Optimization and Characterization of a Novel Self Powered Solid State Neutron Detector

by

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ABSTRACT

There is a strong interest in detecting both the diversion of special nuclear material (SNM) from legitimate, peaceful purposes and the transport of illicit SNM across domestic and international borders and ports. A simple solid-state detector employs a planar solar-cell type p-n junction and a thin conversion layer that converts incident neutrons into detectable charged particles, such as protons, α-particles, and heavier ions. Although simple planar devices can act as highly portable, low cost detectors, they have historically been limited to relatively low detection efficiencies; ~10% and ~0.2% for thermal and fast detectors, respectively. To increase intrinsic detection efficiency, the incorporation of 3D microstructures into p-i-n silicon devices was proposed.

In this research, a combination of existing and new types of detector microstructures were investigated; Monte Carlo models, based on analytical calculations, were constructed and characterized using the GEANT4 simulation toolkit. The simulation output revealed that an array of etched hexagonal holes arranged in a honeycomb pattern and filled with either enriched (99% ^{10}B) boron or parylene resulted in the highest intrinsic detection efficiencies of 48% and 0.88% for thermal and fast neutrons, respectively. The optimal parameters corresponding to each model were utilized as the basis for the fabrication of several prototype detectors.

A calibrated ^{252}Cf spontaneous fission source was utilized to generate fast neutrons, while thermal neutrons were created by placing the ^{252}Cf in an HDPE housing designed and optimized using the MCNP simulation software. Upon construction, thermal neutron calibration was performed via activation analysis of gold foils and measurements from a ^{6}Li loaded glass scintillator. Experimental testing of the prototype detectors resulted in maximum intrinsic efficiencies of 4.5 and 0.12% for the thermal and fast devices, respectively. The prototype thermal device was filled with natural (19% ^{10}B) boron; scaling the response to 99% ^{10}B enriched boron resulted in an intrinsic efficiency of 22.5%, one of the highest results in the literature. A comparison of simulated and experimental detector responses demonstrated a high degree of correlation, validating the conceptual models.