Performance Evaluation of Lead-loaded 3D-Printed Plastic Scintillators

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Plastic scintillators, a one of organic scintillators, are widely used in various radiation detection applications due to their short decay time on the order of several nanoseconds, ease of fabrication, and low production cost. However, compared to inorganic scintillators, plastic scintillators generally suffer from low light yield and the inability to measure the full-energy peak of gamma-ray sources. These limitations originate from their low density and low effective atomic number, which cause compton scattering to dominate gamma-ray interactions.

In this study, plastic scintillators were fabricated with enhanced density and effective atomic number by loading a high-Z material, and their relative light yield and detection efficiency were evaluated. ^{137}Cs and ^{60}Co gamma-ray sources were used for experiment. Lead(II) nitrate ($Pb(NO_3)_2$) was selected as the high-Z loading material, and the scintillators were fabricated using a 3D printing method. Compared to conventional thermal polymerization techniques, 3D printing enables a significantly reduced fabrication time of only a few hours and provides flexibility in material composition, such as polymers and additives.

$Pb(NO_3)_2$-loaded plastic scintillators with concentrations of 1 wt%, 3 wt%, 5 wt%, and 7 wt% exhibited an overall reduction in relative light yield compared to the unloaded 3D-printed plastic scintillator. However, a gradual improvement in relative light yield was observed up to a loading concentration of 5 wt%. At this concentration, relative light yields of 90.1% and 91.0% were achieved for ^{137}Cs and ^{60}Co sources, respectively, compared to the unloaded scintillator. Simultaneously, the detection efficiency increased by 4.7% for ^{137}Cs and 12.9% for ^{60}Co.

These results indicate that the fabricated 3D-printed $Pb(NO_3)_2$-loaded plastic scintillators effectively suppress the degradation of relative light yield caused by self-absorption while enhancing detection efficiency through high-Z material loading. This approach suggests that 3D-printed $Pb(NO_3)_2$-loaded plastic scintillators can be considered for applications requiring high count rate capability. Future work will focus on evaluating the energy-dependent response of the fabricated 3D-printed scintillators using additional gamma-ray sources.