Enriched Boron-Doped Amorphous Selenium-Based Position-Sensitive Solid-State Thermal Neutron Detector for MPACT Applications

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ABSTRACT

High-efficiency thermal neutron detectors with compact size, low power-rating, and high spatial, temporal and energy resolution are essential to execute non-proliferation and nuclear safeguard protocols. Furthermore, world-wide shortage of ^{3}He gas has further prompted to design an alternative system. Therefore, solid-state direct read-out neutron detectors without the requirement of ^{3}He will be highly desirable. To address the above technology gap, we propose to develop a new room temperature solidstate thermal neutron detector based on enriched boron doped amorphous Se semiconductor for MPACT applications. The proposed alloy material has been identified for its many favorable characteristics – a wide bandgap for room temperature operation, high glass transition temperature, a high thermal neutron cross-section (3840 barns, 1 barn = 10^{-24} cm^2), low effective atomic number of Se for small gamma ray sensitivity, and high radiation tolerance due to its amorphous structure.

The research will be divided into four 12-month phases. In Year 1, we will demonstrate the feasibility of this new thermal neutron detector with B-doped a-Se alloys films (>5 x 5 cm^2 and 300 µm thickness) on ITO/Al substrates. In Year 2, we will optimize alloy synthesis process and demonstrate thermal neutron detector performance on 10 x 10 cm^2 alloy film. In Year 3 we will fabricate alloy films up to 15 x 15 cm^2 area and ≥ 500 µm in thickness. To reduce leakage current, we will investigate the junction properties between B-doped a-Se material and a wide variety of metals with different work functions. Different detector structures, surface encapsulation and packaging will also be investigated in Year 3. In Year 4 we will select the optimized detector structure and interface electronics to fabricate large devices by tiling individual detectors in a seamless arrangement. We will fabricate a prototype *'direct read-out'* solid-state neutron detector with front-end electronics and perform extensive investigation to determine electronic and charge transport properties, detection efficiency, spatial resolution, gamma-ray discrimination, radiation damage, and long term stability of the fabricated devices.

These solid-state detectors will offer substantial performance advantages over existing neutron detectors and will find widespread use in nuclear power plant including safeguard of special nuclear materials, reactor instrumentation, process monitoring, and nuclear waste management.