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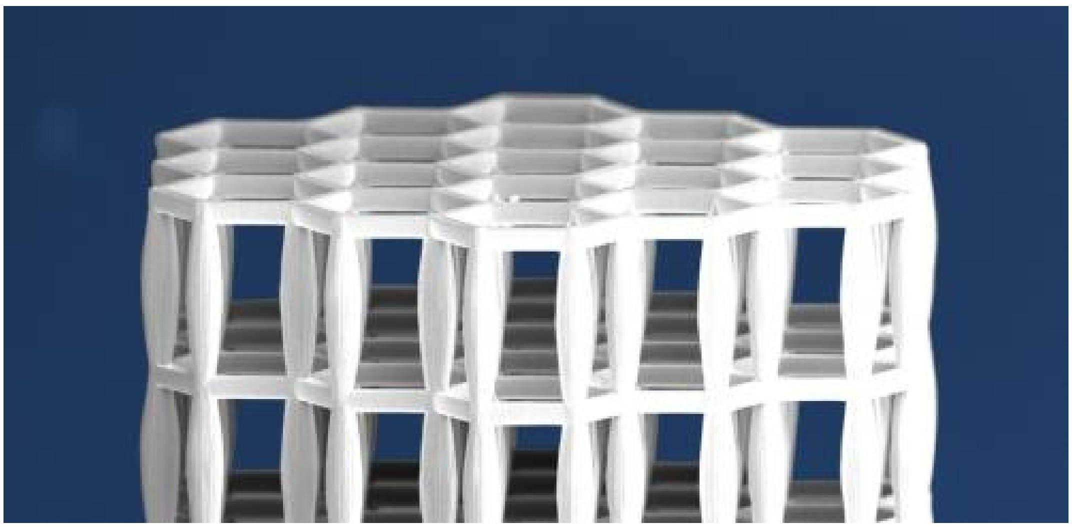
New bone-like material is lighter than water but as strong as steel

February 3 2014, by Akshat Rathi



Lighter, stronger, better. Credit: Jens Bauer

Materials shape human progress – think stone age or bronze age. The 21st century has been referred to as the molecular age, a time when scientists are beginning to manipulate materials at the atomic level to create new substances with astounding properties.

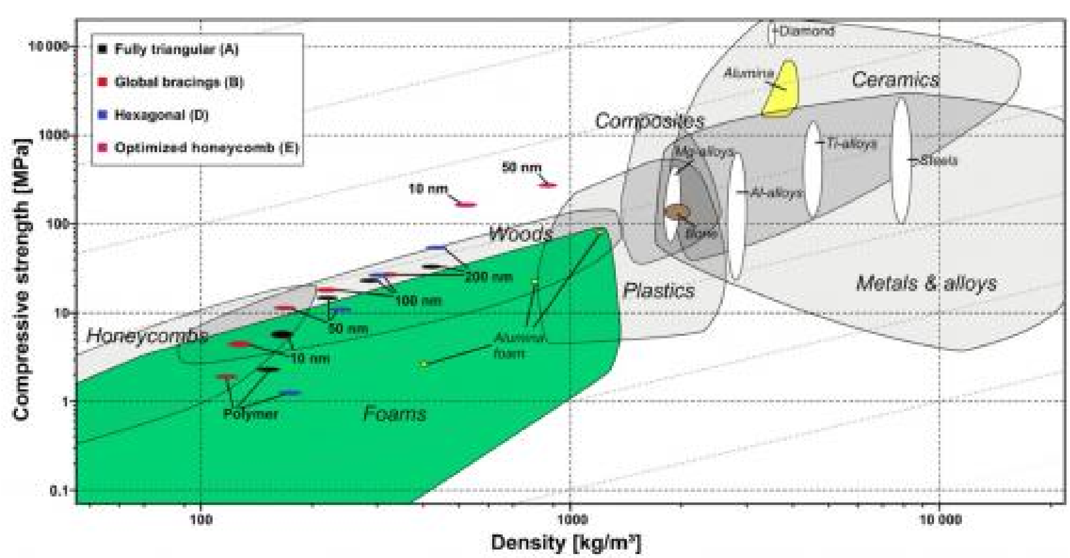
Taking a step in that direction, Jens Bauer at the Karlsruher Institute of Technology (KIT) and his colleagues have developed a bone-like material that is less dense than water, but as strong as some forms of steel. "This is the first experimental proof that such materials can exist," Bauer said.

Material world

Since the Industrial Revolution our demand for new materials has outstripped supply. We want these materials to do many different things, from improving the speed of computers to withstanding the heat when entering Mars' atmosphere. However, a key feature of most new materials still remains in their strength and stiffness – that is, how much load can they carry without bending or buckling.

All known materials can be represented quite neatly in one chart (where each line means the strength or density of the material goes up ten times):

The line in the middle at 1000kg/m^3 is the density of water – all materials to its left are lighter than water and those on the right are heavier. No solid material is lighter than water unless it is porous. Porous materials like wood and bone exhibit exquisite structures when observed under a microscope, and they served as inspiration for Bauer's work.



Credit: Jens Bauer/PNAS

For many years, material scientists have thought that some empty areas on the compressive strength-density chart should be filled by materials that theory predicts. Computer simulations could be used to indicate an optimum microstructure that would give a material the right properties. However, nobody had tools to build materials with defined patterns at the scale of a human hair.

With recent developments in lasers and 3D printing, however, a German company called Nanoscribe started offering lasers that could do just what Bauer wanted. Nanoscribe's system involves the use of a polymer that reacts when exposed to light and a laser that can be neatly focused on a tiny spot with the help of lenses.

A drop of a honey-like polymer is placed on a glass slide and the laser is turned on. A computer-aided design is fed into the system and the slide carefully moves such that the laser's stationary focus touches only those points where the material is to be made solid. Once complete, the extra liquid is washed away, leaving behind materials with intricate internal structures.

However, these materials on their own are not as strong as Bauer wanted. So he coats them with a thin layer of alumina (aluminium oxide) before subjecting them to stress tests. Based on the tests, he was able to improve the theoretical models he used to design the internal structure of the materials. Their results were just published in the Proceedings of the National Academy of Sciences.

Even though alumina layers increase the density of these materials, all of them remain lighter than water. Bauer's strongest material has a specific honeycomb internal structure and is coated with a 50 nanometre-thick (billionth of a metre) layer of alumina. It beats all natural and man-made materials that are lighter than $1000 kg/m^3$, being able to withstand a load of 280MPa (mega pascals is a unit of measuring pressure), which makes it as strong as some forms of steel.

There are limitations. Nanoscribe's system can only make objects that are tens of micrometres in size. "One of their newer machines can make materials in the milimetre-range, but that's about it for now", Bauer added. But that is not enough for any real-life application.

However, there have been rapid improvements in all the areas this work relies on: 3D printing, new polymers and laser technology. That means we may soon have a suite of new, super lightweight materials for everything from skis to aircraft parts. If nothing else, Bauer's work shows that we are definitely in the molecular age.

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