MECHANICAL ENGINEERING SEMINAR

Practice Your Scales! Thermal, Energy, and Bio Nanomaterials for Fast Processes

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Abstract

The theory of energy and charge transport is a century old, yet classical and quantum size effects have been exploited usefully in practical materials only for the past two decades, and often with a modest level of success in practice. Many of the remaining challenges involve problems of time and length scales – e.g., faster energy transport processes enabled by new materials that can be manufactured economically at human scales. Success in the large-scale adoption of nanomaterials, with their prevalence of interfaces, will likely depend on deeper fundamental understanding of both interfacial transport in assemblies of nanomaterials over wider time scales and high-throughput manufacturing processes over larger length scales in order to tune their performance and engineer them for desired properties in real applications. For example, individual carbon nanotubes possess extremely high axial thermal conductivity, yet when placed in a composite matrix, the effective thermal properties are quite ordinary. For high-performance cooling applications, single-phase convection is a limited option because of its inability to dissipate ultra-high thermal loads, thus constraining the performance of the host system. With these challenges in mind, this presentation will consider how nanomaterials can be exploited at appropriate engineering scales to improve the performance of realistic thermal and energy storage technologies, particularly those requiring rapid transient response. Carbon nanomaterials for use in fast-charging and discharging electrochemical energy storage devices offer particular promise as scalable, high-performance electrodes, and similar structures show outstanding sensitivity to biological analytes. Moreover, the microstructure of granular assemblies of battery cathode materials will be shown to have a profound effect on charge/discharge speed. As another example, a tunable cooling technology befitting fast transient thermal events will be described. In this system, the rapid depressurization of the working fluid triggers coincident flash boiling and desorption events, thereby achieving very high cooling rates for short periods of time. We anticipate that this technology, when properly controlled, will achieve instantaneous peak cooling efficiencies surpassing those other advanced cooling systems. The presentation will close with a discussion of opportunities to 'practice our scales' further in order to enable cost-effective, large-scale production of these technologies.

Biography

Timothy S. Fisher (PhD in Mechanical Engineering, 1998, Cornell) was born in Aurora, IL USA. He joined UCLA's Department of Mechanical & Aerospace Engineering in 2017 after spending 15 years in Purdue's School of Mechanical Engineering, and several previous years at Vanderbilt University. In 2018 he was named Department Chair and received the John P. and Claudia H. Schauerman Endowed Chair in Engineering. He is an Adjunct Professor in the International Centre for Materials Science at the Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR) and co-directs the JNCASR-Purdue Joint Networked Centre on Nanomaterials for Energy. From 2009 to 2012, he served as a Research Scientist at the Air Force Research Laboratory's newly formed Thermal Sciences and Materials Branch of the Materials and Manufacturing Directorate. He is active in service to the American Society of Mechanical Engineers through a variety of responsibilities, and is a former Co-Editor of the journal Energy Conversion & Management and currently Specialty Chief Editor for Thermal and Mass Transport of the journal Frontiers in Mechanical Engineering.