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COLLOIDS AND INTERFACES

Secrets of the Venus' Flower Basket

Nature produces the most unusual building blocks out of the simplest raw materials. The glass sponge *Euplectella* provides a good example of this. Peter Fratzl's team at the Max Planck Institute of Colloids and Interfaces in Potsdam, together with colleagues from Bell Laboratories and the University of California (both in the US), has found out why these constructions made of bioglass fibers are almost unbreakable, helping the sponge survive even in the extremely high pressures found deep in the ocean. (SCIENCE, July 8, 2005)

It has inhabited the sea for more than 540 million years, lives at a depth of 40 to 5,000 meters and has a cage-like glassy skeleton: the glass sponge *Euplectella*. Its shape resembles a white cylinder full of fine holes. Shrimp larvae can get inside the structure through these tiny apertures and usually live there in pairs. As the larvae soon become too large for the holes of their abode, the shrimp pair spends their entire life in the sponge, entering into a symbiosis with it. This may explain why *Euplectella* is also called the "prison of marriage" in Japan and is a popular wedding present.

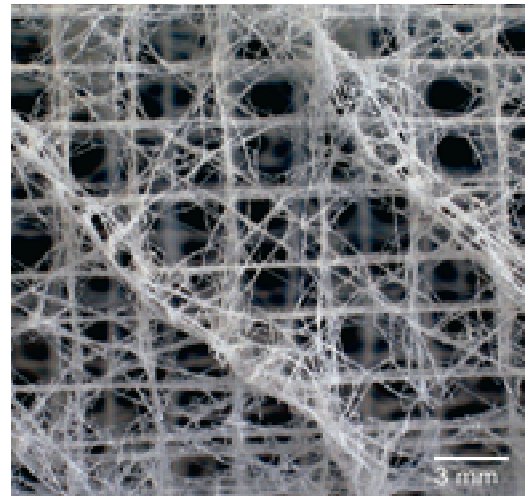
Just how does the sponge manage to withstand the enormous mechanical strain at the bottom of the sea? Aside from the great weight bearing down on it – in some cases the pressure reaches 500 atmospheres – the imprisoned shrimps also maltreat the structure with their pincers. But the prison is escape-proof.

Material researchers in Potsdam have now investigated the structures from the nanometer to the centimeter scale. During the course of their work, they discovered that the cage is constructed from at least seven hierarchically arranged levels. The skeleton itself is comprised of bioglass fibers. But how can these glass fibers be used to construct an unbreakable housing? "We found the answer in the interior of the glass fibers, which are made up of concentrically arranged layers a few millimeters thick," says Max Planck scientist Peter Fratzl. "These glass layers, in turn, are joined together by a very thin layer of glue made from an organic matrix." The researchers believe that the glass itself is formed by the consolidation of silicate nanoparticles that *Euplectella* synthesizes from the water.

The microlayer construction reduces the brittleness of the glass. Cracks and scratches such as those caused by the shrimps' pincers do not lead to breaks as easily as they would with solid glass, since they are diverted in the organic interlayer and prevented from spreading further. Several glass fibers of varying thicknesses are in turn bundled together with glass cement – also composed of silicate nanoparticles – to form strong construction filaments.

The filaments, for their part, are arranged vertically, horizontally and diagonally and woven into a dense net. "Their structure resembles a high-tech construction," says Fratzl. "Our investigations with the sponge have shown that the diagonal filaments are sufficient to protect the structure from torsion." In addition, the structure is reinforced by spiral-like ribs that prevent the cage-like construction from collapsing. "The last layer is the curved shape of the cage, which continues to grow from the bottom," explains the material researcher. "Here, the sponge is anchored to the seabed by glass fibers."

For the Potsdam researchers, *Euplectella* is a textbook example of how brittle materials like glass can produce non-breakable structures. "What was amazing for us was the fact that the sponge manages to combine a whole range of mechanical construction principles on many size scales, from the nanometer to the centimeter range," explains Peter Fratzl. Even engineers and designers are still not familiar with this kind of construction principle. This provides a completely new stimulus for material research. But *Euplectella* has still not revealed all of its secrets: "As yet, it is not clear how a comparatively primitive organism can produce such a complex and optimized structure at all." ●



A detail image of the glass fiber construction of sponges reveals ingenious structural engineering.

Escape-proof prison: The skeleton of the deep-sea sponge *Euplectella*, also known as the "Venus' flower basket".

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