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## Understanding neutron irradiation-assisted stress corrosion cracking mechanisms of 316L stainless steel made by laser additive manufacturing

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### ABSTRACT:

This project will study the irradiation-assisted stress corrosion cracking (IASCC) and radiation damage mechanisms of neutron-irradiated 316L stainless steel (SS) made by laser powder bed fusion (LPBF) and direct energy deposition (DED) additive manufacturing (AM). The first ASME code case of AM 316L SS will soon receive endorsement for light water reactor (LWR) environments (ASME Section III Division I). The industry and regulatory bodies require the neutron data related to corrosion and radiation effects to assess the benefits and limitations of AM for structural applications, including pressure-boundary and reactor internal uses.

IASCC is one of the most critical and complex material degradation issues in most water-based reactors - both large LWRs and small modular reactors (SMRs). It reflects the synergetic interaction between mechanical loading, corrosion and radiation damage at high temperature. Extensive work has been done to assess the IASCC susceptibility and mechanisms of both LPBF and DED AM 316L SS in LWR environments. Those studies were performed using proton irradiation, where the depth of irradiation damage is limited (a few microns). This proposed research is framed based on the mechanistic understanding from prior work, targeting radiation damage and IASCC mechanisms of neutron-irradiated AM 316L SS through advanced characterization and multiscale modeling. We will leverage the unique NSUF capabilities, such as synchrotron X-ray micro-computed tomography ( $\mu$ CT) and grain-resolving high-energy x-ray diffraction microscopy (HEDM), advanced electron microscopy characterization, and crystal plasticity modeling, to validate the mechanistic hypothesis. This project will use neutron-irradiated samples (larger depth of irradiation damage, mm scale) that were recently included in NSUF's Nuclear Fuels and Materials Library (NFML). The general approach is illustrated in Fig. 1. First, interrupted IASCC test coupled with  $\mu$ CT and HEDM at ANL to develop the grain- and subgrain-level understandings of grain deformation, stress localization, and crack initiation and growth in 3D space, and produces a first-of-its-kind analysis of crack development with respect to AM microstructure, grain orientation/texture, grain boundary (GB) characteristics, grain size distribution in AM SS. Second, advanced electron microscopy characterization at PNNL to understand the effect of AM microstructure (LPBF vs. DED) on radiation damage mechanisms and GB oxidation. This study will also focus on characterizing local deformation near crack tip. Third, data from 3D synchrotron X-ray study and electron microscopy characterization will be fed into the crystal plasticity finite element model (FEM) for model validation/optimization, and provide micro-mechanical insights towards IASCC initiation and propagation inside a 3D grain network.