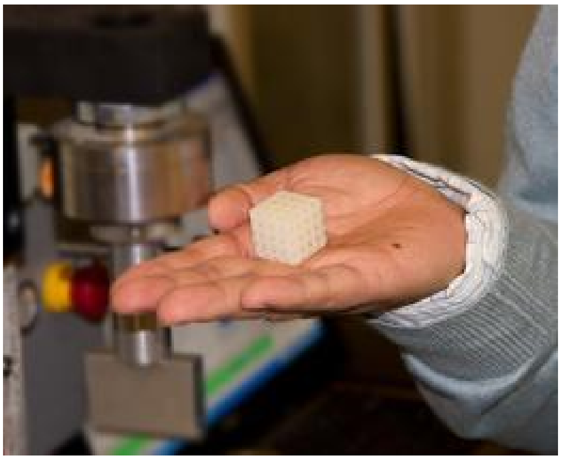
Making materials to order: Fine-tuning mechanical, electrical, thermal, other properties of composites

26 May 2011, by David L. Chandler



A sample of a co-continuous polymer composite material produced in the lab by a team including MIT postdoctoral researcher Lifeng Wang. Device in background is used to test the strength of the material. Photo: Melanie Gonick

A team of researchers at MIT has found a way to make complex composite materials whose attributes can be fine-tuned to give various desirable combinations of properties such as stiffness, strength, resistance to impacts and energy dissipation.

The key feature of the new composites is a "co-continuous" structure of two different materials with very different properties, creating a material combining aspects of both. The co-continuous structure means that the two interleaved materials each form a kind of three-dimensional lattice whose pieces are fully connected to each other from side to side, front to back, and top to bottom.

The research - by postdoc Lifeng Wang, who worked with undergraduate Jacky Lau and professors Mary Boyce and Edwin Thomas - was published in April in the journal *Advanced Materials*. The research was funded by the U.S. Army through MIT's Institute for Soldier Nanotechnologies.

The initial objective of the research was to "try to design a material that can absorb energy under extreme loading situations," Wang explains. Such a material could be used as shielding for trucks or aircraft, he says: "It could be lightweight and efficient, flexible, not just a solid mantle" like most present-day armor.

In most conventional materials - even modern advanced composites - once cracks start to form they tend to propagate through the material, Wang says. But in the new co-continuous materials, crack propagation is limited within the microstructure, he says, making them highly "damage tolerant" even when subjected to many crack-producing events.

Some existing composite materials, such as carbon-carbon composites that use fibers embedded in another material, can have great strength in the direction parallel to the fibers, but not much strength in other directions. Because of the continuous 3-D structure of the new composites, their strength is nearly equal in all dimensions, Wang says.

Thomas, the Morris Cohen Professor of Materials Science and Engineering and head of MIT's Department of Materials Science and Engineering, says that in most existing composite materials, the fibers form disordered mass with "zero continuity," while the other material - typically a resin that fills the space and then hardens - is continuous and connected in three dimensions. The material that forms the continuous structure "tends to dominate the properties" of the composite, he says. "But when both materials are continuous, you can get benefits that are surprisingly synergistic, not just additive."

In their experiments, the MIT researchers combined two polymer materials with quite different properties: one that is glass-like, strong but brittle, and another that is rubber-like, not so strong, but tough and resilient. The result, Thomas says, was a material "that is stiff, strong and tough."

In the quest for new materials with specific combinations of properties, Thomas says, "we've pretty much exhausted the natural homogeneous materials," but the new fabrication techniques developed in this research can "take to another level" the material development process.

The researchers designed the new materials through computer simulations, then made samples that were tested under laboratory conditions. The simulations and the experimental data "agree nicely," Thomas says. While this initial research focused on tuning the material's mechanical properties, the same principles could be applied to controlling a material's electrical, thermal, optical or other properties, the researchers say.

The process could even be used to make materials with "tunable" properties: for example, to allow certain frequencies of phonons - waves of heat or sound - to pass through while blocking others, with the selection of frequencies tuned through changes in mechanical pressure. It could also be used to make materials with shape-memory properties, which could be compressed and then spring back to a specific form.

Richard Vaia, acting chief of the Nanostructured and Biological Materials Branch at Wright-Patterson Air Force Base in Ohio, says this work is "an exciting demonstration of the crucial importance of architecture in materials-by-design concepts."

Vaia says this work "provides an example of the future of composite and hybrid materialstechnology where direct-write fabrication, printing technologies and complex fiber-weaving techniques are not simply manufacturing tools, but an integral part of a robust, implementable digital design and manufacturing paradigm."

The next step in the research, Thomas says, is to make co-continuous composites out of pairs of materials whose properties are even more drastically different than those used in the initial experiments, such as metal with ceramic, or polymer with metal. Such composites could be very different from any materials made before, he says.

This story is republished courtesy of MIT News (web.mit.edu/newsoffice/), a popular site that covers news about MIT research, innovation and teaching.

Provided by Massachusetts Institute of Technology

APA citation: Making materials to order: Fine-tuning mechanical, electrical, thermal, other properties of composites (2011, May 26) retrieved 27 October 2021 from https://phys.org/news/2011-05-materials-fine-tuning-mechanical-electrical-thermal.html