U.S. Department of Energy

Multipurpose, Radiation- and Temperature-Resistant Semiconductor Radiation Detectors for Advanced Process Monitoring and Nuclear Safeguards

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Program: Fuel Cycle

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ABSTRACT:

With the expansion of nuclear power and development of advanced nuclear fuel cycle processes, there is a growing need for high performance, solid-state nuclear detectors capable of operating for extended times at elevated-temperatures (300°C – 600°C) and high radiation fluxes. Silicon carbide (SiC) radiation detectors are excellent candidates for such environments, since the material is extremely radiation hard and chemically inert. 4H-SiC has a wide bandgap (3.27 eV at 300K) allowing low leakage currents for low-noise high-temperature operation, high thermal conductivity allowing enhanced heat dissipation, high thermal stability, and smaller anisotropy which is suitable for fabricating harsh-environment compatible nuclear radiation detectors where conventional semiconductors (e.g. Si, Ge, CdTe, CdZnTe) show inadequate performance.

A three-year project is proposed. Year one will be devoted to develop application-specific design, fabrication, and testing of SiC detectors. In Year two, pixilated detector structures with guard ring geometry and edge terminating passivation layer will be developed and tested rigorously. These tests will include long-term exposures at high temperature and under high radiation background. In year three, we will investigate front-end readout electronics that are capable of operating in harsh environments. Such devices will provide continuous monitoring of these environments without the need to use long signal cables to the detectors to distance the front-end electronics from the harsh environment.

The developed SiC detectors will be deployed in key locations in nuclear fuel reprocessing facilities for radiation monitoring applications. The detectors could be mounted on spent fuel assemblies at either commercial fuel storage locations or government fuel storage repositories. The detectors could be installed at any time following discharge and could potentially monitor both the neutron and gamma-ray activity from discharge, during transportation and long-term storage. Diversion of fuel assemblies or changes to the neutron and gamma-ray output due to tampering or physical changes to assemblies from physical or chemical degradation can be detected through unexpected changes in the observed neutron and gamma-ray activities. Crosscutting applications include nuclear material safeguards, nuclear waste management, national security, and verification for nuclear treaty enforcement. The program also offers an ideal platform for educational development.