



## Materials & Coatings

### High-Temperature, Lightweight, Self-Healing Ceramic Composites for Aircraft Engine Applications

Applications include the nuclear power generation industry and military ships.

*John H. Glenn Research Center, Cleveland, Ohio*

The use of reliable, high-temperature, lightweight materials in the manufacture of aircraft engines is expected to result in lower fossil and biofuel consumption, thereby leading to cost savings and lower carbon emissions due to air travel. Although nickel-based superalloy blades and vanes have been successfully used in aircraft engines for several decades, there has been an increased effort to develop high-temperature, lightweight, creep-resistant substitute materials under various NASA programs over the last two decades. As a result, there has been a great deal of interest in developing SiC/SiC ceramic matrix composites (CMCs) due to their higher damage tolerance compared to monolithic ceramics. Current-generation SiC/SiC ceramic matrix composites rely almost entirely on the SiC fibers to carry the load, owing to the premature cracking of the matrix during loading. Thus, the high-temperature usefulness of these CMCs falls well below their theoretical capabilities.

The objective of this work is to develop a new class of high-temperature, lightweight, self-healing, SiC fiber-reinforced, engineered matrix ceramic composites. Several engineered matrices

were designed to be thermally compatible with SiC. Several different tests were conducted on these matrices, which helped to down-select suitable compositions. Engineered matrix composites (EMCs) designed to match the coefficient of thermal expansion (CTE) of the SiC fiber were fabricated by slurry casting and melt infiltration techniques. The matrix composition was designed to convert any ingressed oxygen into low-viscosity oxides or silicates so they can flow into the cracks due to capillary action and seal them, thereby activating its self-healing properties.

The present concept uses the fundamental principles of physics and materials science to develop a new class of self-healing ceramic composites (SHCCs). Unlike current SiC/SiC CMC technology, the present concept develops SiC fiber-reinforced SiC-Si<sub>3</sub>N<sub>4</sub>-silicide matrix composites with a composition formulated to match the CTE of the fibers, and with an ability to get ingressed oxygen and self-heal cracks by filling them with low-viscosity oxides.

The present concept provides considerable flexibility in designing the composite matrix for a wide variety of high-

temperature applications. Depending on the composition, silicides deform plastically at high temperatures, unlike SiC and Si<sub>3</sub>N<sub>4</sub>. Thus, the matrix is likely to be compliant to the applied loading conditions at high temperatures rather than develop cracks. This important feature allows the matrix to carry some load before transferring to the reinforcing SiC fibers, extending the life of the composite. The ability of these matrices to self-heal fine cracks is also expected to increase composite life. For matrices containing (Cr,Mo)<sub>3</sub>Si, the expected amount of free silicon after melt infiltration is expected to be low, which would allow composites made with this engineered matrix to be used in applications at or above 1,755 K.

*This work was done by Sai V. Raj of Glenn Research Center, and Mrityunjay Singh and Ramkrishna Bhatt of the Ohio Aerospace Institute. Further information is contained in a TSP (see page 1).*

*Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steven Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18964-1.*

### Treatment to Control Adhesion of Silicone-Based Elastomers

Ultraviolet radiation is used to control and decrease the level of adhesion.

*John H. Glenn Research Center, Cleveland, Ohio*

Seals are used to facilitate the joining of two items, usually temporarily. At some point in the future, it is expected that the items will need to be separated. This innovation enables control of the adhesive properties of silicone-based elastomers. The innovation may also be effective on elastomers other than the silicone-based ones. A technique has been discovered that decreases the level of adhesion of silicone-based elastomers to negligible levels. The new technique causes less dam-

age to the material compared to alternative adhesion mitigation techniques.

Silicone-based elastomers are the only class of "rubber-like" materials that currently meet NASA's needs for various seal applications. However, silicone-based elastomers have natural inherent adhesive properties. This stickiness can be helpful, but it can frequently cause problems as well, such as when trying to get items apart.

In the past, seal adhesion was not always adequately addressed, and has

caused in-flight failures where seals were actually pulled from their grooves, preventing subsequent spacecraft docking until the seal was physically removed from the flange via an extravehicular activity (EVA). The primary method used in the past to lower elastomer seal adhesion has been the application of some type of lubricant or grease to the surface of the seal. A newer method uses ultraviolet (UV) radiation — a mixture of UV wavelengths in the range of near ultravi-