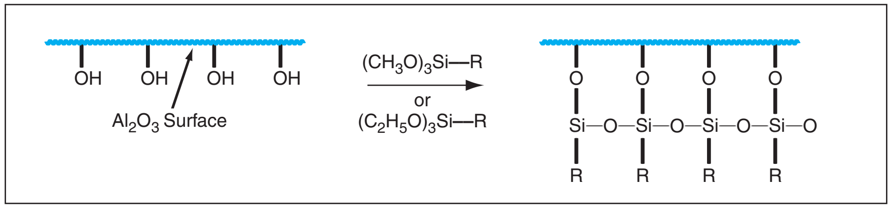
Materials

Oxygen-Permeable, Hydrophobic Membranes of Silanized α-Al_2O_3

These membranes perform better than do organic polymer oxygen-diffusion membranes.

Lyndon B. Johnson Space Center, Houston, Texas

Membranes made of silanized alumina have been prepared and tested as prototypes of derivatized ceramic membranes that are both highly permeable to oxygen and hydrophobic. Improved oxygen-permeable, hydrophobic membranes would be attractive for use in several technological disciplines, including supporting high-temperature aqueous-phase oxidation in industrial production of chemicals, oxygenation of aqueous streams for bioreactors, and oxygenation of blood during open-heart surgery and in cases of extreme pulmonary dysfunction. In comparison with organic polymeric oxygen-permeable membranes now commercially available, the derivatized ceramic membranes are more chemically robust, are capable of withstanding higher temperatures, and exhibit higher oxygen-diffusion coefficients.



Hydrophobic Groups (R) have been attached to alumina surfaces by silanization. Thus far, four hydrophobic groups have been studied: R = $—CH_2—CH_2—CH_2—CH_3$, R = $—CH_2—CH_2(CF_2)_7CF_3$, R = $—(CH_2)_{11}CH_3$, and R = $—(CH_2)_{17}CH_3$.

Membranes made from alumina as well as such other ceramics as titania and zirconia are permeable to oxygen and capable of withstanding higher temperatures. However, without modification, these ceramics are also hydrophilic. Hence, it is necessary to modify the surface properties of these ceramics to render them hydrophobic. For a series of experiments, the prototype membranes were made from α-Al_2O_3 with pore sizes from 5 to 200 nm. Hydrophobic molecular groups were attached to each α-Al_2O_3 membrane through silanization, using a suitable trimethoxy- or triethoxysilane (see figure).

In the experiments, both the silanized α-Al_2O_3 membranes and an organic polymer membrane based on polydimethylsiloxane (PDMS) were used as media for the transport of oxygen from a constant-pressure gas phase into a recirculating aqueous stream. Coefficients of diffusion of O_2 and H_2O across the membranes were measured. At room temperature, the silanized α-Al_2O_3 membranes exhibited oxygen-diffusion coefficients ranging from 1.24 to 5.75 times that of the PDMS membrane, the value in each case depending on the pore size and on which hydrophobic functional groups were present. Water-loss rates of the silanized α-Al_2O_3 membranes were found to be as much as two orders of magnitude below that of the PDMS membrane. In one test at a temperature of 90 °C, one of the silanized α-Al_2O_3 membranes exhibited an oxygen-diffusion coefficient 23.9 times that of the PDMS membrane at 23 °C.

This work was done by James E. Atwater and James R. Akse of Umpqua Research Co. for **Johnson Space Center**. *For further information, contact the Johnson Innovative Partnerships Office at (281) 483-3809. MSC-23384*

SiC Composite Turbine Vanes

Y-cloth was conceived to provide fiber reinforcement for sharp trailing edges.

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Turbine inlet guide vanes have been fabricated from composites of silicon carbide fibers in silicon carbide matrices. A unique design for a cloth made from SiC fibers makes it possible to realize the geometric features necessary to form these vanes in the same airfoil shapes as those of prior metal vanes.

The fiber component of each of these vanes was made from SiC-fiber cloth coated with boron nitride. The matrix was formed by chemical-vapor infiltration with SiC, then slurry-casting of SiC, followed by melt infiltration with silicon.

These SiC/SiC vanes were found to be capable of withstanding temperatures 400 °F (222 °C) greater than those that can be withstood by nickel-base-superalloy turbine airfoils now in common use in gas turbine engines. The higher temperature capability of SiC/SiC parts is expected to make it possible to use them with significantly less cooling than is used for metallic parts, thereby enabling engines to operate more efficiently while emitting smaller amounts of NO_x and CO.

The SiC/SiC composite vanes were fabricated in two different configurations. Each vane of one of the configurations has two internal cavities formed by a web between the suction and the pressure sides of the vane. Each vane of the other configuration has no web (see Figure 1).

