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USING ICE TO MAKE NATURE-INSPIRED HYBRID MATERIALS

Antoni P. Tomsia

Lawrence Berkeley National Laboratory
Materials Sciences Division
Berkeley, CA 94720, USA

The structure of materials invariably defines the mechanical behavior. However, in most materials, specific mechanical properties are controlled by structure at widely differing length scales. Nowhere is this more apparent than with biological materials, which are invariably sophisticated composites whose unique combination of mechanical properties derives from an architectural design that spans nanoscale to macroscopic dimensions. Moreover, they are generally able to defeat the "law of mixtures" by devising such hierarchical structures with weak constituents into strong/tough hybrid materials that display superior properties to their individual constituents. The fracture resistance of such materials originates from toughening mechanisms at each dimension; few engineering composites have such a hierarchy of structure. However, the biomimetic approach has not been that successful because of the difficulty of synthesizing such materials. In this presentation we describe attempts to develop a range of bone- and nacre-like structural materials using a new freeze-casting technique, which utilizes the intricate structure of ice to create hybrid materials with complex lamellar and/or mortar and brick structures modeled across several length-scales. Our initial results show ceramic-polymer and ceramic-metal hybrid materials with toughness well in excess of those expected from a rule of mixtures construction. The architecture and properties of the synthetic materials are compared to their natural counterparts in order to identify the mechanisms that control mechanical behavior over multiple dimensions and propose new design concepts to guide the synthesis of hybrid/hierarchical structural materials with unique mechanical responses.

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