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BiI_3 Gamma-Ray Spectrometers for Reliable Room Temperature Nuclear Materials Safeguarding

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ABSTRACT

Gamma-ray detectors based on cadmium telluride (CdTe) and cadmium zinc telluride (CZT) are used in nuclear materials protection, accounting, and control technologies (MPACT) applications, but the current technology can be improved through the development of new detectors with better energy resolution, efficiency, and environmental performance. We propose to develop a bismuth triiodide (BiI_3) gamma-ray spectrometer for nuclear materials safeguarding applications. BiI_3 has a much higher intrinsic photopeak efficiency than other detector materials, such as CdTe, CZT, or $LaBr_3$, and has a higher efficiency than an equivalent-sized germanium detector. The growth process of BiI_3 is simpler and more economical than CZT.

The goal of the proposed work is to develop gamma-ray spectrometers based on BiI3 single crystals for MPACT applications such as burnup validation quantification, improved assay of plutonium, determination of uranium enrichment and overall monitoring spent fuel within the fuel cycle. To achieve this goal, and be able to evaluate the potential and benefit of the proposed detector materials and spectrometers, we will apply defect engineering strategies to grow doped BiI_3 single crystals with enhanced electrical response. Large (> 1 cm^3) BiI_3 single crystals will be grown using a modified vertical Bridgman technique with a static ampoule and a computer-controlled dynamic heating profile.

Following this, we will design and manufacture BiI_3 detector prototypes with pixelated electrodes. The performance of these prototypes will be calibrated and tested in a laboratory setting, determining detector response and energy-dependent efficiency. Field measurements will be done at the University of Florida Test Nuclear Reactor and in near-to-service conditions on spent-fuel in collaboration PNNL. An evaluation will be made of the potential of these detectors under mixed environmental conditions via a field-test, proof-of-concept evaluation using burnup indicator measurements on spent fuel, and isotopic ratio measurements of uranium and plutonium standards.