Researchers create artificial mother-of-pearl using bacteria

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This abalone shell is a natural form of nacre -- also known as mother-of-pearl -- an exceptionally tough material found in shells and pearls. Rochester biologists have developed an innovative method for creating nacre in the lab -- and maybe on the moon. Credit: University of Rochester / J. Adam Fenster

The strongest synthetic materials are often those that intentionally mimic nature.

One natural substance scientists have looked to in creating synthetic materials is nacre, also known as mother-of-pearl. An exceptionally tough, stiff material produced by some mollusks and serving as their inner shell layer, it also comprises the outer layer of pearls, giving them their lustrous shine.

But while nacre's unique properties make it an ideal inspiration in the creation of synthetic materials, most methods used to produce artificial nacre are complex and energy intensive.

Now, a biologist at the University of Rochester has invented an inexpensive and environmentally friendly method for making artificial nacre using an innovative component: bacteria. The artificial nacre created by Anne S. Meyer, an associate professor of biology at Rochester, and her colleagues is made of biologically produced materials and has the toughness of natural nacre, while also being stiff and, surprisingly, bendable.

The method used to create the novel material could lead to new applications in medicine, engineering—and even constructing buildings on the moon.

Impressive mechanical properties

The impressive mechanical properties of natural nacre arise from its hierarchical, layered structure, which allows energy to disperse evenly across the material. In a paper published in the journal *Small*, Meyer and her colleagues outline their method of using two strains of bacteria to replicate these layers. When they examined the samples under an electron microscope, the structure created by the bacteria was layered similarly to nacre produced naturally by mollusks.

Although nacre-inspired materials have been created synthetically before, the methods used to make them typically involve expensive equipment, extreme temperatures, high-pressure conditions, and toxic chemicals, Meyer says. "Many people creating artificial nacre use polymer layers that are only soluble in nonaqueous solutions, an organic solvent, and then they have this giant bucket of waste at the end of the procedure that has to be disposed of."

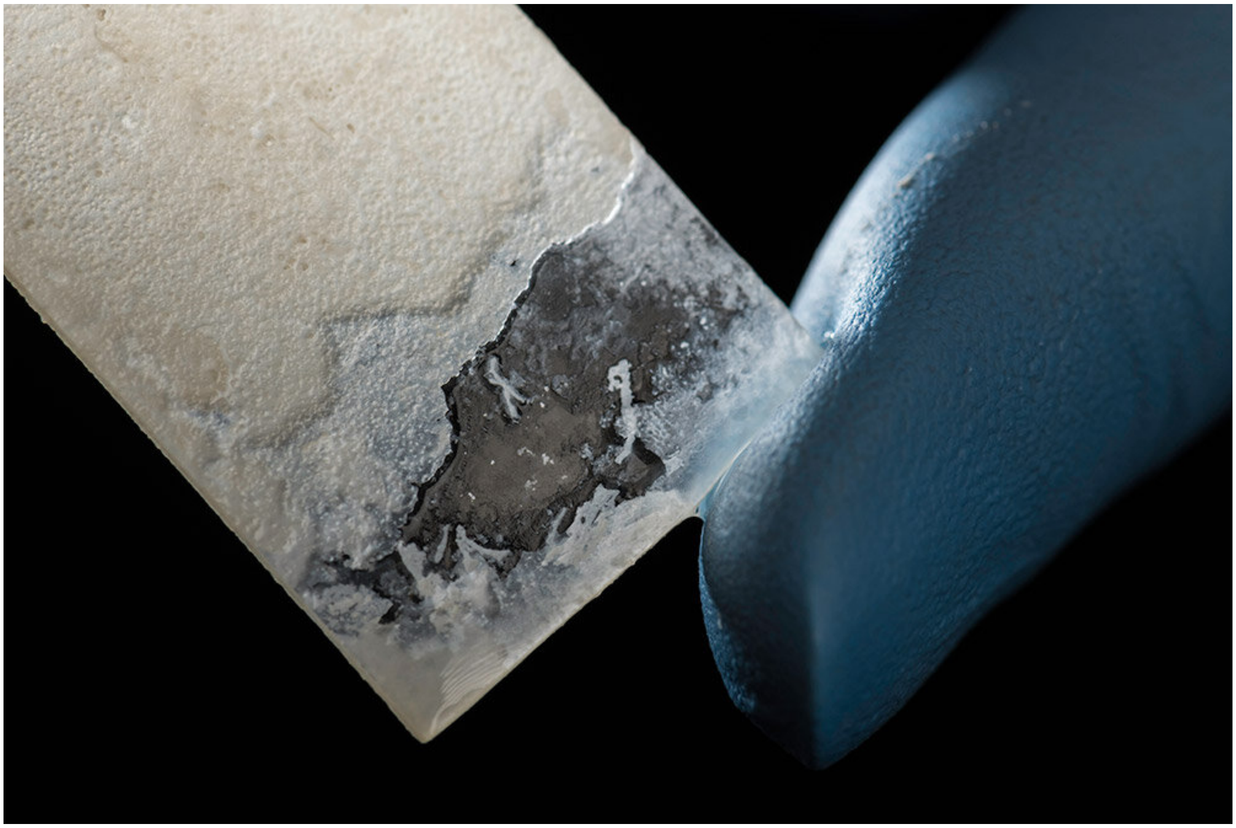
To produce nacre in Meyer's lab, however, all researchers have to do is grow bacteria and let it sit in a warm place.

