High-Throughput Serial Sectioning of Nuclear Fuels, Materials & Sensors

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ABSTRACT:

This project will expand Nuclear Science User Facilities (NSUF) capabilities at Purdue to include automated, high-throughput three-dimensional (3D) serial sectioning tomography (SST) for defect and structure characterization of nuclear fuels, materials, sensors, radiation detectors, and waste forms. Quality assurance (QA) of these manufactured materials remains paramount to ensuring their performance, safety, and long-term integrity. A suite of 3D tomographic methods such as focused ion beam (FIB) tomography and atom probe tomography, provide exceptional spatial resolution for QA, but are limited to small material volumes. X-ray computed tomography (XCT) can analyze larger volumes, but loses spatial resolution and become volume-limited for high-Z nuclear materials. Mechanical SST (i.e., layer-by-layer polishing and characterization) fills a key volume-resolution gap between FIB and XCT, but has historically been tedious, time-consuming, costly, and not agile enough to keep up with modern manufacturing speeds. However, many mechanical SST steps can be accelerated through automation. Hence, there is a critical need to automate mechanical SST to become a high-throughput, agile technique enabling QA to keep pace with process automation and machine learning innovations being implemented throughout the nuclear energy research enterprise.

We will purchase an off-the-shelf Robo-Met.3D system from UES, Inc., for automated mechanical SST with interchangeable platens for both radioactive and non-radioactive materials without cross-contamination. The Robo-Met will be available to NSUF users to fill national infrastructure gaps as the only automated mechanical SST equipment within the Nuclear Energy Infrastructure Database (NEID). We have secured six industry, lab, and academic partnerships, including with a university designated as a minority-serving institution (MSI), underscoring the value of the Robo-Met across all nuclear stakeholders. The instrument is aligned with university priorities on advanced manufacturing education and research and will become part of the Purdue Manufacturing Research Institute (PMRI).

The scientific impact will be a deeper understanding of processing-structure relationships – obtained with unprecedented acceleration – toward the practical impact of qualifying new materials. Educationally, the proposed equipment will propel an innovative project-based course on data science for nuclear materials, providing students with direct experience using automation and artificial intelligence to synthesize large volumes of 3D data. This project is strategically relevant because the Robo-Met offers a tremendous advancement in the NSUF's capabilities in characterization, QA, and qualification of manufactured materials, closely aligned with the October 2022 National Strategy on Advanced Manufacturing.