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USING BACTERIA TO MAKE IMPROVED, NACRE-INSPIRED MATERIALS

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ABSTRACT

New materials inspired by nature could find applications as coatings in the civil and aeronautical/aerospace industries. A natural material that has caught much attention of researchers is nacre, a composite consisting of calcium carbonate platelets that are connected by an organic matrix. Due to its unique structure, nacre has outstanding material properties such as very high compressive and tensile strength and toughness.

We use prokaryotes to generate new, nacre-inspired composite materials, consisting of alternating layers of calcium carbonate and poly-gamma-glutamate (PGA). Calcium carbonate is precipitated by the action of *Sporosarcina pasteurii*, which hydrolyzes urea. This reaction increases the pH of the growth medium and thus precipitates calcium carbonate out of solution.

PGA, an anionic polymer produced by many *Bacillus* species, mimics the complex organic layers found in natural nacre. PGA is non-toxic, non-immunogenic, biodegradable, edible, water soluble and protease resistant. We alternate calcium carbonate precipitation and PGA application to produce a new composite material.

Scanning electron microscopy of our samples reveals large regions of layered calcium carbonate structures, which resemble the ones found in nacre. In samples produced by repeated precipitation of calcium carbonate, but without PGA application, layered structures are much less prevalent. However, on the microscale, these samples show an arrangement of micrometer-sized, randomly oriented crystallites as opposed to more columnar crystals in the layered composite.

Microindentation measurements show that the calcium carbonate-PGA composite is stiffer than the only-calcium carbonate material. However, the latter dissipates more of the deformation energy. This result might be explained by the microstructure, as the many small crystallites could allow cracks to take a longer path through the material, dissipating more energy in the process – a phenomenon observed in natural nacre.

Thus we have produced two new, nacre-inspired materials with differing properties: a stiffer one that recovers more deformation energy, and a softer one that dissipates more deformation energy. These are two of the first examples of the generation of high-performance composite materials produced by bacteria, potentially providing more environmentally-friendly and sustainable materials with applications in e. g. construction or medicine.