Nanostructured Bulk Thermoelectric Generator for Efficient Power Harvesting for Self-powered Sensor Networks

PI: Yanliang Zhang, Boise State University

Program: NEET-2.1 Power Harvesting Technologies for Sensor Networks

Co-PIs:

Darryl P. Butt, Boise State University;

Vivek Agarwal, Idaho National Laboratory;

Xiaowei Wang, GMZ Energy, Inc.

ABSTRACT:

The research goal is to develop efficient and reliable thermoelectric generators (**TEGs**) using high-efficiency nanostructured bulk materials that directly convert heat into electricity to power wireless sensor nodes (**WSNs**) for nuclear applications. The TEG-based power harvesting technology proposed has crosscutting significance to all DOE nuclear energy programs, as it will enable self-powered sensor technology in reactors and spent fuel storage facilities. Following tasks will be executed to achieve the research goal: (1) develop WSN power requirement and a sensor simulator, (2) select optimal thermoelectric (TE) materials for suitable TEG implementation location, (3) quantify and understand the irradiation effects on nanostructured TE materials and devices, (4) design and simulate TEGs, (5) fabricate and test a TEG prototype, and (6) integrate the TEG and WSN and develop a self-powered WSN prototype for proof-of-concept demonstration.

The proposed research is based on breakthroughs in nanostructured high-performance TE materials of up to 50% increase in thermoelectric figure of merit, and will leverage significant results obtained in an ongoing DOE funded project on automotive waste heat recovery using high-efficiency TEGs. Our team will study and employ TE materials based on Half-Heusler and Bismuth Telluride compositions that cover a broad working temperature from 30–600 ^{o}C with the combined merits of high efficiency and high thermal stability and mechanical strength. We will identify suitable hot surfaces for TEG implementation with desired temperature, and design and optimize the TEG performances using a multiphysics model based on computational fluid dynamics and finite element model. We will fabricate and test TEG prototypes using existing capabilities in our industrial partner. To address the issue of irradiation damage, which has not been studied in detail in these nanostructured TE materials, we will perform comprehensive characterizations on TE material and devices properties before, during and after gamma irradiation at various user facilities, and the outcomes will lead to fundamental understandings of irradiation effect on nanostructured TE materials. The project will ultimately demonstrate a WSN powered by the TEG under a simulated environment representative of nuclear power plant or spent fuel storage.

The thermoelectric power harvesting technology proposed here is expected to play a crucial role in establishing self-powered WSNs for nuclear industry. Self-powered WSNs will not only save the cost by removing the need for cable installation and maintenance, but also offer significant expansion in remote monitoring of nuclear facilities, and provide important data on plant equipment and component status during station blackouts or accident conditions. Such data will significantly improve the reliability and safety of both nuclear power plants and spent fuel storage facilities. The proposed research will also significantly expand the existing partnership between Boise State, national lab and industrial collaborators, and will provide opportunities to train graduate students in this emerging field. Attempts will be made to recruit underrepresented groups to the growing graduate programs at Boise State.