

## Innovative, Low-Cost Composites for Windpower and Transportation Applications

### Oxide Ceramic and Thermally Robust Resin Matrix Composites

Applications for large-size and large-volume composites are emerging in the aerospace, windpower (turbine blades and poles), and automotive markets. To support evolving needs of these sectors, demand for fiber-reinforced composites is growing rapidly, while advanced technologies are being developed that require lighter and tougher materials.



1.5m long candle filters developed by 3M

**Easily processed, low-cost oxide and resin composites operate at high temperatures to meet emerging windpower, automotive, and aerospace needs.**

In response, organic resin-based materials meeting the required characteristics are now the leading composites in the market, replacing structural metals.

Thermally stable resins, carbon, and ceramic matrix composites are progressively used for components operating at elevated temperatures.

While technology for high-temperature resins still presents opportunities for further growth in temperatures below 300°C, progress in developing new carbon and non-oxide matrix composite applications remains slow because of very high production cost. Another obstacle is oxidation, especially for carbon-based composites. SRI's variable preceramic polymer matrix capability opens the door to low-cost oxidation-stable composites at both the resin (as high as 400°C) and the ceramic matrix (as high as 1000°C) stages.

### Advantages of SRI's Matrix Approach

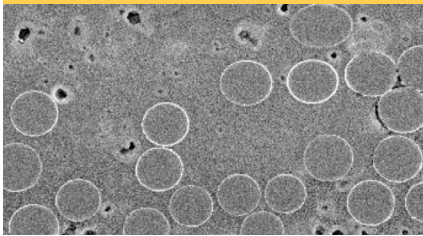
Our platform for silicon-based polymers offers diverse capabilities for low-cost, oxide-oxide ceramic matrix composites (CMC) with a wide array of applications, including aerospace, automotive, windpower components, and composite tools.

These composites are based on silica containing oxide matrices derived from SRI's low-cost preceramic polymers (<\$20/kg) with simple composite processing and a single matrix-infiltration/heating cycle. SRI's concepts can be extended to oxide matrices that do not contain the silica phase or contain unique nano-compositional matrices.

SRI's oxide matrices — containing metal silicates of aluminum, zirconium, titanium, or other oxides — can be tailored for development of specific tools. Both dense and porous matrices can be produced, offering flexibility for different manufacturing scenarios, such as

- *Dense composites: Excellent for applications where the deposition of weak interface coatings ( $\text{LaPO}_4$ ) can be afforded. Dense matrices are vacuum-tight and provide the best mechanical performance*
- *Very homogeneous porous matrices: Feasible where interface coatings are not as critical and relatively low cost is essential.*





LaPO<sub>4</sub> coated fibers embedded in dense aluminum-silicate matrix

These composites have been demonstrated with significant benefits, including

- High homogeneity of matrices for achieving a mechanical edge over other porous CMCs
- Variable techniques to seal their surfaces if needed
- Mechanical stability at temperatures exceeding 1000°C, with strength values greater than 45 Ksi (300 MPa)
- Four-point bend test values as high as 470 MPa after exposure of the porous composites to moist environments at 850°C

### Specific Benefits of Our Platform

Our platform consists of a broad range of polymer modifications and curing strategies to provide versatile solutions for processing, final compositions, physical characteristics, and performance.

- Matrix processing of the composite with SRI's preceramic polymer is similar to conventional thermoset processes, assisted by the low-viscosity characteristics of the polymers (20 to 500 cP) and rapid curing of the preceramic polymer, once activated.

- Thermal robustness of the cured inorganic-organic hybrid resins provides additional capability of using the thermoset preceramic polymers for making preceramic matrix composites (PCMCs), allowing composite processing at or below 150°C.
- PCMCs can perform in harsh thermal environments as high as 400°C while maintaining low weight, sealing, UV stability, water-proofing, and nonflammability.
- Tensile strength values of 350 MPa (50 Ksi) have been measured for such hybrid resin composites.

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### About SRI International

Silicon Valley-based SRI International is one of the world's leading independent research and technology development organizations. SRI, which was founded by Stanford University as Stanford Research Institute in 1946 and became independent in 1970, has been meeting the strategic needs of clients and partners for more than 60 years. The nonprofit institute performs sponsored research and development for government agencies, businesses, and foundations. SRI also licenses its technologies, forms strategic alliances, and creates spin-off companies. In 2009, SRI's consolidated revenues, including its wholly owned for-profit subsidiary, Sarnoff Corporation, were approximately \$470 million.

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