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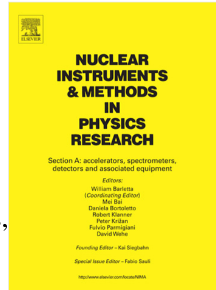

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Characterization of Lithium-Glass and Polyvinyl Toluene Heterogeneous Composites with Varying Geometries for Fast Neutron Detection

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Abstract

In heterogeneous composite neutron detectors, materials with dissimilar characteristics are optically coupled to achieve functionalities that extend beyond those enabled by intrinsic properties of constituent materials. However, the mismatched optical properties of the dissimilar materials introduce light scattering inside the detector, which could potentially affect its performance. Understanding the effects of the glass filler shape and content on light transport and light output is crucial for developing high performance composite detectors. Detectors with glass rods and shards were fabricated and characterized using UV/Vis, gamma, and neutron sources. The glass/PVT interfacial surface area significantly affects the light transmission; the highest reduction is measured with the shards which have higher surface area than the rods. The light output is impacted more significantly by the glass weight content than by the filler shape. The dimensions of the rods detector are 12.7cm x 12.7cm and those of the shards detector are 7cm x 3.8cm. The neutron intrinsic efficiencies of the fabricated detectors were also measured for ^{252}Cf spontaneous fission neutrons and found to be 4.80±0.05% and 0.097±0.036% for the larger rods detector and the prototype shards detector, respectively, *with good gamma rejection for both (measured to be better than 10^{-4}).*

Keywords: composite, neutron, detection, light output, pulse-shape discrimination

Introduction

Heterogeneous composite neutron detectors are an emerging alternative to conventional homogeneous detectors. These detectors couple materials with dissimilar characteristics to create a device with additional functionality. The combination of dissimilar materials allows for a higher degree of flexibility when tailoring the detector properties, such as the degree of sensitivity and specificity to thermal and fast neutrons, and gamma radiation. A seminal composite neutron detector was developed by Knoll et. al using ^{3}He filled glass spheres embedded in a polyvinyl toluene matrix [1]. Since then several other groups have focused on different types of fillers such as lithium gadolinium borate (LGB) glass, cerium activated lithium glass (GS20), nanoparticles, silicon pillars, lithium fluoride crystals, and, more recently, Cs_2LiYCl_6 crystals (CLYC) [2]–[11]. While recent advances proved the viability of these detectors, there is generally a lack of detailed understanding of how filler shape, size and content affect the detector properties. For example, the addition of the fillers with optical properties different from those of the matrix introduces light scattering interfaces within the detector. The scattering could reduce the light transmission as well as output by increasing the mean path length through the detector, leading to increased light absorption. This letter discusses the results of an experimental study that reveals how the filler shape, i.e. interfacial surface area, and content impact the composite's optical properties and PSD capabilities.

Materials & Methods

The geometric design for each composite discussed in this paper is inspired from the work by Mayer et al. [12]. The rods and shards geometries were selected because of their simulated higher efficiency and low gamma rejection compared to a two-dimensional layered geometry. Two types of composites were fabricated using steps that were described in prior work [4]. The schematics for each composite are