NEUP Nuclear Energy University Programs

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High-Temperature Atmosphere-Controlled Raman Microscope for Fuel Cycle Materials Research

PI: Luiz G. Jacobsohn, Clemson University **Collaborators**: N/A

Program: General Scientific Infrastructure

ABSTRACT: Objectives: We aim to acquire a unique experimental capability for research and education in support of DOE-NE's mission to conduct crosscutting nuclear energy research and development. This proposal requests a Raman microscope with high-temperature atmosphere-controlled capability for the characterization of ceramic materials relevant to diverse aspects of the nuclear fuel cycle. Raman spectroscopy is a mature technique for materials characterization that yields significant structural and chemical information, including the identification of phases, local atomic arrangement, and residual strain. The Raman microscope furthers this capability by enabling spatially resolved (mapping) analysis with micrometric spatial resolution. The high-temperature atmosphere-controlled capability associated with contacts for electrical measurements is a unique combination of features, rarely associated with a Raman microscope. This instrument will allow for in-situ dynamical structural evaluation of materials combined with the evaluation of in-operando electrical behavior as a function of temperature (up to 1500 oC) in a precisely controlled ambient (air, vacuum, or selected flowing gas). Description: Five research thrusts are proposed centered on the unique capabilities of the Raman microscope covering a broad variety of topics supporting the Fuel Cycle Research and Development program, particularly nuclear fuel cladding, nuclear waste immobilization, and radiation damage. Thrust 1 - Crystalline and Glass Composite Materials for the Immobilization of Combined High Level Waste (HLW): Immobilization of the HLW fraction may be achieved by chemical incorporation into a suitable matrix which retains the radionuclide and limits their mobility. Investigation of the appearance of detrimental secondary phases by Raman microscopy will help to develop highly durable glass and ceramic matrices for nuclear waste immobilization. Thrust 2 - Characterization of Precursor Derived Nanostructure Si-C-X Materials for Extreme Environment: Si-C-X materials with X being minor amounts of C or N have potential for several important nuclear energy applications. Since the excess carbon modifies the polytype of SiC and thus is properties, Raman spectroscopy will allow the investigation of the effect of temperature on both the state of carbon and SiC polytypes. Thrust 3 - Proton and Deuteron Separation through Perovskite Oxide Membranes for Waste Management: proton conducting ceramic membranes are expected to allow for the separation of hydrogen isotopes (proton, deuteron, and tritium) for efficient nuclear waste management. Thrust 4 - Characterization of Radiation Damage of Ceramics by Raman Spectroscopy: Reliable immobilization of nuclear waste requires materials that withstand radiation damage for extremely long times. Raman microscopy will allow radiation damage studies, including insitu investigation of the evolution of radiation damage as a function of temperature and ambient conditions. Thrust 5 - Characterization of Radionuclide Speciation Within Engineered Barriers: Raman microscopy will be used to monitor interactions between radionuclides and engineered barrier phases at elevated temperatures with control the over oxidation states of the radionuclides and the matrix. Potential Impact: South Carolina is at the epicenter of the current nuclear renaissance in the U.S., with about 50% of the electrical power coming from seven nuclear power plants operating in the State and additional six plants close to its borders. The State is also home to the Savannah River National Laboratory, a commercial low-level radioactive

waste disposal facility, and a commercial nuclear fuel fabrication facility. This project will fill the major institutional infrastructure gap of a Raman system dedicated to high-temperature ceramic materials not available at Clemson University and, in fact, in the whole State of South Carolina. It will enhance the capability to perform research and development, and to promote advanced teaching and training in nuclear science and engineering. Five faculty and their undergraduate and graduate students from two departments of Clemson University will be directly and positively affected by the acquisition of this instrument. Other faculty members from Clemson University as well as from the University of South Carolina and researchers from Savannah River National Laboratory have already expressed interest in using this instrument in their research.