Measurement of Time-Dependent Transmissivity of Materials for Optical Sensors and Instrumentation

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ABSTRACT:

Enhanced monitoring of reactor operational parameters and reactor components, including fuel, structural materials, coolants, and other critical systems will be necessary to maintain safety and reduce the operation and maintenance costs of future nuclear reactors. A desired capability for sensor and instrumentation in new reactors is continuous, in-line measurement of circulated coolant or coolant-fuel composition to prevent reactor system degradation through corrosion. Novel optical sensors are under rapid development and show promising performance for reactor instrumentation, but the changes in their constituent optical materials when exposed to ionizing radiation need to be better understood. While it is well known that materials such as glass and sapphire lose their transparency and undergo compaction and associated refractive change when exposed to high doses of ionizing radiation, several prior studies suggest that the nature of this phenomenon can be highly transient, i.e., the material optical transmission can change significantly after the end of irradiation due to thermal annealing of radiation damage. In recent measurements, the minimum delays between irradiation and post-irradiation characterization were on the order of an hour. Indeed, most measurements reported in the literature have been performed with a significant delay after irradiation – from weeks to months. The results obtained in that way are therefore not representative of *in-operando* sensor performance.

This project will investigate the effect of radiation damage in optical materials on the operation and performance of laser spectroscopic sensors. Significantly beyond the scope of prior studies, we will (1) carry out optical transmission measurements in bulk samples during material irradiation with gamma rays and neutrons and concurrent heating, and (2) extend the in-situ characterization to shorter wavelengths, approaching the ultraviolet region of the spectrum, which is important for characterization of molten salt spectra [8]. We will use two methods: differential absorption and optical frequency-domain reflectometry. To extend the characterization to shorter wavelengths, we will use deep-UV-enhanced solarization-resistant fibers to deliver and collect light from the irradiation setup. Windows and fibers comprised of typical optical materials will be exposed to fast and thermal neutrons as well as gamma rays at the Ohio State University Nuclear Reactor Laboratory and simultaneously measured.

The primary benefit of this NSUF project is that it will yield a more complete understanding of the performance of future optical sensors and instrumentation in the harsh conditions present in nuclear reactors, including the novel molten salt and liquid metal-cooled reactor designs, where optical instrumentation is placed in the vicinity of high radiation fields and high temperature. To that end, the project will provide information on the effect of neutron/gamma and gamma irradiation on spectrally dependent transmissivity in real time, overcoming the key limitation of prior measurements. The project will further yield important dynamic information that can be used to understand the effect of annealing and the possible dynamic effect that arises from annealing when it is applied during irradiation. As a result, we will have collected data that will be suitable for benchmarking of improved radiation damage and annealing models, while at the same time directly yielding qualitative information on strategies for material placement which will ensure optimal performance and long lifetimes.