Metallic microlattice 'lightest structure ever'

Researchers in the US have broken the world record for the lightest structural material. The metal-based microlattice structures are significantly less dense than the rarest aerogels and other ultralight foams, while exhibiting high strength and an unexpectedly high ability to absorb energy and recover shape after compression. The materials could find use in a range of applications, from aircraft structural components to acoustic damping and shock absorption.

The microlattice, created by a team led by Tobias Schaedler of HRL Laboratories in Malibu, consists of a highly controlled, ordered network of interconnected hollow struts made from a nickel-phosphorus alloy. In the prototype sample, the struts are around 100μm in diameter with walls around 100nm thick.

To create the structure, a polymer template is first produced by placing a mask patterned with circular holes over a reservoir of a photosensitive thiol-ene monomer. UV light is shone on the mask and where the light meets the monomer it polymerises it. 'As the light begins to polymerise the liquid monomer, the change in refractive index between the polymer and monomer begins to tunnel the light, just as in a fibre optic,' says Schaedler. 'This leads to the formation of a self-propagating photopolymer waveguide, or fibre, within the monomer reservoir. We form these waveguides in multiple directions and intersect them together to create an interconnected network. Then we clean out the uncured liquid monomer with a solvent, and the result is a micro-lattice structure, where the self-propagating waveguides are the individual structural lattice members.'

This lattice template is then dipped in a catalyst solution before being transferred to a nickel-phosphorus solution. The nickel-phosphorus alloy is then deposited catalytically on the surface of the polymer struts to a thickness of around 100nm. Once coated, the polymer is etched away with sodium hydroxide, leaving an identical lattice geometry of hollow nickel-phosphorus tubes.

'The structure is so fine that it is 99.99 per cent air,' says Schaedler, and around 10 per cent less dense than the lightest aerogels - just 0.9mg/cm^3. Intriguingly, the microengineered structure has remarkably different properties from the bulk alloy. 'The bulk alloy is very brittle, but when the lattice structure is compressed, the hollow tubes do not snap but rather buckle like a drinking straw with a high degree of elasticity,' Schaedler says. The lattice can be compressed to half its volume but still springs back into its original shape.

'By changing the structure at these levels you get completely different properties from the bulk material, which is a very powerful concept,' says Schaedler. 'We think we may be able to introduce new properties into materials by this kind of structured porosity.' He says that, in principle, such a microlattice could be made from any material that is amenable to thin-film deposition on the polymer template and that there is a long list of such potential candidates. The team is now exploring these.

Tao Liu, who researches ultra-lightweight cellular materials at the University of Nottingham in the UK, says that the properties of the lattice are 'striking'. Liu suggests that these materials would make good candidates for novel energy harvesting systems due to their deformation mechanism allowing them to store strain energy, shock mitigation and acoustic absorption, and novel microelectromechanical devices.

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References

T A Schaedler *et al*, *Science*, 2011, **334**, 962, DOI: 10.1126/science.1211649