THE MECHANICAL PERFORMANCE OF NACRE FROM SEASHELLS –MICROSTRUCTURAL FEATURES LEADING TO SUPERIOR TOUGHNESS

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Many structural biological materials such as bone, teeth or seashells exhibit surprisingly high mechanical performances. The case of nacre (mother-of-pearl) is a perfect example, which is attracting a lot of attention in the mechanics and materials science communities. Nacre is mostly made of a brittle ceramic (aragonite), yet it exhibits surprisingly high levels of strength and toughness. This is made possible by a very well designed microstructure organized over several length scales (hierarchical microstructure), and optimized through millions of years of evolution. Extensive research has been pursued on nacre, but the exact microstructural features and mechanisms leading to its remarkable mechanical properties are still unknown.

Nacre has a brick and mortar structure, where polygonal aragonite tablets are bonded together by a small fraction of organic material. The prominent deformation mechanism in tension is the sliding of the tablets on one another. Through experiments and 3-D modeling of the material microstructure, we will demonstrate that a geometric feature previously overlooked, i.e., tablet waviness, together with the properties of the tablet and interface controls sliding and interlocking leading to dilation and strain hardening. As a result the material is able to spread inelasticity over large volumes. We will also show that this mechanism has a direct impact on the toughness of nacre. Fracture experiments and a full characterization of the material resistance to crack propagation will be presented together with RVE modeling based on a FEM formulation including cohesive elements.

The implication of these findings in the context of the design of novel composites will be discussed.