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Plastic Scintillators with Bismuth Nanoparticles for Low Energy Gamma Spectroscopy Using Subtraction Method

Taeseob Lim, Si-won Song, Seunghyeon Kim, Jaehyung Park, Jinhong Kim, Jin-Ho Kim, and Bongsoo Lee*
School of Energy System Engineering, Nuclear engineering, Chung-Ang University, Seoul, Korea
**Corresponding author: bslee@cau.ac.kr*

1. Introduction

Nowadays, gamma spectroscopy using a multichannel analyzer (MCA) with scintillator is the most widely used method to identify gamma-emitted radioactive nuclides by finding the photoelectric peaks in the gamma energy spectrum. When the gamma-ray enters the scintillator, the scintillating light is generated and the types of nuclides are determined by analyzing the spectrum of scintillating light.

In most cases, inorganic scintillators are used to identify gamma-emitted nuclides due to high density and effective atomic number. However, inorganic scintillators are inappropriate to make large sensors for portal monitoring because of their high cost and difficult fabrication process. On the other hand, plastic scintillators generally need a much lower production cost and are easy to make in large sizes. But they have poor light yield, low effective atomic number to occur enough photoelectric effects [1].

In this study, to increase effective atomic number and the density of the plastic scintillator, we use bismuth nanoparticle as it has the highest Z number among non-radioactive isotopes and its derivatives are less toxic than lead or tin equivalents [2,3,4]. A plastic scintillator with bismuth nanoparticles is used to measure gamma spectrum of low energy emitting radionuclides below 150 keV.

2. Method and Results

For ordinary plastic scintillators without high z material, energy peaks due to photoelectric effect cannot be found in gamma spectra. Thus, an energy peak can be found in a positive value by subtracting the gamma spectrum measured without the bismuth. Before experiments, we use MCNP simulation to obtain gamma energy spectra for comparing with experimental values.

We use Co-57 gamma-ray source (122 keV). And two cylindrical plastic scintillators of which size is 5 cm in diameter and 1 cm in thickness, are prepared. Nineteen cylindrical holes of 0.5 cm diameter and depth are drilled in one of them and filled with bismuth nanoparticles. The scintillator and experimental composition can be seen in figure 1. The gamma-ray of Co-57 is measured using the photomultiplier tube (R6231-100, Hamamatsu), the scintillation preamplifier (2007B, Mirion), and the digitizer (DT5725, Caen).

Fig. 1. The scintillator with nineteen holes (left) and experimental composition (right)

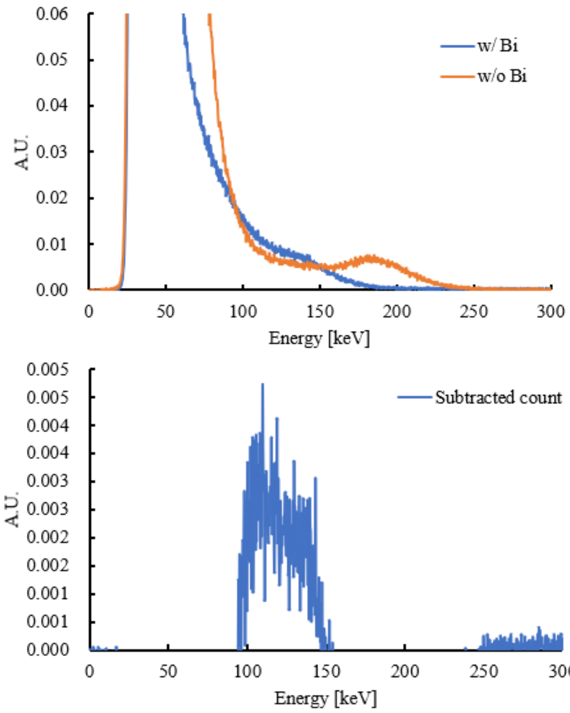
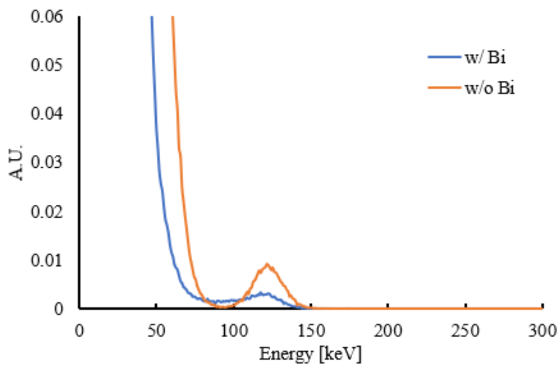


Fig. 2. The spectra of MCNP simulations using the plastic scintillator with (blue line) and without (orange line) bismuth (above) and positive part of the energy spectrum subtracted the result of scintillator without bismuth from with bismuth (below)



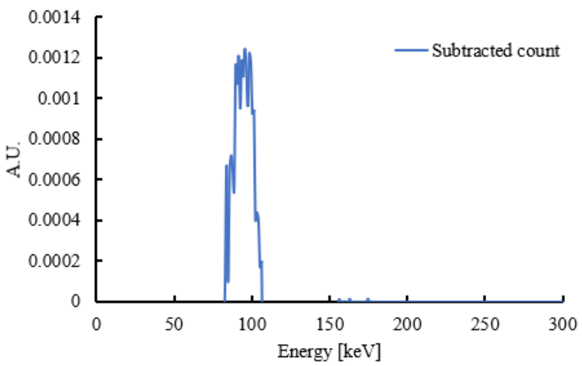


Fig. 3. The spectra of experiments using the plastic scintillator with (blue line) and without (orange line) bismuth (above) and positive part of the energy spectrum subtracted the result of scintillator without bismuth from with bismuth (below)

As shown in figure 2, we find the photopeak in the spectra of Co-57 using MCNP simulation. In the experimental results in figure 3, the energy peak due to the photoelectric effect is identified when the results without bismuth are subtracted from the spectrum obtained using bismuth.

Table I: FWHM and energy resolution of photopeak measured by MCNP simulation and experiments

	FWHM (keV)	Energy resolution (%)
MCNP simulation	30.35	24.88
Experiments	38.64	31.67

We tabulate full width and half maximum and energy resolution of the photopeak of Co-57. As shown in table I, the energy resolution of experiment is differed from MCNP simulation by 6.79 percent.

3. Conclusions

In this study, we find a clear energy peak of Co-57 by subtracting the MCA result of ordinary plastic scintillator from the result of scintillator with bismuth nanoparticles. The results demonstrate the possibility of gamma-ray sources identification using plastic scintillators with high z materials. Further studies will be carried out to measure gamma-ray spectra with the same system using variable gamma-ray sources.

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