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CFA-17-12633: Integrated silicon/chalcogenide glass hybrid plasmonic sensor for monitoring of temperature in nuclear facilities

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ABSTRACT

The proposed research aims to advance sensor based on phase change in chalcogenide glasses which forms plasmon modes at specific measured temperature. Doing so offers opportunity for nuclear safety in facilities, their employees, and the public by offering increased sensor system accuracy, reliability and efficiency. This interdisciplinary, inter-institutional research also potentially offers a broader range of desirable features than competing technologies addressing nuclear materials quantification and tracking such as low power consumption and optical signal harvesting. The project supports needs in the Fuel Cycle Research and Development program, specifically those in Embedded/Integrated Sensors in Components and Functional Materials. Limitations in *current* temperature monitoring strategies include thermocouples that oxidize fast and break by usage at high temperatures, have low flexibility and are difficult to embed in nuclear structures; or melt wires, which do not give data in real time. The proposed research ultimately aims to enable manufacturers to deliver a novel hybrid plasmonic sensor that is easier and less costly to manufacture, and which will continue to function properly after radiation exposure. Reusability is a significant feature that will further reduce cost; after reaching critical temperatures, the nuclear facility could quickly and easily reset and reuse the sensor for a subsequent measurement.

Background: This research builds upon preliminary data related to phase change effects that occur when chalcogenide glasses are heated to their crystallization temperature. The amorphous/crystalline phase change is accompanied with dramatic change of the band gap of the material which drastically changes the optical properties of the material. As a result transmitted photons transition from a quasi-transverse-electronic (TE) mode to tightly confined plasmon mode. Based on this phenomenon, we envision two types of sensor architectures for sensing temperature – 1) an integrated chip based sensor, and 2) a fiber bundle array. The best performing sensor will be selected based on characterization results.

Objectives: This proposal is focused on the research and development of a new concept for a *real time*, reusable, reversible integrated temperature sensor that employs combination of the photonic properties of silicon and the phase transition properties of chalcogenide glasses. This sensor will be suitable for the monitoring of components with temperatures in the range of 500°C, typical for Light Water Reactors (LWR), although adjustment of the material composition can result in applicability for Sodium-cooled Fast Reactors (SFR) and temperatures about 650°C. This provides a measurement method for multiple components in the reactor design domain. The sensor can be further employed as a paradigm for a number of hybrid electron/photonic tandem solutions for other characterization methods in nuclear facilities since the chalcogenide glasses are radiation hard materials. In addition, knowledge concerning performance of silicon waveguides in a reactor environment may result in extending their application to much more important characterization methods such as light transmission for *in situ* (in pile) Raman spectroscopy. In addition, this project will develop a photonic system for data collection which can be used in numerous cases when sharp band gap transition occurs, caused not only by temperature but also by pressure and other extrinsic effects.