Nature points the way to tougher ceramics

Taking a lesson from seashells and teeth, materials scientists have figured out how to make ceramics tougher and more versatile. One of their new "organoceramics" shows promise as artificial bone, they report.

Ceramics have enormous potential as high-tech materials: They resist wear and tear, withstand very high temperatures and do not easily corrode or disintegrate. One even holds the record as the highest-temperature superconductor developed so far.

But ceramics are difficult to process into mechanical parts, and their brittleness can make those parts unreliable, notes Samuel I. Stupp of the University of Illinois in Urbana-Champaign. Materials scientists add polymers to minimize such drawbacks, but even these composites fall short for some applications, he says.

Since 1983, Stupp has worked to mimic natural composites such as teeth and shells. Nature's organoceramics contain only small amounts of organic polymers, yet they are quite tough and perfectly shaped for their functions, he says. At the Fourth Chemical Congress of North America, held in New York City last week, Stupp and graduate student Phillip B. Messersmith described successful attempts to strengthen ceramics with various organic polymers.

"The secret lies in the way the organic component is dispersed," Stupp says. By mixing tiny amounts of the long organic molecules into solutions saturated with inorganic crystals, and then precipitating out the resulting organoceramic, the researchers discovered they could make the polymers thread their way among very small ceramic particles. The resulting materials "trap squashed polymers between ceramic, so there's a very intimate dispersion," Stupp explains. These composites should fracture less readily than other ceramics and should be easier to manufacture into useful devices, he says.

Most of these synthesized composites consist of layers of ceramic with organic polymers sporadically jammed between the layers, which the polymers push apart slightly, says Stupp.

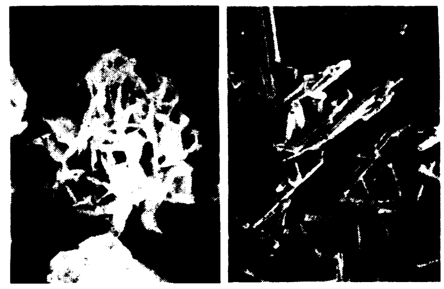
But with one of the polymers they used, the researchers found that the ceramic components formed crystals with channels running through them. They think the polymers fit into these channels. "We expect this to be a much more compact material, with a higher mechanical strength," Stupp says.

A new organoceramic made with calcium phosphate seems to work well as artificial bone, he adds. In experiments with dogs, Stupp and his collaborators replaced small pieces of bone with this material and monitored the animals for up to six months. "We've found excellent adhesion between the organoceramic and the surrounding bone," he reports.

The body seems to accept the foreign material as natural, Stupp says, noting that the implants did not activate the canine immune system. He adds that certain bone-eating cells eroded away some of the organoceramic, making room for natural bone to grow into it.

Stupp hopes to tailor ceramics for specialized microelectronic devices by adding organic polymers that conduct electricity or process light. He also envisions replacing the usual polymers with drugs to create organoceramics that slowly release medication within the body. Moreover, he says, "it's not out of the question to follow the same approach with superconducting ceramics" to make them more amenable to processing.

– E. Pennisi



Stupp, Messersmith/Univ. of Ill.

Scanning electron micrographs show that organoceramics can consist of rosette-like crystals (left) or hexagonal rods (right), depending on the type of polymer used.

Earthquake warning: Racing the waves

When the San Andreas fault finally unleashes the "Big One" on southern California, a sophisticated warning system could provide 60 seconds of advance notice before damaging vibrations start rattling Los Angeles buildings. Although no such system exists in the United States at present, a panel of experts says little stands in the way of its development.

Seismologists and engineers assembled by the National Research Council recommended last week that U.S. officials move now to install a prototype system that can quickly sense seismic waves from a strong quake and send warning signals to outlying areas.

"Technology is not a barrier. It could be implemented now," says panel member Nafi Toksöz, a seismologist at the Massachusetts Institute of Technology.

The system would rely on a network of advanced sensors that detect seismic waves before they spread from the epicenter of a quake. A central computer would use data transmitted by the sensors to determine the size and location of the quake, and within seconds would send out information to areas in the path of the damaging vibrations. While such systems would not benefit regions closest to the epicenter, they could provide seconds to tens of seconds of advance warning to more distant areas.

The early notice could activate automated systems that would save lives and property, the panel maintains. Utilities could shut off gas lines, reducing the risk of damaging fires. Computers could retract disk file heads to protect stored information. Broadcasts could alert people to seek safety under a strong desk or table.

The proposed system could also provide information immediately after the quake to help emergency officials locate the sites hardest hit by the shaking. At present, accurate postquake information takes hours or days to obtain because tremors disrupt power and telephone lines.

For two decades, Japan has used a warning system that automatically stops high-speed trains in a quake. In October 1989, during the days that followed the Loma Prieta quake in the San Francisco Bay area, the U.S. Geological Survey (USGS) installed a simple warning system that detected aftershocks in the epicentral region and radioed a warning to Oakland, providing 12 to 20 seconds of warning for people working on the collapsed I-880 highway overpass.

The panel recommends upgrading an existing seismic network, probably in California, to create a sophisticated prototype system. Since the seismometers used in most such networks were designed to measure small earthquakes, the prototype would require newer devices that can gauge strong vibrations as well.

The panel provided little information about the price of a full-scale prototype. Panel member Thomas H. Heaton, a USGS seismologist in Pasadena, Calif., told SCIENCE NEWS that he estimates a cost of about $5 million per year for developing and operating the prototype system.

The idea has yet to win widespread endorsement from companies and government agencies that would use such a system. According to a 1989 poll, most potential users in California fear that false alarms could prove excessively costly. The panel contends, however, that these groups have difficulty envisioning the benefits of an early warning system. Says Heaton, "It's like asking people 30 years ago: What would you do with a computer in your home?"

– R. Monastersky