



## Strong, Lightweight, Porous Materials

**These materials, derived from silica aerogels, can be tailored to have superior properties.**

*John H. Glenn Research Center, Cleveland, Ohio*

A new class of strong, lightweight, porous materials has been invented as an outgrowth of an effort to develop reinforced silica aerogels. The new material, called X-Aerogel is less hygroscopic, but no less porous and of similar density to the corresponding unmodified aerogels. However, the property that sets X-Aerogels apart is their mechanical strength, which can be as much as two and a half orders of magnitude stronger than the unmodified aerogels. X-Aerogels are envisioned to be useful for making extremely lightweight, thermally insulating, structural components, but they may also have applications as electrical insulators, components of laminates, catalyst supports, templates for electrode materials, fuel-cell components, and filter membranes.

In broad terms, X-Aerogels are formed by chemical reaction of a cross-linking agent with the surfaces of the nanoporous network of the native aerogel. The cross-linking agent may be a monomeric or an oligomeric precursor of a polymer that forms a conformal

coating on the nanoparticles, reinforcing the underlying structure while preserving the mesoporosity. The nanoporous network itself may consist of silica, alumina, titania, vanadia, or other metal oxide aerogels. Research with various other oxide nanoparticle skeletal frameworks has led to X-Aerogels based on approximately 35 different metals from the Periodic Table.

The nanoparticles that comprise the aerogels can be cross-linked in their native form through the hydroxyl groups, which are found naturally on their surface. Thus, the first class of X-Aerogels utilizes isocyanates for cross-linking, which react both with the surface hydroxyl groups and any water adsorbed on the surfaces of the nanoparticles. This limits polymer accumulation only on the internal surfaces of the aerogel, leaving the mesopores empty. The result is a greatly reinforced structure at a minimal increase in density.

While the isocyanate cross-linked aerogels show great improvements in properties, relying on the native hy-

droxyl group functionality of aerogels for cross-linking limits the variety of possible precursors that can react with the mesoporous surfaces. This issue has been addressed by chemical modification of the aerogel itself. The mesoporous surface of silica has been modified with amines and olefins, and the resulting particles have been cross-linked with epoxides and with polystyrene. Many other combinations of surface functional groups and cross linkers can be envisioned, which would impart additional desired properties to the X-Aerogels.

*This work was done by Nicholas Leventis, Mary Ann B. Meador, and James C. Johnston of Glenn Research Center and Eve F. Fabrizio and Ulvi Ilhan of Ohio Aerospace Institute. 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-17685-1.*

## Nanowicks

**Fiber geometries could be tailored for pumping, filtering, mixing, separating, and other effects.**

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Nanowicks are dense mats of nanoscale fibers that are expected to enable the development of a variety of novel capillary pumps, filters, and fluidic control devices. Nanowicks make it possible to obtain a variety of novel effects, including capillary pressures orders of magnitude greater than those afforded by microscale and conventional macroscale wicks. While wicking serves the key purpose of transporting fluid, the nanofiber geometry of a nanowick makes it possible to exploit additional effects — most notably, efficient nanoscale mixing, fluidic effects for logic or control, and ultrafiltration (in which mats of nanofibers act as biomolecular sieves).

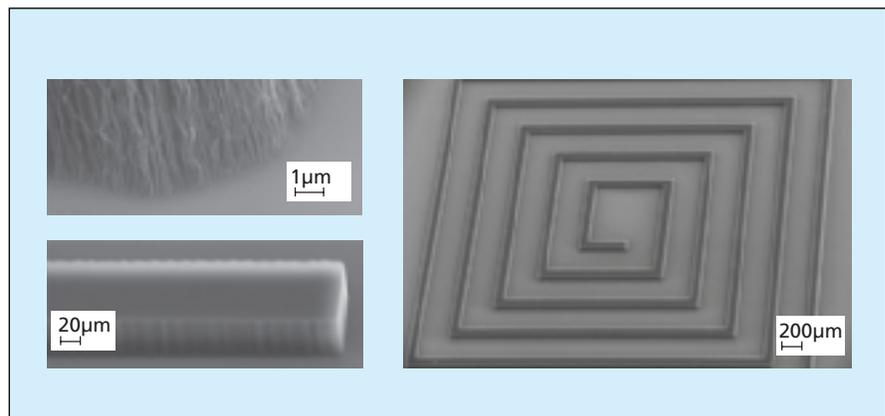


Figure 1. This Scanning Electron Micrograph depicts a nanowick in the form of a mat of carbon nanotubes, which can be grown in a tailorable pattern as shown on the right.