Smart Materials and Structures

Session co-chairs: Geoff Brennecka (Colorado School of Mines, USA) and Hidehiro Yoshida (National Institute for Materials Science, Japan)

Session abstract:
Without materials, there is no engineering; yet the underlying materials and structures that enable modern engineering wonders, from supercomputers in our pockets to transportation and information infrastructure, often go unnoticed. The goal of this session is to show how learning about and employing fundamental materials behavior enables us to both know more about the world from atomic to planetary scales and to build structures and devices that are almost magical in their performance, yet elegantly simple in their design.

While the phrase *Smart Materials and Structures* implies that the materials themselves are intelligent in some way, actual utility comes from structures and systems that take advantage of functional material responses. 'Smart materials' are simply those whose natural response to some stimulus can be exploited for some engineering application, often in a different property regime than the stimulus itself. Common examples of smart materials include piezoelectrics, which transduce electrical and mechanical energies; shape memory alloys, which experience large and reversible mechanical deformations related to a thermally-induced phase transformation; and electrochromic materials, whose color and/or transparency can be modified by an applied electric field.

In this session, we highlight the link between a fundamental understanding of materials chemistry, structure, and behavior with the engineering of smart structures that exploit useful aspects of innate material response.

For example, Prof. Takehiko Hiraga from the Division of Earth and Planetary Materials Science in the Earthquake Research Institute at The University of Tokyo will discuss the superplastic flow and microstructural development of the Earth's mantle on global geologic processes. At the other end of the size spectrum, Prof. Naoya Shibata from the Institute of Engineering Innovation in the School of Engineering at The University of Tokyo will describe recent advances in tools and techniques for making truly atomic-scale observations and analysis of structural and functional materials. Despite the massive difference in physical scale of these two topics, they share a great deal in terms of underlying materials mechanisms and highlight the importance of developing fundamental understanding of materials across all scales.

Our two speakers from the United States focus on taking advantage of functional materials behaviors in order to fabricate smart structures and devices. Prof. Robert Shepherd from the School of Mechanical and Aerospace Engineering at Cornell University will discuss how to utilize complex fluids which are field-responsive (to stress, thermal, electric, and/or magnetic fields) in order to tailor how materials and devices such as soft robotics can interface with humans. Prof. Kira Barton from Mechanical Engineering at the University of Michigan will discuss how engineers can start from a desired response and build/fabricate materials and structures in

order to perform a desired function, with a focus on feedback and controls associated with additive manufacturing (and related) processes in ways that can account for a large degree of inherent imprecision.

Overall, we hope that this session opens minds to the ubiquity and boundless opportunities of leveraging the responses of smart materials to address the myriad needs of society. Starting with a fundamental understanding of the multi-scale structure of materials and associated functional responses enables further scientific advances as well as the engineering of smart devices and systems across all scales and disciplines.