



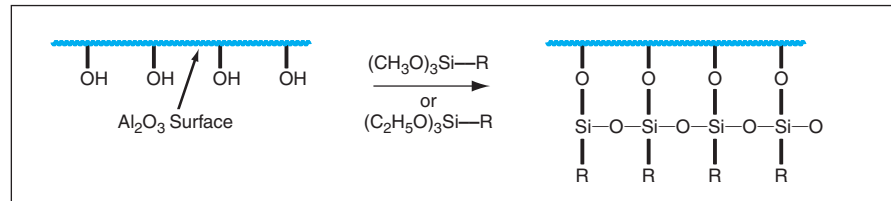
## Oxygen-Permeable, Hydrophobic Membranes of Silanized $\alpha$ - $\text{Al}_2\text{O}_3$

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.

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 ren-



**Hydrophobic Groups (R)** have been attached to alumina surfaces by silanization. Thus far, four hydrophobic groups have been studied:  $\text{R} = -\text{CH}_2-\text{CH}_2-\text{CH}_2-\text{CH}_3$ ,  $\text{R} = -\text{CH}_2-\text{CH}_2(\text{CF}_2)_7\text{CF}_3$ ,  $\text{R} = -(\text{CH}_2)_{11}\text{CH}_3$ , and  $\text{R} = -(\text{CH}_2)_{17}\text{CH}_3$ .

der them hydrophobic. For a series of experiments, the prototype membranes were made from  $\alpha$ - $\text{Al}_2\text{O}_3$  with pore sizes from 5 to 200 nm. Hydrophobic molecular groups were attached to each  $\alpha$ - $\text{Al}_2\text{O}_3$  membrane through silanization, using a suitable trimethoxy- or triethoxysilane (see figure).

In the experiments, both the silanized  $\alpha$ - $\text{Al}_2\text{O}_3$  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  $\text{O}_2$  and  $\text{H}_2\text{O}$  across the membranes were measured. At room temperature, the silanized  $\alpha$ - $\text{Al}_2\text{O}_3$  membranes exhibited oxygen-diffusion coef-

ficients 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  $\alpha$ - $\text{Al}_2\text{O}_3$  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  $\alpha$ - $\text{Al}_2\text{O}_3$  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.

John H. Glenn Research Center, Cleveland, Ohio

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 infiltra-

tion 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  $\text{NO}_x$  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-