

CVI SiC matrix into a fiber preform. Using (1) SiC fibers of a type developed by GRC and denoted "Sylramic-iBN" and (2) BN-based fiber coatings, which are both stable in their functions under the treatment conditions, the GRC researchers have observed minimal loss of strength in composite panels formed from two-dimensional architectural preforms and various contents of CVI SiC. More importantly, the NASA treatment significantly increased panel thermal conductivity and creep resistance, as indicated in Figures 1 and 2, respectively.

For the treated panels, the volume fractions of the fibers and BN coatings were about 36 percent and 8 percent, respectively. The first case represented in Figure 1 is that of a panel containing 50 volume percent SiC formed by CVI only. In the second case, the remaining open porosity in the 35-percent CVI SiC matrix was filled by a process denoted

PIP, which involved repeated infiltration and pyrolysis of an SiC-yielding polymer (hybrid CVI + PIP). For the third case represented in Figure 1, the remaining open porosity in a 35-percent CVI SiC matrix was filled by a process that involved repeated melt infiltration (MI) of silicon at a temperature near 1,400 °C (hybrid CVI + MI). For the first two cases, the heat treatment was performed after final matrix formation; for the last case, the treatment was performed after CVI and before MI. In all cases, panel thermal conductivity was significantly increased by the NASA heat treatment. On an absolute scale, Figure 1 also shows the detrimental effect of trapped porosity on composite conductivity for the matrices formed by CVI only or by hybrid CVI + PIP, and the beneficial effects of the hybrid CVI + MI approach that more effectively fills the CVI SiC pores. However, Figure 2 shows that in

the case of the matrix fully formed by CVI only, creep resistance and temperature capability were greater than in the case of the matrix formed by hybrid CVI + MI. Thus, because of their lack of elemental silicon, the long-term use temperature of the CVI-only matrix (as well as the hybrid CVI + PIP matrix) could exceed 1,400 °C, which is well above the long-term use temperature for panels containing matrices made by hybrid CVI + MI.

This work was done by James A. DiCarlo of Glenn Research Center and Ramakrishna T. Bhatt of the Army Research Laboratory. 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: Steve Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17595-1.

Aerogel/Particle Composites for Thermoelectric Devices

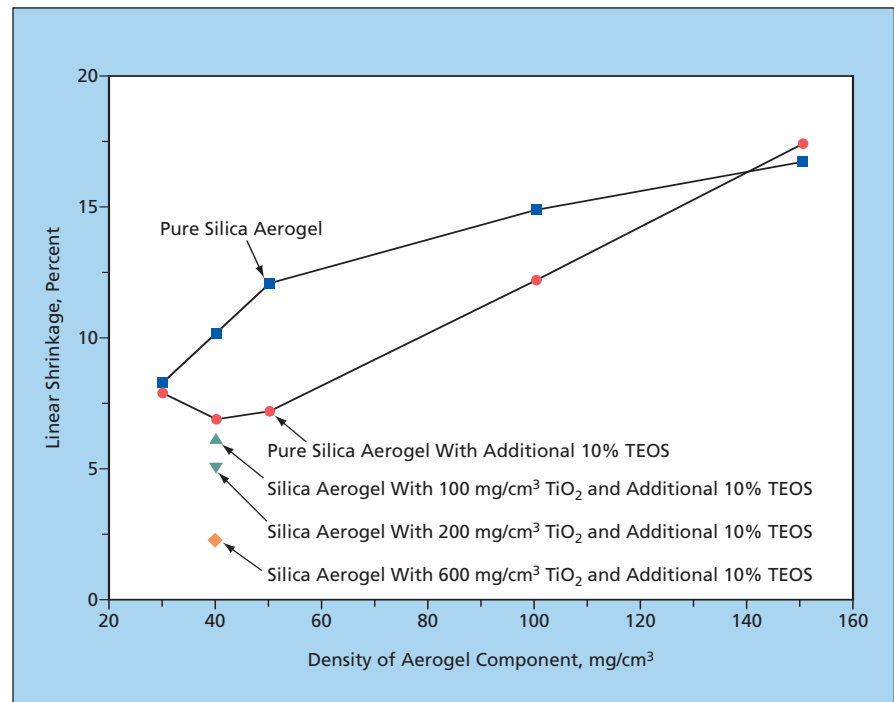
Shrinkage is reduced through addition of titania powder.

NASA's Jet Propulsion Laboratory, Pasadena, California

Optimizing solution chemistry and the addition of titania and fumed silica powder reduces shrinkage. These materials would serve to increase thermal efficiency by providing thermal insulation to suppress lateral heat leaks. They would also serve to prolong operational lifetime by suppressing sublimation of certain constituents of thermoelectric materials (e.g., sublimation of Sb from CoSb₃) at typical high operating temperatures. [The use of pure silica aerogels as cast-in-place thermal-insulation and sublimation-suppression materials was described in "Aerogels for Thermal Insulation of Thermoelectric Devices" (NPO-40630), *NASA Tech Briefs*, Vol. 30, No. 7 (July 2006), page 50.]

