DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

Developing Microstructure-Property Correlation in Reactor Materials Using *in situ* High-Energy X-rays

PI: Meimei Li- Argonne National Laboratory

Collaborators: Jonathan D. Almer- Argonne National Laboratory), Yong Yang- University of Florida, Lizhen Tan- Oak Ridge National Laboratory

Program: NEET: Reactor Materials

ABSTRACT:

The objective of this project is to demonstrate the applications of high energy X-ray measurements with *in situ* thermal-mechanical loading in understanding the microstructure-property relationship. The gained knowledge is expected to enable accurate predictions of mechanical performance of nuclear reactor materials subjected to extreme environments, and to further facilitate design and development of new materials.

The use of synchrotron X-ray radiation techniques represents one of the most important opportunities that need to be fully exploited for nuclear materials research and development. Third-generation synchrotron sources produce high-brilliance hard X-rays, which enable *in situ* measurements with high spatial and temporal resolution. The recently-developed *in situ* high-energy X-ray capability for irradiated materials allows simultaneous characterization of microstructure and mechanical properties of an irradiated specimen using a combination of wide-angle X-ray scattering, small-angle X-ray scattering, three-dimensional X-ray tomography, and imaging while the specimen is subjected to uniaxial tension, creep, and fatigue loading in a vacuum furnace in a MTS servo-hydraulic test frame. These techniques interrogate microstructure at different length scales concurrently in real time, and allow direct connections with macroscopic mechanical responses.

The proposed research will focus on the evolution of irradiation defects, phase transformation and their interactions with materials' deformation and fracture behaviors. *In situ* X-ray measurements on several representative ferritic/martensitic steels, austenitic alloys, and duplex stainless steels will be conducted under tensile and creep conditions at temperatures of 20-550°C. *In situ* X-ray studies will be complemented and benchmarked by *ex situ* characterization using advanced electron microscopy, atom probe tomography and micro/nano-indentation, and computational modeling. The integration of *in situ* X-ray measurements, ex *situ* characterization and modeling will provide a comprehensive mapping on the radiation defects and precipitates and their effects on deformation and failure mechanisms, and form a major new basis for materials model development and design of new materials for improved irradiation performance.