New Lightest Aerogel Is Nothing to Look At

Materials not much denser than the air on a foggy San Francisco morning may prove valuable in a number of applications

IT LOOKS LIKE THICK CIGARETTE SMOKE frozen into immobility, but the substance sitting on Lawrence Hrubesh's desk is actually solid. Well, almost. The wispy, bluish material is 99.8% air, Hrubesh says. What gives it shape and substance is the remaining 0.2%, a tenuous web of silicon dioxide.

This bit of next-to-nothing is an aerogel—a gel from which all the liquid has been removed, leaving only a porous framework with air-filled interstices. Hrubesh, a physicist at Lawrence Livermore National Laboratory, has recently produced the airiest aerogels ever made. They have a density of approximately 5 milligrams per cubic centimeter, one-fifth that of the previous lightest aerogel, and only about four times greater than the density of air at sea level.

Hrubesh is one of a growing number of aerogel aficionados. According to the newsletter *Science Watch*, the number of journal articles on aerogels more than doubled from 1988 to 1989, and their applications are beginning to multiply, too. They are now employed in particle detectors for high-energy physics research, and in the future may be used for such diverse purposes as traps to catch tiny meteoroids in space and insulation for refrigerators and homes.

The Lawrence Livermore technique to produce super-light aerogels, which was developed by Thomas Tillotson, Hrubesh, and Ian Thomas, is a modified version of the standard method for making the materials. This method, first devised in the early 1930s, starts by making a gel—basically, a mixture of interlinked polymer molecules swollen with a liquid. Gelatin, for example, is a gel. Then comes the tricky part: The liquid must be removed without disturbing the polymer network.

Normally, as liquid leaves a gel, surface tension causes the remaining material to collapse in on itself, much as gelatin left out in the sun will crack and shrink to a small fraction of its former size. This happens because the replacement of liquid by air in the individual pores creates surfaces inside them, and the resulting surface tension pulls the sides of the pores together.

The solution is to dry the gel at a very high temperature and pressure so that the liquid is in a supercritical state. In such a state, there is no difference between a liquid and a gas, so no surfaces form to create surface tension. With this supercritical extraction, the molecules of liquid can be slowly removed from the gel without disturbing the remainder.

The result is a form of matter unlike any other. Silica aerogels, the best studied of the aerogels, have a microscopic structure that resembles a bunch of pearl necklaces heaped on a table. In an aerogel, however, the "pearls" are clusters of silicon dioxide, or glass, that are each a few nanometers (billionths of a meter) across. And the strands of glass beads in an aerogel, unlike strands of pearls, can branch off in quite complicated patterns, hooking up with each other to produce structures that vary from rigid to frail, depending on the density of chains and their interconnections.

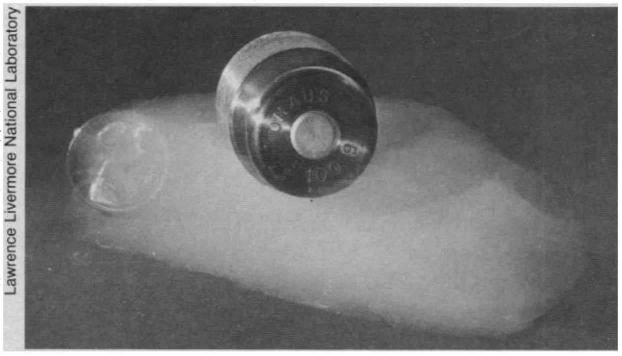
To produce his light aerogels, Hrubesh adds an extra step to the standard aerogel technique. Instead of forming a silica gel, Hrubesh first makes a "condensed silica form" that has the consistency of an oil. It contains short polymers with two, three, or four units of silicon oxide with methoxy groups attached to each silicon. Hrubesh then forms a gel from this precursor by adding water, a solvent, and a base catalyst, and uses supercritical extraction to produce the aerogel.

The advantage of this technique, Hrubesh says, is that it allows greater control of the size of the beads on the long silicon dioxide chains in the gel and the aerogel. Instead of the usual 5 or 6 nanometers, the beads formed by the two-step process are less than 1 nanometer across, he says, and the resulting aerogel is much less dense.

These irregular chain-like structures create some unusual properties, says Dale Schaefer at Sandia National Laboratories. Unlike normal solids, the atoms in an aerogel are only weakly connected to one another, so that energy cannot pass quickly through the material. As a result, aerogels conduct both heat and sound very slowly. And because an aerogel's pores are much smaller than the wavelength of visible light, an aerogel is transparent. The pores do refract light, however, which gives aerogels their bluish tint.

These properties suggest a number of applications. But the only commercial use to date has been in Cerenkov radiation detectors for high-energy physics experiments. Cerenkov radiation is generated when a charged particle moves through a medium, such as a gas or solid, in which the speed of light is slower than the particle's speed. Since light travels at a different speed in aerogels than in the materials more commonly used for Cerenkov detectors, aerogel detectors perform in ranges that others do not. CERN, the particle physics laboratory in Switzerland, is the biggest buyer of aerogels today.

But it is the insulating properties of silica aerogel that has recently caught the attention of companies in the United States and Europe. Silica aerogels transmit heat only one hundredth as fast as normal density glass. This suggests putting aerogels in the middle of double-pane windows. The problem: their bluish tint may limit the use of such glass to skylights. A more potentially valuable application may be as insulation in refrigerators, replacing insulating foams made by ozone layer–destroying chlorofluorocarbons (CFCs).



Lawrence Livermore National Laboratory

Stronger than it looks. *A silica aerogel weighing less than 1 gram supports a 100-gram weight.*

In addition, Hrubesh has been developing aerogels for the National Aeronautics and Space Agency to use in collecting micrometeoroids in space. Because of their low density, aerogels should be able to capture the tiny, fast-moving particles without damaging them. Moreover, because aerogels are transparent, researchers will be able to study the micrometeoroids and their paths through the material without difficulty.

At NASA's request, Hrubesh is working to make aerogels of even lower density than the ones he has already produced. Just how light can an aerogel be and still remain solid? Hrubesh doesn't know, but he'd better be careful. If he goes much further, someone may accuse him of getting paid for working on nothing at all. ■ ROBERT POOL