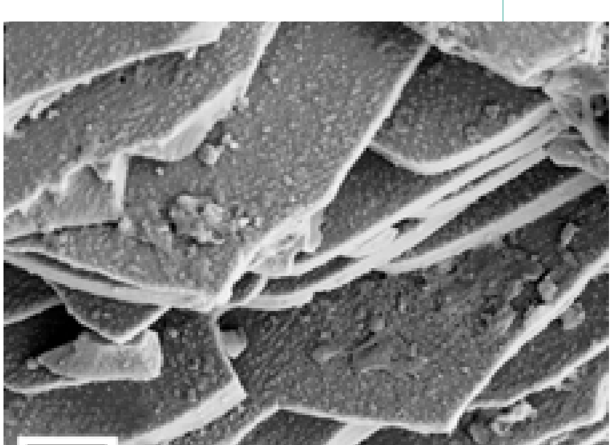
Colloids and Interfaces

Mother of Pearl's Strength Shines Through

Not only is mother of pearl a favorite choice among jewelry makers, it is also an outstanding basic material. Although it consists of 97 percent lime, owing to its layered structure, it has a three thousand times higher fracture toughness. Now, scientists at the Max Planck Institute of Colloids and Interfaces in Potsdam and the German Federal Institute for Materials Research and Testing (BAM) have studied this in detail. In doing so, they discovered that the surface of the individual aragonite platelets that make up mother of pearl is not an ordered, three-dimensional ion structure, but is formed instead of disordered ions, and is thus wavy. (PNAS, September 6, 2005)

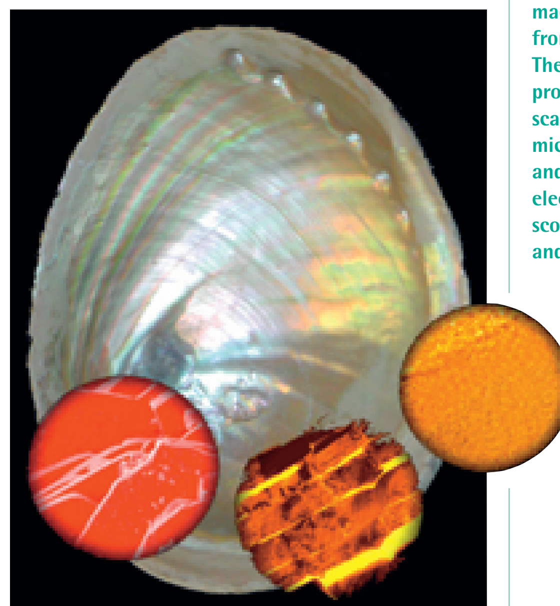
Mother of pearl, also known as nacre, owes its extraordinary fracture toughness to its lamellar structure of soft, organic layers and hard aragonite platelets. Aragonite is a modification of calcium carbonate in which the molecules are ordered in an orthorhombic lattice. "One can imagine the structure of mother of pearl like the pattern in which bricks are laid to build a house, where the aragonite platelets are the bricks that are surrounded by a soft, organic matrix, the mortar. The organic scaffold is composed of very thin chitin layers on which water-insoluble proteins adsorbed," says Helmut Cölfen from the Max Planck Institute of Colloids and Interfaces. Chitin is a polysaccharide that comprises many connected nitrogenous sugar building blocks. Insects, in particular, use chitin as a high-tech composite material.

The Potsdam-based materials researchers now wanted to find out in detail how mother of pearl is structured. They wanted to know how the interface between the aragonite platelets and the organic matrix is built. To study the material of the aragonite platelets, the scientists used the shell of the abalone *Haliotis laevigata*. Its exterior is made up of calcite and its interior is lined with nacre.



Scanning electron microscope view of the fractured surface of mother of pearl. The length of the bar corresponds to one micrometer.

With the aid of high-resolution transmission electron microscopy and nuclear magnetic resonance spectroscopy, the materials researchers discovered that there is a very thin layer – just five nanometers (millionths of a millimeter) thick – of disordered calcium carbonate at the interface between the soft organic matrix and the aragonite platelets. This interface of disordered molecules is probably created by impurities that accumulate there. When crystallization occurs – that is, the ions form aragonite – they are not built into the orthorhombic crystal lattice.



The shell of the abalone *Haliotis laevigata*. The circles show detailed views of the structure of mother of pearl – with increasing magnification from left to right. The images were produced with a scanning electron microscope (red) and a transmission electron microscope (yellow and orange).

If it were possible to copy the construction principle of mother of pearl, we would see a revolution in the materials industry. Engineers could make stronger wallboard or lighter concrete elements with the same strength. But that is still a long way off. For the time being, the Potsdam-based Max Planck scientists are trying to create mother of pearl on its organic scaffold. They hope this will shed light on the material's formation mechanism. So far, they have even succeeded in growing calcite platelets there. Calcite is the thermodynamically stable form of calcium carbonate. Aragonite will follow soon. Synthesizing the organic scaffold of mother of pearl, however, will be quite difficult. Currently, the materials researchers are still using the natural matrix. "Copying the organic structure as the basis for breeding is the greatest challenge, since it is created in nature through cell processes," says Helmut Cölfen. ●

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