U.S. Department of Energy

Additive manufacturing of thermal sensors for in-pile thermal conductivity measurement

PI: Yanliang Zhang,

Boise State University

Co-PI: David H. Hurley,

Idaho National Laboratory

Program: NSUF 1.2A

ABSTRACT:

Objectives: The goal of this project is to develop and demonstrate an additive manufacturing approach to fabricate nonintrusive and spatially resolved sensors for in-pile thermal conductivity measurement through direct sensor printing onto fuel components. Additive manufacturing is a key enabling technology to realize a seamless transition from functional materials to sensor devices of significantly enhanced functionality, complexity, flexibility, and accuracy compared with state-of-the-art sensors. The proposed project will achieve four important research objectives: (1) Print sensors onto conforming surfaces; (2) Evaluate sensor performance with characterization, testing, & modeling; (3) Evaluate sensor in-pile performance and irradiation effect; (4) Validate the performances of printed sensors.

Project description: In order to overcome the challenges of in-pile measurement and instrumentation, we propose an innovative method to directly print sensors onto the components of interests using an aerosol jet printer. We propose to print thermal conductivity sensors onto substrates representative of fuel components, and study in-pile performances of the printed sensors through irradiation and post-irradiation test. Thermal conductivity is one of the most important fuel properties driving heat transfer performance as well as temperature distributions of the fuel assembly. Thermal conductivity is determined by materials' physical structure, chemical composition, and thermodynamic state, which can be strongly affected by a variety of physical processes in nuclear fuels, such as species diffusion, neutron capture, and microstructure evolution. The printed sensors can generate in-situ and in-depth thermal conductivity profiles using frequency-modulated thermal wave probing. The 3D conformal printing of sensors directly on curved components (e.g. a fuel rod) provides intimate contact and tight integration with specimens of interest, enabling high measurement accuracy with minimum intrusion. We will irradiate the printed sensor performances under various irradiation conditions and temperatures and perform comprehensive post irradiation test in order to examine the irradiation effect on printed materials microstructures and sensor performances.

Outcomes and impacts: The project will advance scientific knowledge of the in-pile performance for advanced sensors fabricated by additive manufacturing. Furthermore, the insight gained will significantly accelerate the deployment of additive manufacturing to fabricate a broad range of sensors and instrumentation for both in-pile and out-of-pile measurements. The research outcome will have a broad impact on a number of DOE-NE initiatives including Fuel Cycle Research and Development, the Transient Reactor Test Facility, and Advanced Modeling and Simulation. This research has the potential to establish a new sensor manufacturing paradigm for the nuclear industry, and advance sensor research and development activities in various areas of importance to DOE including research associated with the Advanced Test Reactor programs, the Transient Reactor Test Facility Restart, Light Water Reactor programs, and spent nuclear fuel storage.