MATERIALS ENGINEERING SEMINAR

"Unraveling Microstructure-Property Correlations in Natural Biological Materials by Multiscale and Multimodal Characterization"

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ABSTRACT

Through thousands of years of evolution, natural biological systems have optimized their structures to thrive in diverse ecological conditions. Extracting and leveraging the inherent design principles of these biological systems can provide inspiration for the development of advanced lightweight structural materials. To effectively facilitate this transition, it is crucial to understand the specific mechanisms by which the microstructure of biological materials influences their mechanical properties. This dissertation focuses on understanding microstructure-property correlations in three biological systems: Venus flower basket, Cholla cactus, and Organ pipe coral.

The Venus flower basket exhibits a cylindrical cage-like structure made from a complex network of silica fibers which exhibit a core-shell like layered architectures. A novel multimodal approach involving nanoindentation, *ex situ* and *in situ* fiber testing, and post-failure fractography was utilized to precisely understand the impact of the layered structure on the tensile and fracture behavior of fibers. The observation of fibers in real-time revealed, for the first time, that the initiation of failure occurs at the fiber's surface and progressively advances towards the core, traversing multiple layers. The concentric layers encompassing the central core act sacrificially, employing various toughening mechanisms to protect the core. Furthermore, nanoindentation experiments performed *in situ* in water shed light on the significance of the layered fiber structure in a marine environment. Another interesting system is the Cholla cactus. In arid environments, Cholla cactus produces porous wood with a mesh-like structure. To comprehensively understand the structure, properties, and designs of Cholla cactus wood, various techniques such as x-ray tomography, scanning electron microscopy, nanoindentation, and finite element simulations were employed. The structure and function of different wood components was investigated from both biological and mechanical behavior perspectives. The impact of the unique structure of wood components on the design of engineering materials will be discussed. Finally, we will discuss the behavior of the Organ pipe coral, which exhibits a hierarchical structure comprising vertical tubes and horizontal platforms at the macrostructure level. At the microstructure level, cells are formed through a unique arrangement of micrometer-sized plates made of calcium carbonate. Nanoindentation was used to assess the impact of this hierarchical structure on micromechanical properties. The results unveiled distinct toughening mechanisms operating at different length scales within the coral.

By gaining a precise understanding of the correlations between microstructure and properties in various biological materials, this research provides valuable insights for the design of advanced architected structural materials. The unique interplay between microstructure, function, and properties will be discussed.

Date: Tuesday, July 18, 2023
Time: 2:00 P.M.
Place: ARMS 1021 or via this link: https://purdue.webex.com/meet/nikc

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