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Toughening mechanisms in bioinspired multilayered materials

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ABSTRACT

Outstanding mechanical properties of biological multilayered materials are strongly influenced by nanoscale features in their structure. In this study, mechanical behavior and toughening mechanisms of abalone nacre-inspired multilayered materials are explored. In nacre's structure, the organic matrix, pillars and the roughness of the aragonite platelets play important roles in its overall mechanical performance. A micromechanics model for multilayered biological materials is proposed to simulate their mechanical deformation and toughening mechanisms. The fundamental hypothesis of the model is that nanoscale pillars and asperities have near theoretical strength. It has been shown earlier that organic matrix behaves stiffer in proximity of mineral platelets. However, the suggested values for stiffness and strength of organic matrix appear to be high. The proposed model assumes that pillars and the asperities confine the organic matrix to the proximity of the platelets and hence increase their stiffness and strength. The modeling results are in excellent agreement with the experimental results for abalone nacre. The results show that the stiffness of the organic matrix affects the stiffness of material, whereas platelets' aspect ratio determines the ultimate strength. The pillars and the asperities are responsible for the ductility of multilayered material. In the proposed model, although all the components of the bioinspired structure have brittle behavior, the overall structure has a ductile response. The highly nonlinear behavior of the suggested multilayered material is a result of a distributed deformation in the nacre-like structure due to existence of nanoasperities and nanopillars with near theoretical strength.