



## Materials

### Coating Reduces Ice Adhesion

Developed for the space shuttle, this coating may be used on aircraft and automobiles.

*John F. Kennedy Space Center, Florida*

The Shuttle Ice Liberation Coating (SILC) has been developed to reduce the adhesion of ice to surfaces on the space shuttle. SILC, when coated on a surface (foam, metal, epoxy primer, polymer surfaces), will reduce the adhesion of ice by as much as 90 percent as compared to the corresponding uncoated surface. This innovation is a durable coating that can withstand several cycles of ice growth and removal without loss of anti-adhesion properties.

SILC is made of a binder composed of varying weight percents of siloxane(s), ethyl alcohol, ethyl sulfate, isopropyl alcohol, and of fine-particle polytetrafluoroethylene (PTFE). The combination of these components produces a coating

with significantly improved weathering characteristics over the siloxane system alone.

In some cases, the coating will delay ice formation and can reduce the amount of ice formed. SILC is not an ice prevention coating, but the very high water contact angle (greater than 140°) causes water to readily run off the surface. This coating was designed for use at temperatures near -170 °F (-112 °C). Ice adhesion tests performed at temperatures from -170 to 20 °F (-112 to -7 °C) show that SILC is a very effective ice release coating.

SILC can be left as applied (opaque) or buffed off until the surface appears clear. Energy dispersive spectroscopy

(EDS) and x-ray photoelectron spectroscopy (XPS) data show that the coating is still present after buffing to transparency. This means SILC can be used to prevent ice adhesion even when coating windows or other objects, or items that require transmission of optical light. Car windshields are kept cleaner and SILC effectively mitigates rain and snow under driving conditions.

*This work was done by Trent Smith of Kennedy Space Center; Michael Prince, Charles DeWeese and Leslie Curtis of Marshall Space Flight Center; and Erik Weiser and Roberto Cano of Langley Research Center. For more information, contact the Kennedy Space Center Innovative Partnership Program Office at (321) 861-7158. KSC-13100/1.*

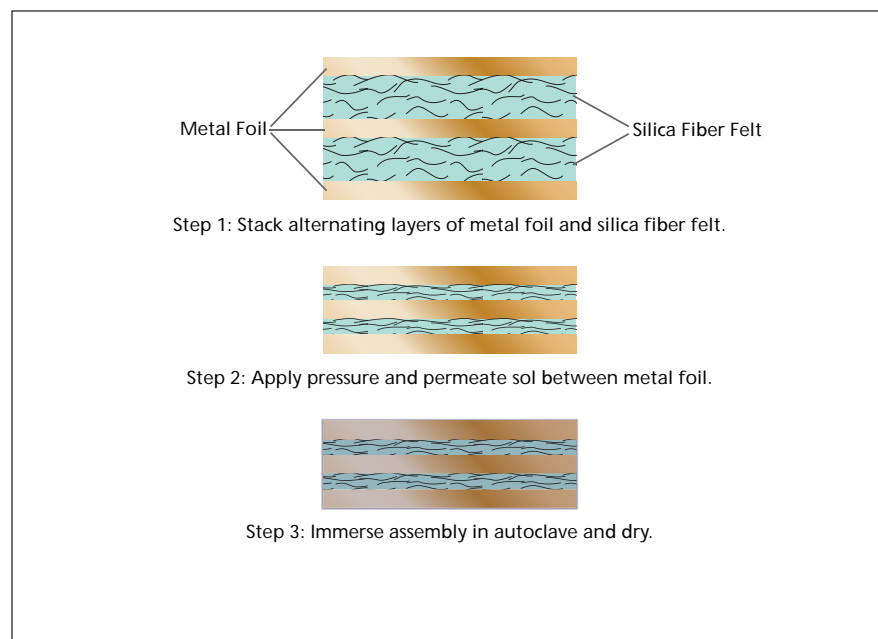
### Hybrid Multifoil Aerogel Thermal Insulation

Aerogel used in place of astroquartz makes lighter, more efficient insulation.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

This innovation blends the merits of multifoil insulation (MFI) with aerogel-based insulation to develop a highly versatile, ultra-low thermally conductive material called hybrid multifoil aerogel thermal insulation (HyMATI). The density of the opacified aerogel is 240 mg/cm<sup>3</sup> and has thermal conductivity in the 20 mW/mK range in high vacuum and 25 mW/mK in 1 atmosphere of gas (such as argon) up to 800 °C. It is stable up to 1,000 °C. This is equal to commercially available high-temperature thermal insulation. The thermal conductivity of the aerogel is 36 percent lower compared to several commercially available insulations when tested in 1 atmosphere of argon gas up to 800 °C.

Layers of metal foil block infrared radiation (IR), which are separated by thin (100–1,000-micron) layers of opacified aerogel (see figure). The aerogel further reduces IR transport and, more importantly, significantly reduces gas and solid conduction when compared to the astroquartz used in heritage MFI (that used



HyMATI Blends Multiple Layers of Foil Separated by Fiber Reinforced, Opacified Aerogel. Fabrication consists of: (a) stacking alternating layers of reflective metal foil and high purity quartz fiber, (b) applying slight pressure to the stack to control the spacing between metal foil layers, and (c) permeating the liquid aerogel precursor into the stack, followed by solidification and supercritical drying.

7.6-micron thick molybdenum foil separated by ≈90-micron thick astroquartz with 60 layers of each forming a stack 1.7 cm thick). By replacing the astroquartz with JPL-developed aerogel, the overall mass of MFI is reduced by 36 percent. Further reductions in mass may also be had by selecting lower density metal foils, such as titanium, zirconium, or reflective Grafoil®. In addition to mass reduction benefits, HyMATI is a tunable insulation that can be tailored for use in various temperature ranges up to 1,000 °C, and can be considered for use in space vacuum,

with a cover gas such as argon or xenon or on other planets with atmosphere.

By replacing heritage MFI with aerogel, the HyMATI will reduce the mass of future RPS (radioisotope power systems) technology. Also, the aerogel has the lowest gas conductivity of any material in its class, enabling RPS operation in vacuum, cover gas, or atmosphere. This means enabling a single RPS design for all NASA missions requiring RPS as opposed to current situations where NASA has a Multi-Mission RTG (for Mars Science Laboratory, for example) and

GPHS-RTG (General-Purpose Heat Source-Radioisotope Thermoelectric Generator) for deep-space exploration.

*This work was done by Jeffrey Sakamoto, Jong-Ah Paik, Steven Jones, and Bill Nesmith of Caltech for NASA's Jet Propulsion Laboratory. 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, NASA Management Office-JPL. Refer to NPO-45219.*