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NUMERICAL INVESTIGATION OF NATURALLY-OCCURRING HIGH PERFORMANCE MATERIALS

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Abstract. There is a strong demand for new paradigms of design and development of advanced high-performance materials with exceptional mechanical properties and novel combinations of other properties and qualities such as durability, low-cost, renewability, environmental- and biocompatibility. However, it is well known that, for engineering materials, there exists an inverse relation between pairs of desired properties. On the other hand, Nature has evolved efficient strategies to synthesize materials that often exhibit exceptional mechanical properties that significantly break the conventional trade-offs often required in man-made materials. In fact, most biological materials achieve high toughness without sacrificing stiffness and strength by controlling key nano-and microstructural features that significantly improve the mechanical performance of otherwise brittle materials. Interrogating how Nature employs these strategies and decoding the structure-function relationship of these materials is a challenging task that requires knowledge about the actual loading and environmental conditions of the material in their natural habitat, as well as a complete characterization of their constituents and hierarchical ultrastructure through the use of modern tools such as in-situ electron microscopy, small-scale mechanical testing capabilities, prototyping, and advanced multiscale numerical models. In turn, this provides the necessary tools for the design and fabrication of biomimetic materials with remarkable properties.

I will particularly focus my talk on the synergetic role of geometry and length scales by discussing specific features such as hierarchy, periodicity and patterning in the microstructure and interfaces observed in some extraordinarily strong natural materials, including biomineralized materials from abalones, chitons and mantis shrimps. In this context, I will present an analysis of geometry and size effects in the design of biomimetic materials using a combined computational and prototype modeling approach that employs advanced 3D printing techniques and multiscale models.