The mechanical behavior of nacre across length scales

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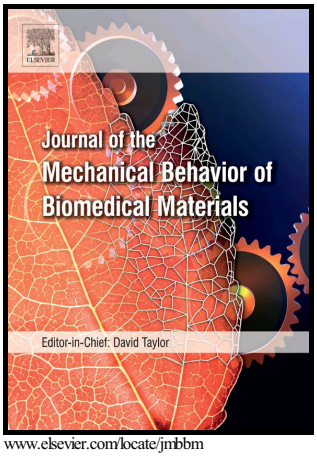

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Abstract

Nacre achieves excellent mechanical properties with a relatively simple hierarchical structure. Analyses suggest that a significant gain in toughness is realized with a modest reduction in strength, with increasing levels of hierarchy. This study probes the role of different hierarchical length scales in governing the strength and modulus of nacre using a combination of bulk compression tests, microindentation and nanoindentation tests. The variability in the measured properties is assessed through Weibull analyses. The transition from elastic deformation is characterized using spherical indentation tests at the micro and nano scales together with a Herztian analysis. The modulus of the organic phase at different scales was deduced using indentation data and appropriate micromechanical models. The results show a minimal influence of length scales on elastic-plastic transitions, suggesting that initiation of plasticity occurs through a common biomineral sliding mechanism across length scales. However the ultimate strengths follow the trends of models for hierarchical materials, with the strength reducing by a factor of ~2 with each increase in level of hierarchy. The modulus of the organic phase was higher at the lowest scale, in contrast to an earlier study, indicating that confinement significantly modifies the effective properties of the organic.

Keywords: Nacre, hierarchy, strength, modulus, inter-tablet and trans-tablet organic