OPUS
College of Engineering

MARQUETTE UNIVERSITY

Department of Civil, Construction and Environmental Engineering

SPECIAL SEMINAR

1:30-2:30 p.m., Thursday, March 28, 2019
323 Engineering Hall, 1637 W. Wisconsin Ave., Milwaukee, WI

Bioinspired Design of Next-Generation Structural Materials

Dr. Nima Rahbar

Associate Professor of Structural Engineering and Mechanics
Department of Civil and Environmental Engineering
Worcester Polytechnic Institute

Abstract

This talk focuses on the fundamental ideas arising from understanding the mechanisms behind the superior mechanical and thermal properties of biological materials through specific examples of nacre, bamboo, and lipid bilayers. Our studies on the mechanical behavior and toughening mechanisms of abalone nacre show that the organic matrix, pillars, and the roughness of the aragonite platelets play important roles in its overall mechanical performance. A micromechanical model for multilayered biological materials is proposed to simulate the mechanical deformation and toughening mechanisms in these structures. We have further shown that the outstanding mechanical behavior of nacre is primarily due to the existence of nano-pillars with near-theoretical strength. Novel applications such as multilayered ceramic composites, cementitious metamaterials, and Sprayed Fire-Resistant Materials (SFRMs), emerging from this fundamental work, will be presented. Bamboo, a fast-growing grass, has higher strength-to-weight ratios than steel and concrete. The unique properties of bamboo come from the natural composite structure of fibers that comprises mainly cellulose nanofibrils in a matrix of intertwined hemicellulose and lignin called lignin-carbohydrate complex (LCC). Here, we have experimentally and numerically studied mechanical and fracture properties of bamboo at multiple scales. We have shown that while hemicellulose has better thermodynamic and mechanical properties than lignin, lignin exhibits a greater tendency to adhere to cellulose nanofibrils, and therefore provides the strength in bamboo fibers. Lastly, given the amphiphilic nature and chemical structure, phospholipids exhibit a strong thermotropic and lyotropic phase behavior in an aqueous environment. The results of our non-equilibrium molecular dynamics simulations for a range of different temperature gradients show that the thermal properties of the Dipalmitoylphosphatidylcholine (DPPC) bilayer are highly dependent on the temperature gradient. We also found that the thermal conductivity of DPPC is lowest at the transition temperature whereby one lipid leaflet is in the gel phase and the other is in the liquid crystalline phase. These results provide significant new insights into developing new thermal insulation for engineering applications such as thermal diodes.

Biography

Dr. Nima Rahbar received his Ph.D. degree in Mechanics, Materials and Structures in the Department of Civil Engineering at Princeton University in 2008. He joined Worcester Polytechnic Institute in August 2012 as an Assistant Professor and was promoted to Associate Professor (with tenure) in 2016. His research interests are in the area of bioinspired design of materials with an emphasis on mechanical and thermal properties. Dr. Rahbar has won several awards including the NSF CAREER award in 2012, the TMS Young Leader's award in 2013, an Air Force Summer Faculty Fellowship Award in 2013, consecutive Outstanding Reviewer awards in 2015 and 2016 from the *ASCE Journal of Nanomechanics and Micromechanics*, and the 2018 Sigma Xi Outstanding Junior Faculty Research Award.