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Mesoscale Materials Science: Experiments and Modeling

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The macroscopic behavior of materials is defined by defects and structures present in the material at the microscopic scale. One of the very well-known examples of such a multiscale behavior is metal plasticity. Plasticity in metals is caused by the nucleation and evolution of a system of dislocations on specific crystallographic slip planes. Gliding of a collection of dislocations and their interaction with other defects (vacancies, grain boundaries, phase boundaries, etc.) result in the formation of heterogeneous cell structures, which dictate structural properties such as strength and ductility. Thus, to develop a thorough understanding of deformation mechanisms in engineering materials and design new materials with desired properties, a predictive understanding of the effect of microscopic configurations on macroscopic properties is required. One of the multiscale approaches is hierarchical characterization, which involves the development of novel experimental methods and robust computational approaches applicable at different spatial and temporal scales. This approach involves the analysis of materials at atomic, microscopic, mesoscopic, and macroscopic scales and linking the behavior at these different scales. This particular topic is focused on progress in localized mechanical testing and high-resolution imaging techniques and integration of experiments and modeling for elucidating the evolution of structures and defects at the mesoscopic resolution. Mesoscopic properties can be reliably accessed because of recent advances in the small scale-fabrication and characterization techniques and the availability of high-performance computational frameworks.

Enhancements in in situ micromechanical testing methods for small volumes have enabled the study of local as well as bulk properties of materials. Also, high-resolution images can be easily captured using electron microscopes and digital image correlation (DIC) algorithms.[1] It is this combination that has made in situ micromechanical testing useful for various engineering applications.[2] Experimental techniques used in this special topic include in situ transmission electron microscopy (TEM) tests for analyzing Cu-Au interface, micro-pillar compression experiments to study the effect of interfaces on plasticity in lath martensite, drop hammer tests with thermal imaging to study the effect of impact loading on microstructure-dependent properties of energetic materials, hot compression tests to undertstand the influence of temperature and strain rate on microstructural evolution in titanium aluminide alloys, and bending tests for studying creep in metallic materials. Although significant progress has been made in in situ testing approaches using x-ray diffraction and electron microscopy, there are still challenges that need to be addressed. One of the main issues is the efficient handling of data obtained from these experiments. A novel machine learning algorithm for extracting the behavior of grains from the data collected using high-energy x-ray diffraction microscopy technique is described in this special topic.

With the advent of computational power, this is an ideal time for the development of rigorous and reliable physics-based mesoscopic models. Usage of such computational frameworks in conjunction with the accurate material data will lead to a transformation in scientific understanding of structure–property relationships, material design, and product innovation. This special topic includes a paper on a crystal plasticity-based model for analyzing the behavior of crystals in the vicinity of grain boundaries and comparison of computational results with experimental data obtained from synchrotron Laue microdiffraction and digital image correlation techniques.

The following list summarizes the papers being published under the topic of "Mesoscale Materials Science: Experiments and Modeling." To read or download any of the papers, follow the URL http://link.springer.com/journal/11837/71/10/page/1 to the

Saurabh Puri and Amit Pandey are the guest editors for the invited topic Mesoscale Materials Science: Experiments and Modeling in this issue.

table of contents page for the October 2019 issue (vol. 71, no. 10). We hope that readers will enjoy reading this collection of research articles.

- "Automated Grain Yield Behavior Classification" by Darren Christopher Pagan, Jakob Kaminsky, Wesley A. Tayon, Kelly E. Nygren, Armand J. Beaudoin, and Austin R. Benson.
- "Visualization of Kirkendall Voids at Cu-Au Interfaces from in situ TEM Heating Studies" by Paul Kotula and Somuri Prasad.
- "Examination of Local Microscale-Microsecond Temperature Rise In Hmx-Htpb Energetic Material Under Impact Loading" by Ayotomi Olokun, Bing Li, Chandra Prakash, Zhiwei Men, Dana D. Dlott, and Vikas Tomar.
- "Characterization of Plastic Deformation in Lath Martensitic Steel by Micro-Pillar Compression Focused on Sub-Block and Lath Boundaries" by Ye-eun Na, Woojin Jeong, Myoung-Gyu Lee, and Dongchan Jang.
- "Validity of Crystal Plasticity Models Near Grain Boundaries: A Contribution of Elastic Strain Measurements at the Micron Scale" by Emeric Plancher, Pouya Tajdary, Thierry Auger, Olivier Castelnau, Véronique Favier, Dominique Loisnard, Jean-Baptiste Marijon, Claire Maurice, Vincent Michel, Odile Robach, and Julien Stodolna.
- "Influence of Temperature and Strain Rate on Microstructural Evolution during Hot Compression of Ti-45Al-*x*Nb-0.2C-0.2B Titanium Aluminide Alloys" by Nitish Bibhanshu, Amit Bhattacharjee, and Satyam Suwa.
- "Creep of Metallic Materials in Bending" by Syed Idrees Afzal Jalali, Praveen Kumar, and Vikram Jayaram.

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2. A. Pandey, A. Shyam, Z. Liu, and R. Goettler, *J. Power Sources* 273, 522–529 (2015).