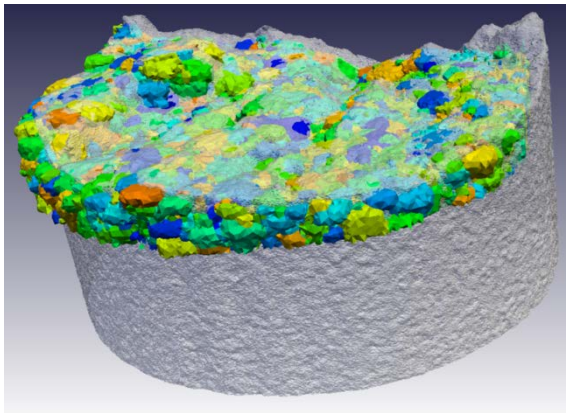
Revealing 3D Microstructures at the Advanced Photon Source

Jonathan Almer[1)], Peter Kenesei [1)], Jun-Sang-Park[1)], Hemant Sharma[1)], Meimei Li[2)], Robert Suter[3)], Stuart Stock[4)]
[1)] X-ray Science Division, Argonne National Lab, IL, USA
[2)] Nuclear Science Division, Argonne National Lab, IL, USA
[3)] Physics Department, Carnegie Mellon University, Pittsburg, PA, USA
[4)] Fienberg School of Medicine, Northwestern University, Chicago, IL USA

Abstract: A deeper understanding of how microstructure affects material properties requires information on evolving 3D structures. At present, however, the majority of such information is based on static pictures and 2D data. The reliability of structural components as diverse as batteries, nuclear components and human bones are often limited by fatigue, fracture, and creep failure, in ways that are complex, and beyond simple textbook models. Combining in-situ x-ray imaging methods with simulations of microstructures and their dynamics promises to elevate our understanding of microstructure-property relationships in such systems.

High-energy x-rays from 3rd generation synchrotron sources, including the APS, possess a unique combination of high penetration power with high spatial, reciprocal space, and temporal resolution. These characteristics can be used to image microstructure with both traditional radiography and scattering modalities under a variety of environments. Over the past decade, the X-ray Science Division at the APS has developed specialized programs for these purposes, namely (i) absorption-based tomography, (ii) high-energy diffraction microscopy (HEDM), in which grain and sub-grain volumes are mapped in polycrystalline aggregates, and (iii) combined small-and wide-angle x-ray scattering (SAXS/WAXS) which permits information over a broad range of length scales to be collected from the same volume. Furthermore, SAXS/WAXS can be conducted using 'scattering tomography' collection methods, to yield spatially-resolved, but grain-averaged information, which is particularly useful for studying fine-grained materials below HEDM limits.

Applications of these techniques to study several materials are presented. These include *in situ* studies- under thermal, mechanical and/or thermo-mechanical deformation - of high-temperature coatings [1,2], biological systems [3] and nuclear-relevant materials [4]. Specialized equipment to conduct these in-situ studies will be presented. Finally, the current and near-future landscape at the APS to access and perform these measurements will be discussed.



Fracture surface of a Ni-based superalloy as imaged by high-energy x-rays in absorption tomography mode (grey) and grain-mapping diffraction mode (colors). Image courtesy of R. Suter, CMU.