

Hierarchy Driven Characterization of Ceramic and Polymer Matrix Composites for Aerospace and Energy Applications

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Abstract

Current state of the art in inorganic and organic materials development focuses on obtaining multiphase materials having individual phases spanning a range of lengthscales and expected functionality over a combination of timescales. With this theme, this talk will present material behavior characterization work in my group with focus on analyzing failure strength of ceramic and polymer matrix composite materials at multiple length and time scales.

First part of the talk will focus on a newly discovered class of ceramic matrix composites. These composites have been touted as replacements for current generation of superalloys and coatings in gas turbine based systems and as advanced materials in nuclear energy radiation resistant environments. However, significant problems that include material behavior at a combination of length and time scales in extreme environments have not been addressed. I will present our group's work in analyzing these materials using nanocomposite molecular simulations and nanoscale finite element simulations along with experiments that can explicitly address the multiple length and time scales in these materials. Further morphology development in these nanocomposites will require a considerable effort in method development that can explicitly use quantum mechanically derived structural modifications to suggest material morphology performance in relevant extreme environments at experimentally accessible length and time scales. For this purpose we have developed a quantum hybrid Monte Carlo scheme and an equivalent crystal dynamics scheme. Examples for the successful applications of these schemes to current nanostructures will be presented. In the second part of talk, I will describe our work on polymer matrix composites. As a test case we have analyzed tropocollagen (TC)-hydroxyapatite (HAP) polymer matrix composites. Through our simulations it is shown that the nanoscale environment, texture, and morphology changes could be manipulated to change the macroscopic interfacial behavior in these amorphous looking structures. Using nano-indentation experiments we find that the strength scaling relations predicted using the molecular simulations hold true for bone tissue with similar nanoscale composition at nanometer and micron length scales. We also find that supposedly quasi-brittle bone tissue shows metal like band of plasticity when loaded to its yield point in compression. Besides biological relevance these findings also have important implications for lightweight aerospace materials such as carbon nanotube based composites.

Biosketch

Dr. Tomar received his PhD from the Georgia Institute of Technology on [December 17, 2005](#). Thereafter, he has been working as an assistant professor of the Aerospace and Mechanical Engineering Department at the University of Notre Dame, IN. His research focus is on molecular and continuum modeling combined with some degree of characterization of failure in nanostructured as well as microstructured ceramic and polymer composites, quantum dots, and ceramic-bio hybrid systems and materials. Recent focus include coupling of thermal, electrical, photo, and mechanical behaviors. Through his research, he hopes to make fundamental contributions for advancements in the field of material and systems for aerospace, energy, and medicine. He has written numerous technical articles including 26 journal publications, 1 book chapter, 1 edited journal special issue, and 1 edited volume on conference proceedings. Funding for his work has come from the National Science Foundation, the Department of Energy, the ARMY, and the Air Force Office of Scientific Research (AFoSR). Recent honors include AFoSR Young Investigator Award for years 2009-2012. With research, Dr. Tomar has significantly invested in teaching and outreach activities including establishing a pre-engineering program at West Side High-School in Gary-IN.