Gamma-ray spectroscopy based on a LaBr$_3$:Ce scintillator to detect various kinds of radionuclides simultaneously with high resolution

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1. Introduction

As the research on nuclear power plant decommissioning and decontamination (D&D) has actively proceeded worldwide, the concern about the radioactive aerosols which can be inhaled by workers during D&D is increasing [1]. Especially the primary radionuclides in the aerosols from metal cutting processes vary according to D&D strategies and cutting methods. And, it is important to identify the radionuclides and measure their activities and doses for managing the internal exposure of the workers [2].

In this study, to develop the radioactive aerosol monitoring system, we fabricated a gamma-ray spectrometer based on a LaBr$_3$:Ce scintillator coupled to a photomultiplier tube (PMT) and performed the gamma-ray spectroscopy using various kinds of gamma-ray sources with high resolution as preliminary research.

2. Experimental setup

A 1” × 1” cylindrical shape LaBr$_3$:Ce scintillator (Epic crystal) was used to detect radionuclides for gamma-ray spectroscopy. Due to hygroscopicity, the scintillator was encapsulated with a quartz window and aluminum body. The window side was coupled to a PMT (H6533, Hamamatsu) with an optical pad (EJ-560, Eljen technology). The connecting part was triple wrapped with Teflon tape, aluminum foil, and black insulation tape for optimizing scintillation light collection [3].

To imitate a ventilation system which filters the radioactive aerosols, a 3D-printed plastic cap covered with HEPA filter was fitted on the scintillator.

The signal output of the PMT was integrated by a charge-sensitive preamplifier (A1424, Caen) and fed to a digitizer (DT5725, Caen). The signal was handled with a digital pulse processing method which utilizes a trapezoidal pulse shaping filter [4].

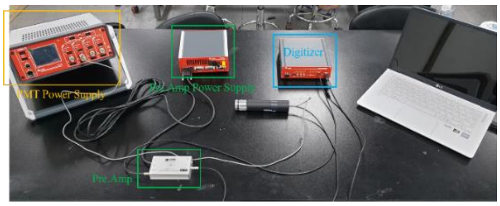

Fig. 1. System configuration.

The gamma-ray spectroscopy was performed using gamma-ray emitting isotopes such as check sources and a mixed source. As the check sources, 0.61 μCi ^{60}Co, 0.70 μCi ^{133}Ba, and 0.22 μCi ^{137}Cs were used. The mixed source used in this experiment contained ^{113}Sn, ^{88}Y, ^{60}Co, and ^{137}Cs. The gamma sources were neighbored on the head of the scintillator.

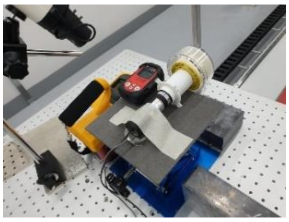

Fig. 2. Experimental setup for gamma spectroscopy with gamma sources.

3. Results

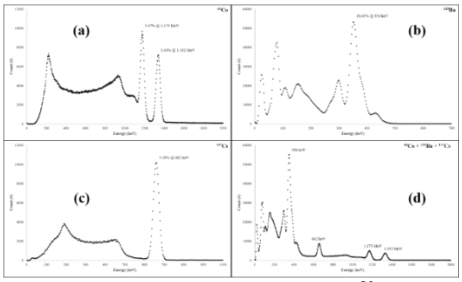

Fig. 3. Measured energy spectra of (a) ^{60}Co, (b) ^{133}Ba, (c) ^{137}Cs, and (d) all three gamma sources.

Figure. 3 shows the measured energy spectra of the gamma-ray check sources. The full-energy peaks of the radionuclides were clearly observed. The energy resolutions at the peaks were calculated as 3.47% for ^{60}Co 1173 keV, 10.43% for ^{133}Ba 356 keV, and 5.10% for ^{137}Cs 662 keV respectively.

Additionally, as shown in Figure.3(d), the full-energy peaks of all nuclides were clearly observed in simultaneous measurement with those three sources.

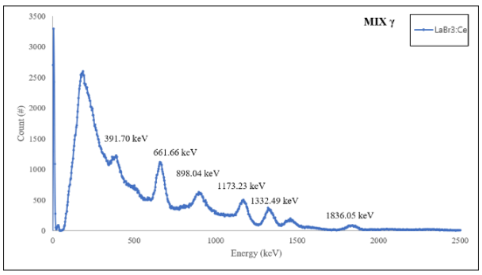

Fig. 4. Energy spectra of the mixed gamma-ray source.

The mixed gamma-ray source consisted of a single paper filter that contains radionuclides and is sealed with a plastic cover. This is equivalent to measuring the radionuclides filtered through the filter.

As shown in Figure. 4, the full-energy peaks of the radionuclides contained in the mixed source are obviously measured. Particularly in the case of ^{113}Sn, whose activity was only 176 Bq, the peak at 391.70 keV was clearly discriminated.

According to the results, it is confirmed that the fabricated spectrometer has the capability to measure very low activity and the energy region which is from 391.70 keV to 1836.05 keV.

4. Conclusion

In this study, we fabricated a small-sized gamma-ray spectrometer based on a $LaBr_3$:Ce scintillator coupled to a PMT and performed the gamma-ray spectroscopy with several gamma-ray sources.

Further studies will be carried out to perform the gamma-ray spectroscopy and radioactivity calculation with gamma-ray sources that can be involved in radioactive aerosol and emit lower energy gamma-ray.

ACKNOWLEDGEMENTS

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