirely domestically.
- All manufacturing steps, including polymer synthesis, fiber manufacturing, weaving, interface coatings, and CMC panel densification, were conducted with US Intellectual property.
- Furthermore, all manufacturing steps were performed by a single small business under one roof.
- This demonstrates the potential for manufacturing scale-up of all aspects of the manufacturing process, with particular emphasis on domestic ceramic fiber manufacturing.