SCIENCE & TECHNOLOGY

Scientists Develop Airier Aerogels

Uses for the nearly invisible substance range from space experiments to efficient insulation

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LIVERMORE, CALIF.

SCIENTISTS at the Lawrence Livermore Laboratory have spent much of the last five years trying to make something that almost doesn't exist.

Called an aerogel, the bluish ghostlike material looks like a special effect from a science fiction movie. It is only four times heavier than air and is nearly invisible under many lighting conditions, yet a block of the substance is strong enough to support coins haphazardly placed on top.

"It looks like it shouldn't be there," says John F. Poco, one of the material scientists who makes the substance, which is more than 99 percent air.

Aerogels were discovered in the 1930s by S. S. Kistler at Stanford University. Since then, their main use has been for detecting particles in high-energy physics experiments.

The group at Livermore, headed by Lawrence Hrubesh, has developed techniques for making aerogels 10 times lighter than similar materials made anywhere in the world. The University of California, which oversees the lab, has applied for a patent on the process.

Livermore's interest in aerogels goes back five years, when the laboratory's laser-fusion program was looking for a new way to hold together the hydrogen gas used to make energy.

"We wanted to use a material that was a foam, and something that was transparent," recalls Mr. Poco.

Aerogels, which are riddled with tiny channels and pockets, seemed to be worth investigating. Then at the end of 1988, the National Aeronautics and Space Administration (NASA) awarded the group a contract to make aerogels for the space shuttle. NASA's plan: Use large blocks of aerogel to catch micro-meteorites and cosmic dust.

MELANIE STETSON FREEMAN - STAFF

LIGHTWEIGHT SOLID: *An aerogel cube almost floats on a bird-of-paradise petal. Made of silica, the material is more than 99 percent air.*

A particle in space that hit a gel would be gently brought to a stop. Later, the gels could be brought back to Earth for analysis, where scientists could study the gel's damage to determine the speed and weight of the meteorite. Since aerogels are chemically pure – their only ingredient is silica – they would not contaminate the material they caught.

But the real payoff from aerogels will probably be on the ground. Aerogels conduct heat 12 times more slowly than glass does, making them phenomenal insulators. Since they are also transparent, aerogels might be used in the future as insulation between the panes of a double-pane window. They could also replace chlorofluorocarbon-blown foam as insulation inside refrigerators.

Another possibility, advocated by Jochen Fricke at the University of Wurzburg in West Germany, would be to use aerogels in passive solar collectors. By painting the sides of a house black and covering the paint with a layer of aerogel, a house in Northern Europe might be able to trap enough sunlight to cut its heating bill in half.

Scientists speculate that the silica in an aerogel is spun out in long fibers, like many strings of pearls tangled together, with the spaces between them filled by air. Aerogels have a bluish tint because they scatter light the same way the sky does.

To make an aerogel, scientists start with a chemical called tetramethylorthosilica, which has an atomic structure that looks like a silicon atom in the center of a pyramid made out of carbon and hydrogen. To this they add water and stir. The oxygen from the water removes the groups of carbon and hydrogen atoms, leaving long chains of silicon dioxide, or glass, in a solution of methanol.

"The tricky part of the process is how you get the liquid out without collapsing what you have made," says Poco. Simply evaporating or boiling off the methanol collapses the gel: As each molecule of methanol leaves, the surface tension of those remaining pulls the gel into a tight blob.

GETTING rid of the liquid requires knowing about something chemists call the critical point. Under normal conditions, matter can exist in three distinct chemical phases: solid, liquid, and gas. Above the critical point – a temperature that is different for every substance – liquids do not exist. Put another way, surface tension vanishes.

So to get rid of the methanol, says Poco, they simply take the beaker with the methanol solution in it and place it in a special kind of oven called an autoclave, where they raise the pressure to 1,200 pounds per square inch and then slowly raise the temperature to 240 degrees C (465 degrees F), the critical point of methanol. The high pressure keeps the methanol from boiling.

As the temperature of the methanol increases, it slowly loses its surface tension until, at the critical point, it has none. Then the scientists lower the pressure inside the autoclave back down to atmospheric pressure and the methanol trapped inside the gel slowly leaves. Since there is no surface tension, the gel does not collapse. The result is an aerogel.

By changing the proportions of the starting materials, and by controlling the changes of pressure and temperature, the Livermore group can make aerogels with densities anywhere from 3 to 200 milligrams per cubic centimeter. (Air at sea level has a density of 1.2, while water has a density of 1,000.)

Interest in aerogels is worldwide and growing quickly. Last year there were 50 scientific papers published on the subject, a little more than twice the number published in 1988. French scientific institutes were responsible for a little more than half of the articles, according to a recent article in Science Watch.

"Commercially, you can buy aerogels with densities between 80 and 270," says Tom Tillotson, another Livermore scientist.

Airglass of Staffanstorp, Sweden, supplies aerogels to CERN, the European particle physics laboratory in Switzerland. Arlon J. Hunt, a Lawrence Berkeley Laboratory scientist, started Thermalux, a company in Richmond, Calif., which sells the materials in the United States.

But nobody has ever made gels as light and airy as the gels from Livermore, which is the cause of all the recent excitement.

"When we were asked [by NASA] to make 50 [milligrams per cubic centimeter density], we thought that it was an insurmountable task," Mr. Hunt says. "Now we can make 3. We can make 8 at the drop of a hat."

With all the publicity, people are thinking up applications for the stuff beyond insulating windows and cosmic dust collectors.

"I bet I have had 150 to 200 calls," says Mr. Tillotson.

A researcher who is studying what bees do inside hives wants to know if he could use aerogels instead of dirt, in order to be able to watch the insects at work.

Another caller wanted to use them for gaskets in automobiles, since aerogels are both nontoxic and inflammable.

A vitamin manufacturer wants to use aerogels in display cases, to make their pills look as if they are suspended in space.

And "about 50 artists have called," says Tillotson, looking for a new material to sculpt.

By adding other chemicals to the starting material, the Livermore scientists can change the color or chemical properties of the gels.

An aerogel the size of a sugar cube has more than 5,000 square feet of surface area, which means the material might be useful for speeding up chemical reactions that take place only on surfaces.

"We were surprised that we got as much publicity on this as we did, knowing that aerogels had been around for so long," says Poco.