It is difficult to fabricate components having small radii, like those of the trail-

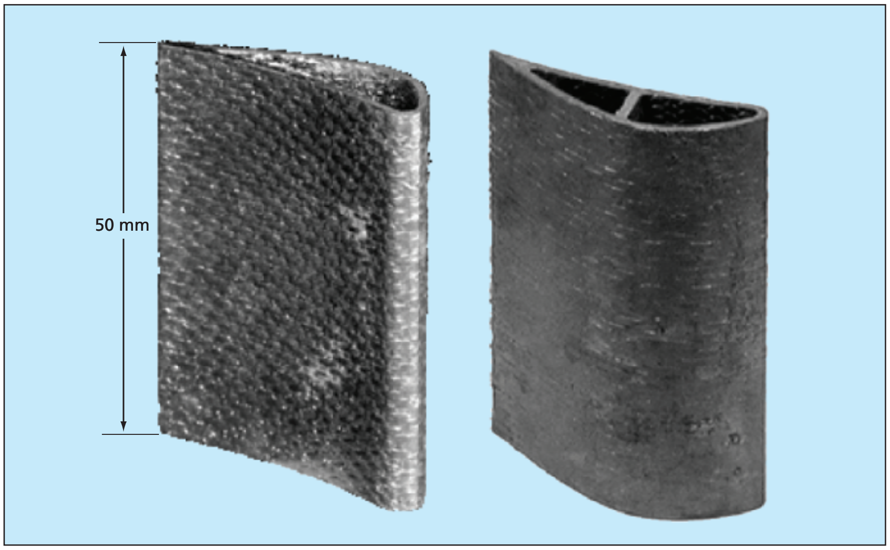

Figure 1. **SiC/SiC Composite Turbine Vanes** were fabricated in two configurations: one webless, one with an internal web.

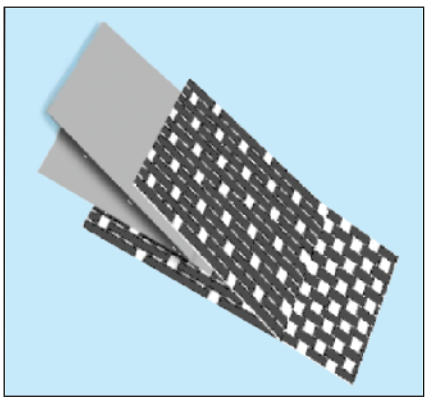

Figure 2. **Y-Cloth** made it possible to form trailing edges to the required small radius.

ing edges of these vanes, by use of stiff stoichiometric SiC fibers currently preferred for SiC/SiC composites. To satisfy the severe geometric and structural requirements for these vanes, the aforementioned unique cloth design, denoted by the term "Y-cloth," was conceived (see Figure 2). In the regions away from the trailing edge, the Y-cloth features a fiber architecture that had been well characterized and successfully demonstrated in combustor liners. To form a sharp trailing edge (having a radius of 0.3 mm), the cloth was split into two planes during the weaving process. The fiber tows forming the trailing-edge section were interlocked, thereby enhancing through-thickness strength of the resulting composite material.

For vanes of the webless configuration, each made from a layup of six plies of Y-cloth, the length of each Y-cloth layer was cut so that the two strips corresponding to the aforementioned two planes would wrap around the perimeter of a graphite vane preform tool with a 10-mm overlap. The overlap was used to join the two strips in a fringe splice. To make the external sixth ply, a standard woven cloth was cut to the required final length and a fringe splice joined the two ends of the cloth at the trailing edge. The cloth was then prepregged. The entire assembly was then placed into an aluminum compaction tool designed to form the outer net shape of the vane. After the prepreg material was allowed to dry, the preform was removed from the aluminum tooling and placed into an external graphite tool before being shipped to a vendor for matrix infiltration.

To make the SiC fiber preform for a vane having an internal web, a slightly different initial approach was followed. Each of two sections forming the internal cavities (and ultimately the web) was created by first slipping two concentric layers of a two-dimensional, 2-by-2, ±45°-braided tube around a net-shape graphite mandrel. The tubes on both mandrels were prepregged and allowed to dry. The resulting two subassemblies were put together, then four additional plies were wrapped around them in the same fashion as that described above for the six plies of the vaneless configuration.

The consolidation of the SiC fiber preforms into SiC/SiC composite parts was performed by commercial vendors using their standard processes. The capability of two of the webless SiC/SiC turbine vanes was demonstrated in tests in a turbine environment. The tests included 50 hours of steady-state operation and 102 two-minute thermal cycles. A surface temperature of 1,320 °C was reached during the tests.

This work was done by Anthony M. Calomino and Michael J. Verrilli of **Glenn Research Center**. *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-17882-1.