



National Aeronautics and  
Space Administration



## TECHNOLOGY SOLUTION

### Materials and Coatings

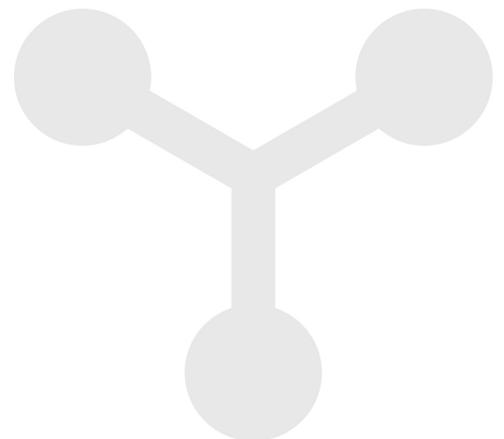
# Silicon Carbide (SiC) Fiber-Reinforced SiC Matrix Composites

Lightweight high-performance SiC/SiC ceramic composite materials and SiC fibers for use in extreme environments.

Innovators at NASA's Glenn Research Center have conducted leading-edge research toward the development of silicon carbide (SiC) fibers and SiC/SiC ceramic matrix composites (CMCs) that can be used in high-temperature structural applications, such as hot components in gas turbine engines. Glenn has gained recognition for the innovative design and processing technologies required for these materials. NASA's patented SiC/SiC CMC technologies use the advantages of non-oxide SiC fibers and matrices to yield ceramic composites that can withstand adverse structural and environmental conditions for long times at temperatures up to 2700°F. The CMC properties offer significant benefits in comparison to other options, including metallic superalloys, monolithic ceramics, carbon fiber composites, and oxide/oxide ceramic composites. These composites are also invaluable in their ability to be engineered for specific stress, temperature, life, and environmental conditions.

#### BENEFITS

- Versus metallic superalloys: lower density, higher temperature capability, and lower thermal expansion
- Versus monolithic ceramics: non-catastrophic failure, higher toughness, better damage tolerance, and capability for large components
- Versus carbon fiber composites: higher oxidative durability, more predictable life, and lower permeability
- Versus oxide/oxide ceramic composites: greater strength, higher temperature capability, better creep-rupture resistance and thermal conductivity, and lower permeability

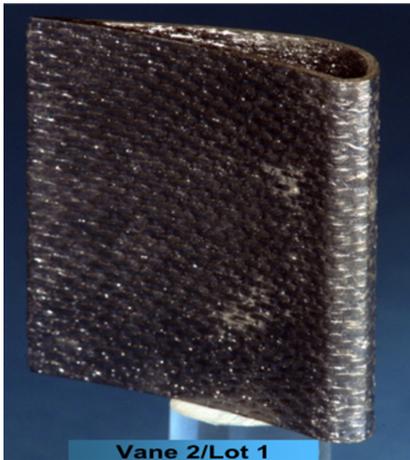


## THE TECHNOLOGY

Aimed at structural applications up to 2700°F, NASA's patented technologies start with two types of high-strength SiC fibers that significantly enhance the thermo-structural performance of the commercially available boron-doped and sintered small-diameter "Sylramic" SiC fiber. These enhancement processes can be done on single fibers, multi-fiber tows, or component-shaped architectural preforms without any loss in fiber strength. The processes not only enhance every fiber in the preforms and relieve their weaving stresses, but also allow the preforms to be made into more shapes. Environmental resistance is also enhanced during processing by the production of a protective in-situ grown boron-nitride (iBN) coating on the fibers. Thus the two types of converted fibers are called "Sylramic-iBN" and "Super Sylramic-iBN".

For high CMC toughness, two separate chemical vapor infiltration (CVI) steps are used, one to apply a boron nitride coating on the fibers of the preform and the other to form the SiC-based matrix. The preforms are then heat treated not only to densify and shrink the CVI BN coating away from the SiC matrix (outside debonding), but also to increase its creep resistance, temperature capability, and thermal conductivity.

One crucial advantage in this suite of technologies lies in its unprecedented customizability. The SiC/SiC CMC can be tailored to specific conditions by down-selecting the optimum fiber, fiber coating, fiber architecture, and matrix materials and processes. In any formulation, though, the NASA-processed SiC fibers display high tensile strength and the best creep-rupture resistance of any commercial SiC fiber, with strength retention to over 2700°F.



SiC inlet turbine vane fabricated by the materials and processes of the NASA technologies



Glenn's SiC/SiC CMC materials are ideal for high-temperature structural applications

## APPLICATIONS

The technology has several potential applications:

- Combustion and turbine section components of aero-propulsion and land-based gas turbine engines
- Heat exchangers, reformers, reactors, and filters for the chemical industry
- Preheaters, recuperators, and radiant tubes for the heat transfer industry
- Thermal protection systems, thruster nozzles, reusable rocket nozzles, and turbopump components for space vehicles
- Furnace components
- Nuclear fission and fusion reactors as fuel cladding and radiation blankets

## PUBLICATIONS

Patent No: 7,427,428; 7,687,016; 8,894,918