In order to make artificial nacre, Anne S. Meyer and her team use bacteria to create alternating thin layers of crystallized calcium carbonate and sticky polymer. Each layer is approximately five micrometers thick. Credit: University of Rochester photo / J. Adam Fenster

From bacteria to nacre

In order to make the artificial nacre, Meyer and her team create alternating thin layers of crystalized calcium carbonate—like cement—and sticky polymer. They first take a glass or plastic slide and place it in a beaker containing the bacteria *Sporosarcina pasteurii*, a calcium source, and urea (in the human body, urea is the waste product excreted by the kidneys during urination). This combination triggers the crystallization of calcium carbonate. To make the polymer layer, they place the slide into a solution of the bacteria *Bacillus licheniformis*, then let the beaker sit in an incubator.

Right now it takes about a day to build up a layer, approximately five micrometers thick, of calcium carbonate and polymer. Meyer and her team are currently looking at coating other materials like metal with the nacre, and "we're trying new techniques to make thicker, nacre-like materials faster and that could be the entire material itself," Meyer says.



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Building houses on the moon

One of the most beneficial characteristics of the nacre produced in Meyer's lab is that it is biocompatible—made of materials the human body produces or that humans can eat naturally anyway. This makes the nacre ideal for medical applications like artificial bones and implants, Meyer says. "If you break your arm, for example, you might put in a metal pin that has to be removed with a second surgery after your bone heals. A pin made out of our material would be stiff and tough, but you wouldn't have to remove it."

And, while the material is tougher and stiffer than most plastics, it is very lightweight, a quality that is especially valuable for transportation vehicles like airplanes, boats, or rockets, where every extra pound means extra fuel. Because the production of bacterial nacre doesn't require any complex instruments, and the nacre coating protects against chemical degradation and weathering, it holds promise for civil engineering applications like crack prevention, protective coatings for erosion control, or for conservation of cultural artifacts, and could be useful in the food industry, as a sustainable packaging material.

The combination of the bacteria Sporosarcina pasteurii, a calcium source, and urea triggers the crystallization of calcium carbonate, pictured above in extreme close up. Credit: University of Rochester / J. Adam Fenster

The nacre might also be an ideal material to build houses on the moon and other planets: the only necessary "ingredients" would be an astronaut and a small tube of bacteria, Meyer says. "The moon has a large amount of calcium in the moon dust, so the calcium's already there. The astronaut brings the bacteria, and the astronaut makes the urea, which is the only other thing you need to start making calcium carbonate layers."

Even beyond its qualities as an ideal structural material, nacre itself—as any pearl jewelry owner knows—is "very beautiful," Meyer says, owing to its stacked layers. Each stacked layer is approximately the same wavelength as visible light. When light hits the nacre, "the wavelengths of light interact with these layers of the same height so it bounces back off in the same wavelength as visible light." While the bacterial nacre does not interact with visible light because the layers are thicker than natural nacre, it could interact with infrared wavelengths and bounce infrared off itself, Meyer says, which "may offer unique optical properties."

More information: Ewa M. Spiesz et al. Bacterially Produced, Nacre-Inspired Composite Materials, *Small* (2019). DOI: 10.1002/smll.201805312

Provided by University of Rochester