Studies of complex materials using high-energy x-rays

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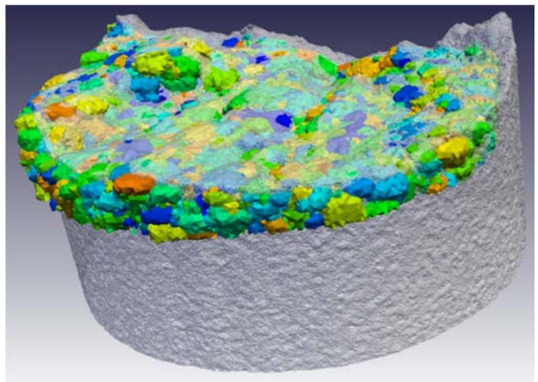

A deeper understanding of how microstructure affects material properties requires information on evolving 3D structures. At present, however, the majority of such information is based on static pictures and 2D data. The reliability of structural components such as batteries, nuclear components and turbine blades 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 1-ID beamline has developed specialized programs for these purposes, namely (i) high-energy diffraction microscopy (HEDM), in which grain and sub-grain volumes are mapped in polycrystalline aggregates, and (ii) 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.

Applications of these techniques to study complex microstructures are presented. These will include studies of biomaterials, void and structural evolution in nuclear-relevant materials under thermo-mechanical deformation, and in-operando studies of microstructural evolution in batteries. Efforts to utilize such unique x-ray data to test and extend predictive simulations of materials are detailed. Finally, opportunities to extend these capabilities through a proposed upgrade of the APS are discussed.

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