X-ray Synchrotron Diffraction Tomography for Materials for Nuclear Energy Systems

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This proposal will provide a new user facility for X-ray Diffraction-Computed Tomography (XRD-CT) on materials for nuclear energy systems. Purchasing XRD-CT equipment for the X-ray Powder Diffraction (XPD) beamline at the National Synchrotron Light Source-II (NSLS-II) will develop a unique, crosscutting tool that can address a gap in materials research. It will provide greater access to tomographic imaging coupled with crystallographic structural information to the entire nuclear community.

The XRD-CT equipment proposed here provides morphological and structural information for engineering scale samples. It will facilitate a science-based approach to materials research by providing a novel characterization capability that can be applied to designing new materials for advanced reactors, understanding materials degradation mechanisms, supplying data for materials qualification for licensing and evaluating manufacturing processes. It can be used to characterize a wide variety of materials (metals, ceramics, composites, concretes and nanocrystalline materials) with limited, to no, sample preparation. The XPD beamline at NSLS-II will host the XRD-CT instrument and enable higher limits for radioactivity than other beamlines due to a previous U.S. Department of Energy-Nuclear Energy (DOENE) investment in the infrastructure at XPD. Therefore, in situ testing on previously irradiated materials or samples containing actinides will be available, allowing crucial data to be collected in areas of direct interest to DOE-NE such as irradiation assisted stress corrosion cracking (IASCC) or eutectic formation during accident conditions. Researchers at national laboratories, universities and from industry will access the new facility.

XRD-CT creates a 3D reconstruction of sample morphology directly from diffraction patterns. Unlike traditional X-ray computed tomography that is based on X-ray absorption, it simultaneously supplies crystallographic structural information with spatial resolution set by the beam size (10×10 μm). The structural information available includes; phase identification, phase fraction, grain size and lattice strain. Elemental mapping will be provided with a fluorescence detector. It is an ideal mesoscale probe; bridging the gap between bulk characterization techniques such as diffraction and local methods such as electron microscopy. Specifically this proposal will support the purchase of focusing optics, a translation/rotation stage, a fluorescence detector, and data reduction and analysis software. It can provide both morphological and spatially resolved structural information. Therefore, it is ideal for engineering scale samples, such as those used for crack growth rate measurements. This makes it exceptionally useful for the verification of mesoscale models that frequently try to capture highly complex and competing phenomena and is of particular importance to code qualification. Two representative experiments that demonstrate the capabilities of the technique and also how it can be integral to the DOE mission through NEAMS model verification are characterization of crack propagation in delayed hydride cracking (DHC) and the influence of engineered microstructure on SiCSiC composite properties.

The project is collaboration between Idaho National Laboratory (INL) and Brookhaven National Laboratory (BNL). This equipment will be made widely available for nuclear energy research through an established user proposal, peer-review process at the NSLS-II. The synchrotron techniques available at BNL are complimentary to the new microscopy capabilities that will be provided by the Irradiated Materials Characterization Laboratory at INL (Users can access both through a partnership between NSLS-II and Advanced Test Reactor - National Scientific User Facility) and the combined resources will enable new insights into materials science on irradiated materials.