Fabrication of authentic nacre by matrix-directed mineralization

With the support by the National Natural Science Foundation of China and the Chinese Academy of Sciences, a research team led by Prof. Yu Shuhong (俞书宏) at the Department of Chemistry of the University of Science and Technology of China reported a new mesoscale strategy for the fabrication of nacre-like material, which was published in *Science* (2016, 354(6308): 107—110).

For a long time, the development of artificial structural materials has highly depended on discovering new compounds. In contrast, living things construct their structural materials, such as nacre, by integrating soft organics and hard but brittle minerals. These components are assembled and organized into hierarchical structures which are well-designed from the molecular scale to the macro scale. It is a promising route for exploring future materials, that is, artificial compounds, which do not exist in the natural environment, combine with the hierarchical structures optimized via natural selection. Nevertheless, the fabrication of biomimetic structural materials is still full of challenges, including the limit of available material type and the low efficiency.

In response to these challenges, Yu's group noticed the growth mechanism of natural nacre is quite inspiring, and then proposed a consecutive assembly-and-mineralization process. First, they produced chitin matrix via freeze-casting-assisted assembly. Then the matrix was mineralized in a cycling system driven by a pump. The mineralized matrix was infiltrated with silk fibroin sol and hot-pressed. Consequently, they obtained nacre-like material that highly resembled natural nacre. The synthetic nacre consisted of ~90 wt.% of aragonite and ~10 wt.% of chitin and silk fibroin with a laminated structure and a Voronoi pattern. The aragonite platelets were composed of small aragonite nanograins. In addition, some fine features such as the "dovetail structure" and platelet waviness, which were suggested to play a key role in the mechanical performance of natural nacre, were observed in the material. The mechanical properties of the synthetic nacre were significantly enhanced because of its nano- and microstructure that mimic the hierarchical structure of natural nacre. There was no micro crack around the residual indents on the platelets, demonstrating its good flaw-tolerance ability. Both the ultimate flexural strength and the fracture toughness of the synthetic nacre were comparable to natural nacre. The rising R-curve indicated both intrinsic and extrinsic toughening mechanisms. Notably, only two days were needed for the fabrication of the synthetic nacre, whereas natural nacre growth always takes several years.

This study contributes to the design principles for preparing robust composite materials with hierarchically ordered structures using various constituents including brittle and heat-labile building block sunder ambient conditions, which is instructive for future work. In particular, this method could lead to materials that are both very hard and tough, which are mutually exclusive in traditional engineering materials. The strategy has potential applications in many fields such as tissue engineering and aerospace industry.

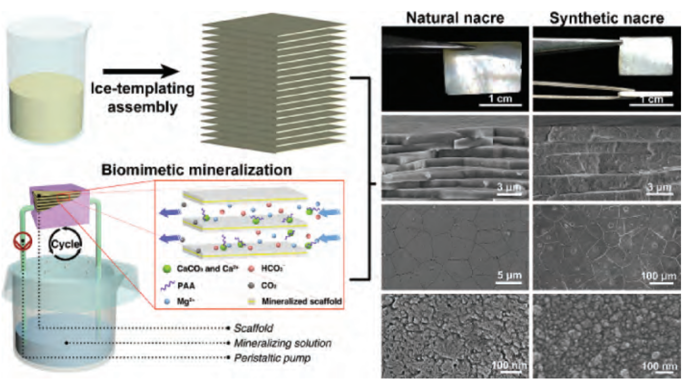

Figure Scheme of the synthetic nacre fabrication and the structural similarities with natural nacre.