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# Changing the Paradigm for Engineering Design by Merging High Energy X-ray Data with Materials Modeling

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The nature of the application of structural materials demands that their performance be reliable. It's well known that the behavior of such materials is a product of the microstructure, and that failure initiation sites can often be linked to local microstructural features. Yet modern design and sustainment methodologies for structural materials remain reliant upon continuum-level models and large-scale conventional mechanical testing efforts. This is extremely costly, both in the sense that conventional mechanical test databases are expensive to produce, and also that continuum-level design inherently requires unnecessary conservatism in component lifing schemes as local microstructural effects are ignored. Moving forward, the development and validation of a microstructure-sensitive modeling framework that can accurately predict materials behavior (including variability and uncertainty) would allow the maximization of component capability and life, while reducing cost/time to certify and improve safety. Such a model would also open new possibilities for design of components with graded microstructures, where the microstructure at a specific point in a component is tailored to provide optimized properties for that location.

Toward this goal, we have endeavored to combine in-situ mechanical testing with advanced characterization methods, including microstructural characterization of the 3D test volume, in order to provide data which can be input and compared to deformation simulations which explicitly represent the 3D microstructure [1,2]. Such information is critical for the validation and further development of microstructure-sensitive modeling tools. In the present work, we describe in-situ tensile tests on polycrystalline metals during integration of three high energy synchrotron x-ray techniques. These techniques include near field orientation microscopy to map the 3D microstructure [3], absorption micro computed tomography to map the presence of voids and/or cracks [4], and far field lattice strain measurements to monitor the internal stress state of individual grains [5]. These experiments have been conducted at Sector 1 of the Advanced Photon Source at Argonne National Lab. An image of the experimental setup is shown in Figure 1.

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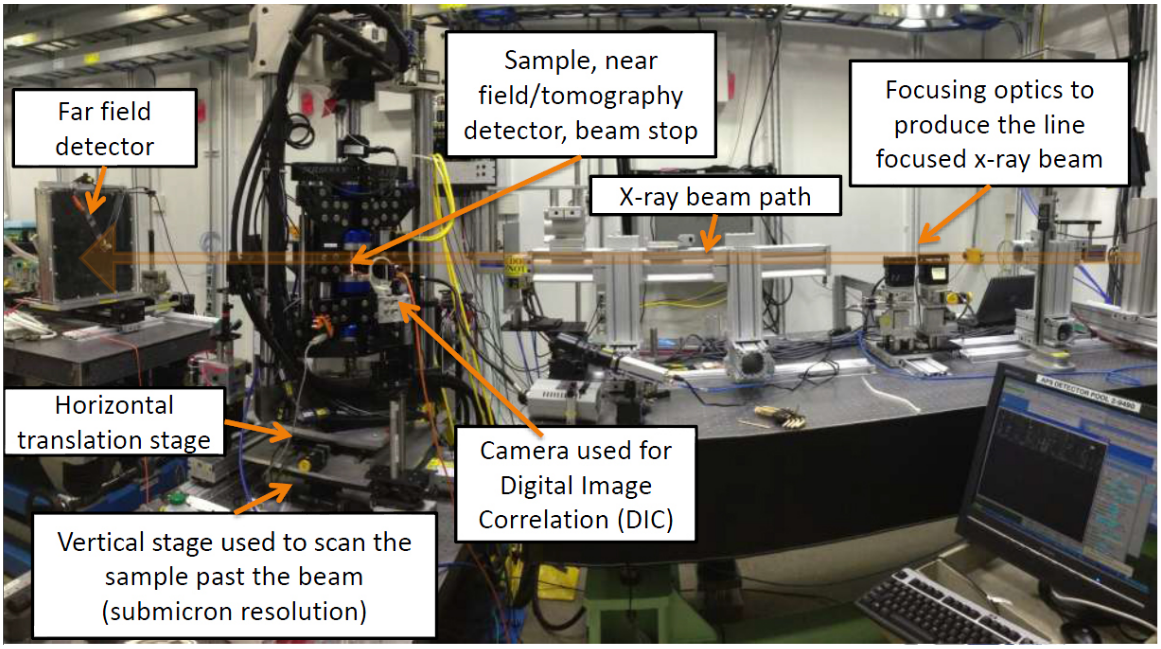


**Figure 1.** Image of the setup at APS-1-ID-E for high energy synchrotron x-ray experiments which integrate in-situ tensile testing, near field orientation microscopy, absorption micro computed tomography, and far field lattice strain measurements. Such experiments provide critical data for the validation and further development of microstructure-sensitive modeling tools.