Materials Science

Ivan Amato reports from San Francisco at a meeting of the Materials Research Society

Striving to make almost nothing at all

To the uninitiated, an aerogel might look like nothing more than a milky bluish tinge inside an empty glass vial. These nearly transparent, ultralow-density materials, also known as frozen or solid smoke, have been turning the heads of fusion researchers, particle physicists, space scientists and others in need of the next best thing to nothing at all.

The near-nothingness of aerogels makes them well suited for collecting speeding micrometeorites without shattering the samples, says materials scientist John F. Poco of the Lawrence Livermore (Calif.) National Laboratory. Instead of stopping a zippy micrometeorite on a dime, a series of increasingly dense aerogel layers would gradually bring it to rest and thereby improve its chances of remaining intact. Poco says an aerogel "mit" for catching micrometeorites is slated for a future shuttle trip.

Since aerogels contain so little solid material, fusion researchers are using them as unobtrusive holders for fusion fuels, says Lawrence W. Hrubesh, who leads the Livermore lab's effort to make ever-more-wispy aerogels. Aerogels don't dilute laser light or other forms of energy used to ignite fusion fuels.

Even sculptors have started using the ethereal materials as a sub-featherweight medium, and window manufacturers are considering placing them between windowpanes as a nearly transparent insulation, Hrubesh notes.

The Livermore researchers make their aerogels — which Hrubesh calls the world's airiest — by chemically transforming tetrahedron-shaped tetramethoxysilane (TMOS) molecules into a dense oil. Then, by reacting the oil with water in the presence of a diluting liquid that serves as temporary wadding to keep the TMOS molecules apart, the scientists link the molecules into delicate networks that surround the liquid wadding. Removing the liquid leaves behind the ultralow-density skeleton. By varying the amount of diluting liquid, the researchers can make aerogels with predetermined densities ranging from 3 to 800 milligrams per cubic centimeter. Air weighs in at about 1.2 mg/cc.

Better ceramics through biology

Biologically produced ceramics remain superior to synthetic versions of the same materials, says Gary L. McVay, who manages materials sciences research at Pacific Northwest Laboratories in Richland, Wash. To catch up with nature, he and his colleagues are taking ceramic-making lessons from mollusks such as the nautilus, sea urchin and abalone. For 600 million years or so, these industrious creatures have transformed such inherently weak materials as calcium carbonate (chalk) into hard, shatter-resistant and intricately shaped ceramic shells.

The key to this feat of molluskan materials processing lies in the biological polymers produced in the organism's shell-manufacturing cells. Made of protein and polysaccharides, the polymers serve as nucleation sites where inorganic ions within the watery cells can settle, aggregate and grow into ceramic crystals with specific shapes and orientations. McVay's group would like to mimic this low-temperature, water-based process to grow technologically important compounds such as artificial bone and nonrusting building materials.

The researchers already have used synthetic polymers as nucleation sites and preforms for depositing needles of iron oxide, the active ingredient in magnetic storage tapes. By varying the distribution of charges on the polymer, the group can control the orientation of the essentially self-assembling crystals. McVay says he and others aim to uncover and imitate more biological ceramic-making tactics for growing additional materials, including high-temperature superconducting ceramics.

Physics

Ivars Peterson reports from Washington, D.C., at a meeting of the American Physical Society

Testing the Pauli exclusion principle

The Pauli exclusion principle stands at the heart of modern molecular, atomic and nuclear physics. By insisting that no two electrons, protons or neutrons can occupy exactly the same quantum state, the principle explains why matter doesn't collapse on itself. Several research groups, prompted by theorists who have recently questioned the principle's validity under certain circumstances (SN: 2/27/88, p.132), are now subjecting it to sensitive experimental tests.

"The theorists have called for wide-scale testing in a variety of systems," says John D. Gillaspy of the National Institute of Standards and Technology (NIST) in Gaithersburg, Md. "It's rather surprising that such a fundamental principle has for so long not really been examined."

In the most precise experimental test to date, Erik J. Ramberg and George A. Snow of the University of Maryland in College Park sent a large electrical current through a copper wire, then searched for certain X-ray signals that would appear only if an electron were to fall into a quantum state already occupied by another electron. By finding no such X-rays, the researchers showed that any violation of the Pauli principle must be smaller than 2 parts in 10^{26}.

NIST scientists are developing a simpler experiment to check some of the assumptions underlying the University of Maryland experiment. "There have been no hints of violations to this point," Gillaspy says. "Even though we believe there won't be a violation, we think it's important to put some very stringent and very rigorous limits on when such violations could occur."

Galactic beads on a cosmic string

Imagine drilling a hole through the universe. At some points, the drill would pierce dense clumps of matter. Elsewhere, it would encounter little resistance as it passed through relatively empty regions. When astronomers determine the distances to galaxies along a long, narrow line of sight, they sample the distribution of matter in the universe in much the same way. They would likely see large numbers of galaxies at some points and few galaxies at others.

That's exactly what a team of astronomers in the United States and Great Britain recently found. However, they also discovered that over a distance of 7 billion light-years, the galaxies appear in regularly spaced clumps about 420 million light-years apart. The finding suggests that this particular line of sight happened to pierce a sequence of 13 evenly spaced "walls" of galaxies.

To get a sense of whether the observed periodicity represents a genuine pattern or merely a statistical fluke, researchers at the Lawrence Livermore (Calif.) National Laboratory and the University of California, San Diego, used simple computer models to study the kinds of patterns generated by various lines of sight through different distributions of matter. In their models, galaxies appear on the surfaces of bubbles or sheets in both random configurations and orderly cellular patterns.

The group's statistical analysis of where galaxies would appear along randomly oriented lines of sight seems to suggest that the most likely explanation for the observations is that all galaxies are arranged in a large-scale, regular pattern. A line of sight passing through a random pattern of bubbles has less than a 2 percent chance of producing the observed sequence, they conclude.

"The observations don't fit a random-cell pattern," says Livermore's Hannu Kurki-Suonio. But there's no good explanation for why galaxies would be arranged in a regular pattern. "If this regularity doesn't go away [in future surveys]," he says, "then the universe is really strange."

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