Feasibility Study of Fast Neutron Activation Analysis of Iron with $LaBr_3$:Ce Scintillation Detector

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1. Introduction

A $LaBr_3$:Ce scintillation detector has superior characteristic of linearity in the γ-ray energy and good energy resolution about 3% in FWHM for the 661.7-keV γ-ray energy of Cs-137. It can be applicable for neutron activation analysis, environmental monitoring, and medical imaging. However, the $LaBr_3$:Ce scintillation detector has a relatively high intrinsic background radiation due to La-138 and Ac-227. For fast neutron activation analysis (FNAA) with the $LaBr_3$:Ce scintillation detector, the intrinsic background radiation of the detector should be considered. In this study, we investigated the feasibility of fast neutron activation analysis of iron with the $LaBr_3$:Ce scintillation detector.

2. Materials and Methods

2.1. Experimental setup

In order to measure the intrinsic background radiation inside $LaBr_3$:Ce scintillator, two detectors were set like Fig. 1. The $LaBr_3$:Ce scintillator was shielded using lead bricks to minimize the room background radiation. An additional semiconductor detector (High Purity Germanium, HPGe) was set in front of the $LaBr_3$:Ce scintillation detector to verify the spectrum of intrinsic background radiation inside the $LaBr_3$:Ce crystal.

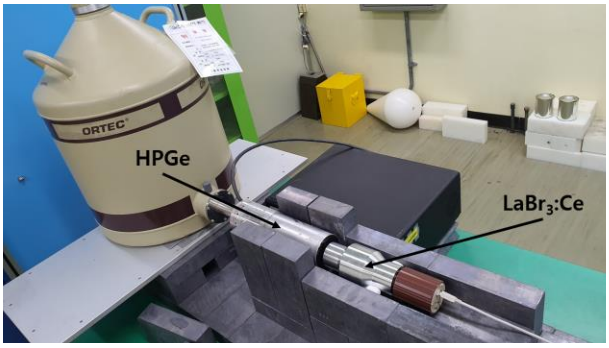

Fig. 1. Experimental setup of the $LaBr_3$:Ce scintillator and the HPGe detector (later shielded totally with the lead blocks).

The next step was to measure the radiation occurring from the iron sample irradiated with the neutron from Ra-Be source (17 mCi for Ra-226). The high-density polyethylene (HDPE) moderator was also set as shown in Fig. 2. The measurement time for the $LaBr_3$:Ce intrinsic background and the iron sample with HDPE moderator was each 268,000 s and 80,000 s.

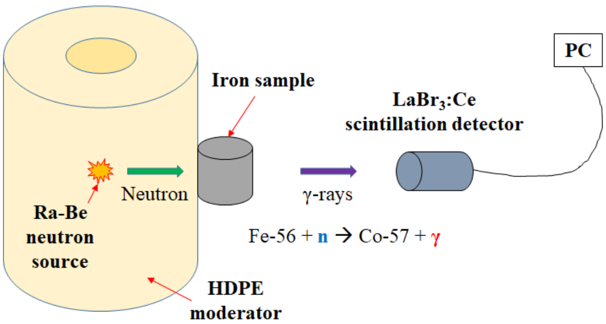

Fig. 2. Schematic diagram of prompt γ-ray measurement of iron sample using the $LaBr_3$:Ce scintillation detector

2.2. Energy calibration

For the LaBr3:Ce scintillator, the channel to energy calibration was conducted with the intrinsic background radiation's peak energies inside the LaBr3:Ce scintillator. Among those are 32 keV (fluorescence X-ray), 788.7 keV (γ-ray), and 1468 keV (coincidence 32 keV X-ray and 1436 keV γ-ray) [1].

3. Results and Discussion

The peak energies of intrinsic background radiation except for the low energy X-ray and α-particles inside the $LaBr_3$:Ce crystal were verified with the HPGe detector as shown in Fig. 3. Unlike γ-ray, the energies of α-particles peaks change depending on the number of impurities in the $LaBr_3$:Ce crystal materials [2]. When the intrinsic background is excluded from spectra, the quantity and position of these α-particles' energies should be considered.

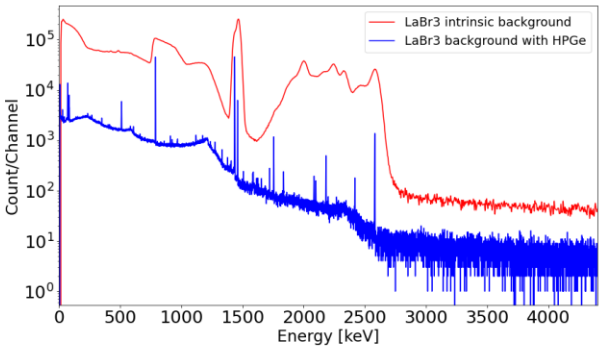

Fig. 3. The background spectra measured with the LaBr3:Ce scintillator and the HPGe detector. The red line is a self-radiation spectrum of LaBr3:Ce crystal, and the blue line is a spectrum from the HPGe detector.

The spectrum of the iron sample (blue) shows one singular peak, which did not occur in the spectrum without the iron sample (red) (Fig. 4). This peak is the prompt γ-ray peak (1238 keV) induced from (n, γ) reaction in ^{56}Fe [3]. The overall counts became lower due to the iron bucket's self-attenuation, although the measurement time was the same for both experiments.

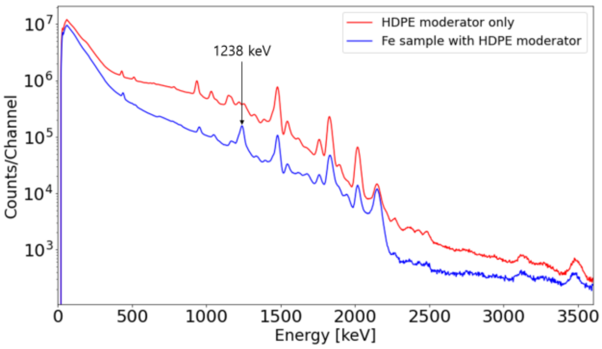

Fig. 4. Prompt γ-ray energy spectra of the iron sample measured by the LaBr3:Ce scintillation detector

The order of both spectra around the 1238 keV was similar, although the measurement time for the LaBr3:Ce intrinsic background was longer than three times that for the iron sample. Therefore, the intrinsic background inside the LaBr3:Ce does not have an impact on iron sample measurement. However, for accurate quantitative analysis, the intrinsic background should also be considered.

4. Conclusions

In this study, we investigated the feasibility of the LaBr3:Ce scintillation detector for fast neutron activation analysis of an iron sample using a Ra-Be neutron source. Unlike the HPGe detector, the LaBr3:Ce scintillation detector has intrinsic background radiation from La-138 and Ac-227 in the LaBr3:Ce crystal. Although it was negligible, it should be considered for accurate quantitative analysis. In the future study, we will quantitatively analyze the prompt γ-ray peaks with a fast neutron source.

REFERENCES

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