THE MATERIALS SCIENCE AND ENGINEERING DEPARTMENT
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Electron microscopy nanocharacterization of chemical segregation in multiphase ceramics via sintering and phase formation in nanocomposite functional oxides via exsolution

Atomic- and nano-scale characterization methods are vital for understanding the migration and accumulation of point defects during materials synthesis, processing, and degradation. Techniques such as (scanning) transmission electron microscopy imaging and spectroscopy have thus been essential in developing engineering ceramics and functional oxides. During processing and service, these materials often experience high temperatures and other substantial driving forces for point defect formation and migration. For example, a classic focus area for the fields of ceramics and solid state ionics has been understanding elemental segregation at grain boundaries in bulk ceramics and thin films during thermal treatments. Like many engineering materials, grain boundaries play a critical role in governing performance related to thermal conductivity, fracture strength, high temperature creep, corrosion, electrical, chemical, and magnetic properties. Knowledge of defect accumulation phenomena thus provides the basis for designing novel processes and advanced materials via grain boundary engineering. In another example, the processing approach of exsolution relies on carefully controlling phase decomposition through the formation and accumulation of point defects to produce nanoscale metal-oxide or oxide-oxide composites. By thermochemically processing certain reducible oxides, exsolution provides an in-situ method for synthesizing tunable nanostructures anchored in the surface or bulk of an oxide support. This flexible approach can, for instance, produce catalytically active particles which are more durable than impregnated nanostructures, and which can be strained by the matrix oxide to offer enhanced activity. Recently, efforts have focused on engineering the bulk properties of functional oxides using bulk (i.e., subsurface) exsolution design strategies, which, for instance have effectively tailored the electronic transport and magnetic properties of a lanthanum ferrite perovskite via exsolution of Fe-based nanostructures.This talk presents our recent work on analyzing point defect accumulation in multiphase oxide ceramics and thin films primarily using high spatial resolution (scanning) transmission electron microscopy. This includes investigating the role of grain boundary and heterointerface chemical segregation, and interfacial energy, on the microstructural evolution of multiphase oxide ceramics, where there is limited understanding of how various sintering techniques affect grain boundary chemistry and microstructure development. This also includes analyzing the variety of metal and metal-oxide nanostructures, and the formation of unexpected nanophases produced during thermochemical processing of Fe-exsolving perovskite oxides.

William J. Bowman joined the Department of Materials Science and Engineering at University of California, Irvine in 2019. He received a B.S.E. in Materials Science and Engineering from Arizona State University in 2012 and a Ph.D. in same department in 2016. During graduate school, he was a visiting Ph.D. student at ETH Zürich in the Department of Materials. After graduate school, he was a Postdoctoral Associate at MIT in the Department of Nuclear Science and Engineering. Bowman's research focuses on understanding and developing oxide ceramics and nanomaterials for electrochemical energy conversion and storage, as well as carbon dioxide capture. The Bowman Lab performs materials synthesis, testing, and multiscale characterization primarily using advanced electron microscopy. His research has been financially supported by The National Science Foundation, The Research Corporation for Science Advancement, The American Chemical Society, The Microscopy Society of American, and the UC Irvine School of Engineering. He has received the NSF CAREER award, the NSF Graduate Research Fellowship, the Swiss Government Excellence Scholarship, the NSF Graduate Research Opportunities Worldwide Award, the Microscopy Society of America Presidential Scholar Award, and the Arizona State University Doctoral Enrichment Fellowship. He is a member of the Microscopy Society of America, the Microanalysis Society of America, the Materials Research Society, TMS, and the National Society of Black Engineers.

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