



# Materials

## Oxide Protective Coats for Ir/Re Rocket Combustion Chambers

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An improved material system has been developed for rocket engine combustion chambers for burning oxygen/hydrogen mixtures or novel monopropellants, which are highly oxidizing at operating temperatures. The baseline for developing the improved material system is a prior iridium/rhenium system for chambers burning nitrogen tetroxide/monomethyl hydrazine mixtures, which are less oxidizing. The baseline combustion chamber comprises an outer layer of rhenium that provides

structural support, plus an inner layer of iridium that acts as a barrier to oxidation of the rhenium. In the improved material system, the layer of iridium is thin and is coated with a thermal fatigue-resistant refractory oxide (specifically, hafnium oxide) that serves partly as a thermal barrier to decrease the temperature and thus the rate of oxidation of the rhenium. The oxide layer also acts as a barrier against the transport of oxidizing species to the surface of the iridium. Tests in which various oxygen/hydrogen

mixtures were burned in iridium/rhenium combustion chambers lined with hafnium oxide showed that the operational lifetimes of combustion chambers of the improved material system are an order of magnitude greater than those of the baseline combustion chambers.

*This work was done by Arthur J. Fortini and Robert H. Tuffias of Ultramet for Johnson Space Center. Further information is contained in a TSP (see page 1). MSC-23214*

## Simplified Waterproofing of Aerogels

**Silanization is performed in a single treatment at moderate temperature and pressure.**

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A relatively simple silanization process has been developed for waterproofing or rewaterproofing aerogels, xerogels, and aerogel/tile composites, and other, similar low-density, highly microporous materials. Such materials are potentially attractive for a variety of applications — especially for thermal-insulation panels that are required to be thin and lightweight. Unfortunately, such materials are also hydrophilic and tend to collapse after adsorbing water from the air. Hence, an effective means of waterproofing is necessary to enable practical exploitation of aerogels and the like.

Older processes for waterproofing aerogels are time-consuming, labor-intensive, and expensive, relative to the present process. Each of the older processes includes a number of different chemical-treatment steps, and some include the use of toxic halogenated surface-modifying compounds, pressures as high as hundreds of atmospheres, and/or temperatures as high as 1,000 °C.

In contrast, the present silanization process involves a single step, pressure and temperature near ambient values, and no use of toxic halogenated compounds. In this process, an aerogel object that has been dried and otherwise fully formed is exposed to the vapor(s) of one or more silicon-containing organic com-

Material	Degree of Water Pickup (Percent of Original Weight) by Untreated Sample	Degree of Water Pickup (Percent of Original Weight) by Sample Treated With MDES
Carbon Aerogel	350	1.6
Carbon Xerogel	170	4.8
Carbon-Aerogel/Carbon-Xerogel Composite	280	2.5

**Water-Pickup Tests** were performed on untreated and treated samples of three microporous materials.

pound(s) at effective concentration(s) in a closed chamber at controlled temperature and pressure. Suitable treatment compounds include silazanes, alkoxy-silanes, and silanes, which react with polar active sites in the aerogel. The temperature need not be particularly high, as long as it is sufficient to sustain vaporization of the treatment compound(s) at the chamber pressure, which typically lies in the range between 76 mm of Hg [0.1 atmosphere ( $\approx 10$  kPa)] and 1.5 m of Hg [ $\approx 2$  atmospheres ( $\approx 0.2$  MPa)].

In one of several experiments, some samples of carbon aerogels, xerogels, and a carbon-aerogel/carbon-xerogel composite were placed in a plastic bag along with an open vial of methyldiethoxysilane (MDES) and the bag was then sealed.

Other samples of the same materials were left untreated. After 24 hours in the bag, the treated samples were shown to have been waterproofed in that they exhibited low degrees of water pickup, whereas the untreated samples showed much higher degrees of water pickup (see table).

*This work was done by Ming-Ta S. Hsu, Timothy S. Chen, Susan White, and Daniel J. Rasky of Ames Research Center. Further information is contained in a TSP (see page 1).*

*This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Ames Research Center, (650) 604-5104. Refer to ARC-14254.*