A silica aerogel is synthesized in a sol-gel process that includes preparation of a silica sol, gelation of the sol, and drying of the gel in a solvent at a supercritical temperature and pressure. The utility of pure silica aerogel is diminished by a tendency to shrink (and, therefore, also to crack) during the gelation and supercritical-drying stages. Moreover, to increase suppression of sublimation, it is advantageous to make an aerogel having greater density, but shrinkage and cracking tend to increase with density.

A composite material of the type



Shrinkages of Representative Aerogels of various densities and of aerogel/titania composites were measured.

under investigation consists mostly of titania oxide powder particles and a small addition of fumed silica powder, which are mixed into the sol along with other

ingredients prior to the gelation stage of processing. The silica aerogel and fumed silica act as a binder, gluing the titania particles together. It is believed

that the addition of fumed silica stiffens the aerogel network and reduces shrinkage during the supercritical-drying stage. Minimization of shrinkage enables establishment of intimate contact between thermolectric legs and the composite material, thereby maximizing the effectiveness of the material for thermal insulation and suppression of sublimation.

To some extent, the properties of the composite can be tailored via the proportions of titania and other ingredients. In particular (see figure), the addition of a

suitably large proportion of titania (e.g., 0.6 g/cm³) along with a 10-percent increase in the amount of tetraethylorthosilicate [TEOS (an ingredient of the sol)] to an aerogel component having a density 40 mg/cm³ makes it possible to cast a high-average-density (>0.1 g/cm³) aerogel/particle composite having low shrinkage (2.3 percent).

This work was done by Jong-Ah Paik, Jeffrey Sakamoto, and Steven Jones of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

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Refer to NPO-42031, volume and number of this NASA Tech Briefs issue, and the page number.

Patches for Repairing Ceramics and Ceramic-Matrix Composites

Patches are simply pressed in place, then heated.

Lyndon B. Johnson Space Center, Houston, Texas

Patches consisting mostly of ceramic fabrics impregnated with partially cured polymers and ceramic particles are being developed as means of repairing ceramics and ceramic-matrix composites (CMCs) that must withstand temperatures above the melting points of refractory metal alloys. These patches were conceived for use by space-suited, space-walking astronauts in repairing damaged space-shuttle leading edges: as such, these patches could be applied in the field, in relatively simple procedures, and with minimal requirements for specialized tools. These design characteristics also make the patches useful for repairing ceramics and CMCs in terrestrial settings.

In a typical patch as supplied to an astronaut or repair technician, the polymer would be in a tacky condition, denoted as an "A" stage, produced by partial polymerization of a monomeric liquid. The patch would be pressed

against the ceramic or CMC object to be repaired, relying on the tackiness for temporary adhesion. The patch would then be bonded to the workpiece and cured by using a portable device to heat the polymer to a curing temperature above ambient temperature but well below the maximum operating temperature to which the workpiece is expected to be exposed. The patch would subsequently become pyrolyzed to a ceramic/glass condition upon initial exposure to the high operating temperature. In the original space-shuttle application, this exposure would be Earth-atmosphere-reentry heating to about 3,000 °F (about 1,600 °C).

Patch formulations for space-shuttle applications include SiC and ZrO₂ fabrics, a commercial SiC-based pre-ceramic polymer, and suitable proportions of both SiC and ZrO₂ particles having sizes of the order of 1 μm. These formulations have been tailored for the space-shuttle

leading-edge material, atmospheric composition, and reentry temperature profile so as to enable repairs to survive re-entry heating with expected margin. Other formulations could be tailored for specific terrestrial applications.

This work was done by Peter A. Hogenson, Gordon R. Toombs, Steven Adam, and James V. Tompkins of The Boeing Co. for Johnson Space Center.

Title to this invention has been waived under the provisions of the National Aeronautics and Space Act {42 U.S.C. 2457(f)}, to The Boeing Company. Inquiries concerning licenses for its commercial development should be addressed to:

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Refer to MSC-24018, volume and number of this NASA Tech Briefs issue, and the page number.

Lower-Conductivity Ceramic Materials for Thermal-Barrier Coatings

Thermal conductivities of certain pyrochlore oxides can be reduced by doping.

John H. Glenn Research Center, Cleveland, Ohio

Doped pyrochlore oxides of a type described below are under consideration as alternative materials for high-temperature thermal-barrier coatings (TBCs). In comparison with partially-yttria-stabilized zirconia (YSZ), which is the state-of-the-art TBC

material now in commercial use, these doped pyrochlore oxides exhibit lower thermal conductivities, which could be exploited to obtain the following advantages:

- For a given difference in temperature between an outer coating surface and

the coating/substrate interface, the coating could be thinner. Reductions in coating thicknesses could translate to reductions in weight of hot-section components of turbine engines (e.g., combustor liners, blades, and vanes) to