



## **■ Nanotube Dispersions Made With Charged Surfactant**

*Lyndon B. Johnson Space Center, Houston, Texas*

Dispersions (including monodispersions) of nanotubes in water at relatively high concentrations have been formulated as prototypes of reagents for use in making fibers, films, and membranes based on single-walled carbon nanotubes (SWNTs). Other than water, the ingredients of a dispersion of this type include one or more charged surfactant(s) and carbon nanotubes derived from the HiPco™ (or equivalent) process. Among reagents known to be made from HiPco™ (or equivalent) SWNTs, these are the most concentrated and are ex-

pected to be usable in processing of bulk structures and materials. Test data indicate that small bundles of SWNTs and single SWNTs at concentrations up to 1.1 weight percent have been present in water plus surfactant. This development is expected to contribute to the growth of an industry based on applied carbon nanotechnology. There are expected to be commercial applications in aerospace, avionics, sporting goods, automotive products, biotechnology, and medicine.

*This work was done by Cynthia Kuper and Mike Kuzma of Versilant Nanotechnologies for*

**Johnson Space Center.** For further information, contact the Technology Transfer Office at (281) 483-3809.

*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 MSC-23383, volume and number of this NASA Tech Briefs issue, and the page number.*

## **■ Aerogels for Thermal Insulation of Thermoelectric Devices**

**Energy-conversion efficiencies would be increased and operational lifetimes prolonged.**

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Silica aerogels have been shown to be attractive for use as thermal-insulation materials for thermoelectric devices. It is desirable to thermally insulate the legs of thermoelectric devices to suppress lateral heat leaks that degrade thermal efficiency. Aerogels offer not only high thermal-insulation effectiveness, but also a combination of other properties that are especially advantageous in thermoelectric-device applications.

Aerogels are synthesized by means of sol-gel chemistry, which is ideal for casting insulation into place. As the scale of the devices to be insulated decreases, the castability from liquid solutions becomes increasingly advantageous: By virtue of castability, aerogel insulation can be made to encapsulate devices having any size from macroscopic down to nanoscopic and possibly having complex, three-dimensional shapes. Castable aerogels can permeate voids having characteristic dimensions as small as nanometers. Hence, practically all the void space surrounding the legs of thermoelectric devices could be filled with aerogel insulation, making the insulation highly effective. Because aerogels have the lowest densities of any known solid materials, they would add very little mass to the encapsulated devices.

The thermal-conductivity values of aerogels are among the lowest reported for any material, even after taking account of the contributions of convection and radiation (in addition to true thermal conduction) to overall effective thermal conductivities. Even in ambient air, the contribution of convection to effective overall thermal conductivity of an aerogel is extremely low because of the highly tortuous nature of the flow paths through the porous aerogel structure. For applications that involve operating temperatures high enough to give rise to significant amounts of infrared radiation, opacifiers could be added to aerogels to reduce the radiative contributions to overall effective thermal conductivities. One example of an opacifier is carbon black, which absorbs infrared radiation. Another example of an opacifier is micron-sized metal flakes, which reflect infrared radiation.

Encapsulation in cast aerogel insulation also can help prolong the operational lifetimes of thermoelectric devices that must operate in vacuum and that contain SiGe or such advanced skutterudite thermoelectric materials as  $\text{CoSb}_3$  and  $\text{CeFe}_{3.5}\text{Co}_{0.5}\text{Sb}_{12}$ . The primary cause

of deterioration of most thermoelectric materials is thermal decomposition or sublimation (e.g., sublimation of Sb from  $\text{CoSb}_3$ ) at typical high operating temperatures. Aerogel present near the surface of  $\text{CoSb}_3$  can impede the outward transport of Sb vapor by establishing a highly localized, equilibrium Sb-vapor atmosphere at the surface of the  $\text{CoSb}_3$ .

*This work was done by Jeffrey Sakamoto, Jean-Pierre Fleurial, Jeffrey Snyder, Steven Jones, and Thierry Caillat 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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