



Nano Focus

Ceramic nanomaterials that are light, strong, and spongy

Strong, ultralight materials could be used to make aircraft wings, battery electrodes, armor, and insulation. But today's high-strength low-density materials, such as silica and alumina aerogels, metal foams, and technical ceramics, are all brittle. They can crack or shatter when they are squashed too hard.

Julia Greer and her colleagues at the California Institute of Technology have now crafted nanoscale ceramic lattices that are strong and lightweight but also elastic. The materials spring back after being crushed down to more than 50% of their original height.

This work is part of a recent push to engineer strong, stiff, and lightweight materials by tailoring their structural design at the nanoscale. The theory is that in a conventional material, properties such as strength and density are correlated. However, those rules don't apply at the nanoscale. Researchers have used laser writing to carve complex, airy lattices of ceramics and metals. The tiny struts and trusses in these materials mean that the materials are mostly air and hence ultralight, but tough at the same time.

Greer and her colleagues make their nanoceramics using a technique called two-photon interference lithography. She used the method in 2011 to construct one of the lightest materials ever made: a microlattice of hollow metal tubes.

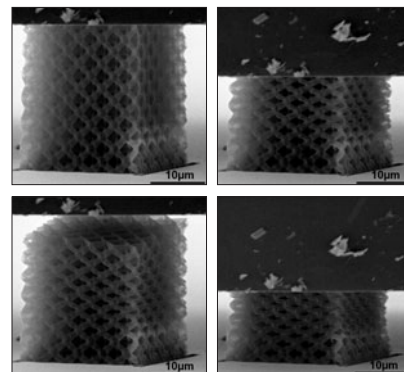
The researchers move a tightly focused laser beam in three dimensions

across a viscous photo-reactive polymer. The polymer cross-links and hardens where the light focuses on it. The rest of the polymer is washed away, leaving behind a three-dimensional (3D) scaffold. Next, the researchers deposit a thin alumina film on the scaffold using atomic layer deposition. Finally, they use oxygen plasma to etch away the polymer inside the tubes, resulting in a 3D nanolattice made of a network of hollow ceramic tubes.

In this work, reported in the September 12 issue of *Science* (DOI: 10.1126/science.1255908; p. 1322), the researchers showed that the thickness of the hollow tube walls affects how the material deforms under compression. They made several lattices containing tubes that were 450–1380 nm in diameter and had wall thicknesses ranging from 5 nm to 60 nm. Then they compressed the different samples to see how they performed.

Lattices with thick-walled tubes—where the wall thickness was around 50 nm—failed catastrophically and shattered into fragments. Those with tubes that had thinner walls, about 10-nm thick, on the other hand, underwent a ductile deformation. The tube walls buckled locally but regained their original shape when the compression was removed.

“To date, no one has conducted such an in-depth study at the nanoscale with these exquisite structures,” says Xiaoyu Zheng, an engineer at the Lawrence Livermore National Laboratory. “This work demonstrates that, through engineering of a material architecture and by control of feature sizes, intrinsically brittle materials can become ductile.” Such lightweight,



The sequence shows how the three-dimensional, ceramic nanolattices can recover after being compressed by more than 50%. Clockwise, from left to right, an alumina nanolattice before compression, during compression, fully compressed, and recovered following compression. Credit: Lucas Meza/Caltech.

ductile, and strong nanostructured ceramic materials could open up a wide range of new applications, he says.

The researchers currently make tiny cubes of the material that are 20 μm to a side. But, says Greer, her group is focusing on making larger volumes. She imagines making paper-like sheets of the material. “We could print such pieces of paper and laminate them together and we could then carve that into whatever shape we want.”

But one drawback of two-photon lithography is that it is slow. “A 50 by 50 by 50 cubic micron piece made from alumina that's fully etched out takes about two hours,” Greer says. Researchers might need to come up with a different technique to make the materials on a large scale, she says.

Prachi Patel

Blue phosphorescent OLEDs exhibit significantly increased lifetime

In a step that could lead to longer battery life in smartphones and lower power consumption for large-screen televisions, Stephen Forrest of the University of Michigan and his research team have extended the lifetime of blue organic light-emitting diodes (OLEDs) by a factor of 10.

Blue OLEDs are one of a trio of colors used in OLED displays such as smartphone screens and high-end TVs. The improvement means that the efficiencies of blue OLEDs in these devices could jump from about 5% to 20% or better in the near future, according to the researchers.

Phosphorescent OLEDs, also known as PHOLEDs, produce light through a mechanism that is four times more efficient than fluorescent OLEDs. Green and red PHOLEDs are already used in

these new TVs—as well as in Samsung and LG smartphones—but the blues are fluorescent.

“Having a blue phosphorescent pixel is an important challenge, but they haven't lived long enough,” said Forrest, the Paul G. Goebel Professor of Engineering.

Forrest's group, in collaboration with researchers at Universal Display Corp., have previously shown that, for blue PHOLEDs, a concentration of energy on one molecule can combine with that on