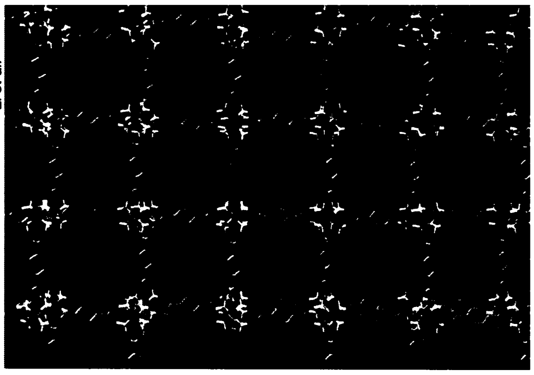
Innovative crystal's got plenty o' nuthin'



Li et al.

MOF-5 crystal architecture. Red is oxygen; gray, carbon; yellow, zinc. Clusters of 23 atoms form the nodes. Benzene rings are the struts. Cavities are about as wide as 8 water molecules. In this diagram, absence of electron clouds exaggerates the amount of empty space.

For years, chemists have fantasized about molecular scaffolds that would catalyze the tricky chemistry that enzymes foster. The structures would provide a framework for assembling and dissecting organic molecules. Toward this goal, researchers have attempted to make gauzy crystals that are themselves organic.

Scientists repeatedly succeeded in precipitating porous crystals from carboniferous broths, but when removed and dried, the crystals always collapsed.

Now, research teams at the University of Michigan in Ann Arbor and Arizona State University in Tempe have engineered a new crystal architecture, which they describe in the Nov. 18 NATURE. Their prototype material, called MOF-5, remains steady as a rock even when bone dry and heated to 300°C.

"I think many people wouldn't even have believed this was possible," comments Stephen Lee, a materials scientist at Cornell University.

The innovation is in the joinery. Earlier organic scaffolds obliged solitary atoms to hold several struts at once, a situation that stretched their capabilities.

For MOF-5, however, Arizona's Hailian Li and his coworkers joined struts using a rugged, 23-atom cluster borrowed from the toolshed of inorganic chemistry. Around an internal structure of zinc and oxygen atoms, each cluster presents six exposed carbon atoms—four in a plane, with one above and one below. The carbons serve as fastening points for organic struts—in this case, benzene molecules.

Chemists know the value of porous crystals from the many uses of zeolites, naturally occurring minerals that scientists have reproduced and improved upon in the lab (SN: 3/2/96, p. 135). These inorganic molecular sieves figure centrally in oil refining and in the separation of gases like nitrogen and oxygen.

By constraining the orientations with which two molecules can combine, the myriad identical pockets in these crystals can coax a pool of pure product from a reaction that would otherwise produce a stew or nothing at all.

Engineering such sieves for specific uses poses a challenge: It's hard to predict how inorganic elements will link up. However, fashioning carbon structures is a snap, Lee says. The properties of MOF-5's cavities will be easy to adapt by ornamenting its braces. "You can put anything on a benzene ring," says Lee. Longer struts should be possible, too.

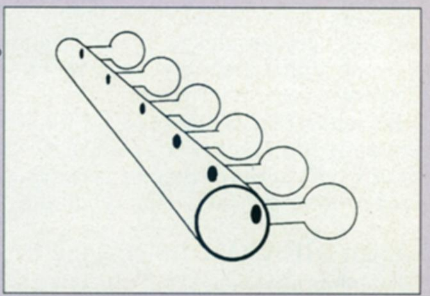
Chemists eagerly anticipate creating such frameworks to order. MOF-5 and its progeny promise other advantages over their inorganic forebears, as well. MOF-5 is lighter and more porous than any inorganic sieve yet made, its inventors say, and has about six times the interior surface area of its closest competitor.

Porous materials can swallow voluminous quantities of gases like methane and hydrogen, potentially making them into easily transportable alternatives to gasoline. Since the amount of methane that fits into different zeolites is proportional to their internal surface area, MOF-5 or related materials may make such fuels more practical, the researchers say.

Although 60 percent of MOF-5 is empty space, there seems little risk that chemists' enthusiasm is much ado about nothing.

—*O. Baker*

Single-wave sounds streak through air



Sugimoto

When pressure pulse passes through tube, it oscillates air in attached resonators (only one row shown in this schematic) and converts it to a distinctive solitary wave.

The oddity of a lone wave cruising tirelessly and undiminished across a body of water has fascinated scientists since the phenomenon was first observed in the 1830s. In recent years, similar solitary waves of light, or solitons, have become a hot topic in optics (SN: 4/6/91, p. 223). Now, Japanese researchers report creating the first solitary pulses of low-frequency sound in air.

"This is particularly satisfying," comments Hans Christian von Baeyer of the College of William and Mary in Williamsburg, Va. Solitary waves "were found in water, much later produced in light, and now are finally observed in sound," he says.

Nobumasa Sugimoto of the University of Osaka and his colleagues generated solitary acoustic waves by forcing compressed air bursts into a narrow, 7-meter-long steel tube studded on two sides with 148 hollow, knobby protrusions. Their findings, described in the Nov. 15 PHYSICAL REVIEW LETTERS, hint at practical payoffs, such as a new means to efficiently transport heat via pipes, Sugimoto says.

"It's a clever design, and they certainly exploit it," comments Andrés Larraza of the Naval Postgraduate School in Monterey, Calif.

The Japanese group made its discovery while studying ways to suppress shock waves caused by fast trains entering narrow tunnels. While baffles reduce shocks that today's 300-kilometer-per-hour trains produce, the advent of even faster bullet trains is spurring more research.

In many materials, such as water and glass fibers, disturbances contain different frequencies that travel at different speeds, causing pulses to widen and smooth out. Because every sound frequency passes through air at virtually the same speed, air pulses don't tend to become smooth. Instead, intense pressure pulses in air develop into sharp-peaked shock waves.

Solitary waves arise in materials only when sharpening and smoothing effects balance, but air lacks a smoothing influence, Sugimoto explains.

The Japanese group has been exploring a model in which a series of regularly spaced hollows attaches to a tunnel via narrow channels. Excited by a wave in the tunnel, air jiggles back and forth inside these side structures at certain characteristic, or resonant, frequencies.

Sugimoto previously theorized that the resonating cavities could either dampen a tunnel shock wave or convert it into a solitary wave. Which effect takes place would depend on the dimensions—and therefore the natural frequencies—of the cavities. His team reports that the wave shapes and speeds measured in the recent experiments are in "good agreement" with predictions of a solitary wave.

Larraza says he finds the data "convincing." However, he notes that the pulse wavelengths are a sizable fraction of the length of the tube, so the team has yet to show that such waves can propagate very far.

—*P. Weiss*