Self-powered Wireless Dual-mode Langasite Sensor for Pressure/Temperature Monitoring of Nuclear Reactors

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ABSTRACT:

The accidents at the Three Mile Island and Fukushima Daiichi nuclear power plants demonstrate a crucial importance but unprecedented challenge for monitoring technologies. When severe accidents happen, the resulting temperature, pressure and radiation can be extremely high. A typical nuclear reactor has 50-200 temperature sensors and 500-2000 pressure sensors to monitor various critical parameters for safe and reliable operation. Unfortunately, the conventional sensors -- including the RTD temperature sensor, capacitance pressure cells and the emerging fiber-optic sensor -- can be melt or be radiation darkened in harsh environments. With a massive loss of power across the plant resulting from an accident, the backup batteries for the monitoring sensors will ultimately be drained and these sensors will stop working.

The objective of this proposal is to develop a novel self-powered wireless hybrid sensor that can accurately monitor both pressure and temperature using a single device without requiring external electricity, even in the extreme harsh environments of severe nuclear accidents, such as up to 1400^0C temperature, 10,000 psi pressure, and excessive radiation. This objective is achieved through three innovations: the first innovation is to design a dual-mode langasite ($La_3Ga_5SiO_{14}$, a new piezoelectric crystal) resonant sensor to detect extreme high temperature and high pressure simultaneously; the second is to create a multi-source energy harvester to harness intrinsic heat of the reactor and the kinetic energy of the reactor components (such as pump vibration or seismic motion) to provide the electric power needed for the sensors; and the third innovation is to design a self-protected sensor package upon integration of radiation shielding and mechanical support for mitigating severe environmental impacts.

The novel concept of self-powered wireless langasite-based P/T sensor that will operate under high temperature, high pressure, and excessive radiation provides a pathway to significantly improve monitoring technology for current nuclear reactors, and unquestionably support the program of Nuclear Reactor Technologies: *Monitoring Technologies for Severe Accident Conditions* (RC-6). Upon success, the technology can also be used during normal operating conditions to provide enhanced monitoring of critical components in a standoff and energy-efficient manner.

This project will be completed through the collaboration of the State University of New York at Stony Brook (SBU), University of North Texas (UNT), and Rensselaer Polytechnic Institute (RPI), with the support from industry partner Westinghouse. Prof. Lei Zuo of SBU, who won multiple national awards on energy harvesting, will lead this project as PI and also lead the multisource energy harvesting and electronics development. The federal budget request for Prof. Zuo is $365,243. Prof. Haifeng Zhang of UNT, who has over 10 years of experience on piezoelectric resonators and sensors for harsh environment applications will be a co-PI, leading the research of langasite resonant sensor. The federal budget for Prof. Zhang is $284,757. Prof. Jie Lian of RPI's nuclear engineering program, who has established an outstanding record in studying radiation induced microstructural evolution of materials, will be a co-PI to lead radiation shielding and environmental hardening for the proposed sensor. The budget requested for Prof. Lian is $150,000. Total cost share $200,145 will be provided.