Compton suppression system with position changeable suppression detector

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1. Introduction

In γ-ray spectrum, Compton continuum is produced by Compton scattering effect between incident γ-ray and a detector crystal. Compton continuum is formed below a full-energy-absorption peak, and it obstructs resolving low-energy γ-ray peaks [1].

To suppress Compton continuum, Compton suppression system by using HPGe main γ-ray detector and NaI(Tl) suppression detectors is developed. In this paper, a characteristic of the developed system according to the position of suppression detector by using ^{137}Cs source is checked.

2. Theory

When Compton scattering occur in the HPGe detector crystal, γ-ray energy is not transferred fully to HPGe crystal. The sum of the energy of Compton scattered γ-ray and the energy deposited in the HPGe crystal almost equals to the energy of the incident γ-ray. The energy of scattered γ-ray can be shown as follows [1]:

$$E' = \frac{E}{1 + \frac{E}{511keV}(1 - \cos\theta)} \qquad (1)$$

where E' is the energy of scattered γ-ray, E is the energy of incident γ-ray, θ is the scattering angle. If the scattering angle is zero, the energy of scattered γ-ray is same as the incident γ-ray and the energy deposited in HPGe crystal is zero. When the scattering angle is increased, the energy of scattered γ-ray becomes smaller and the energy deposited in HPGe crystal becomes bigger. Hence, the suppressed energy range of Compton continuum by Compton suppression system will be changed according to the scattering angle.

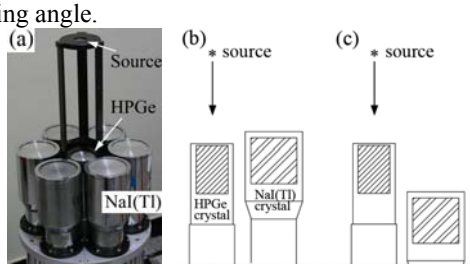

Fig. 1. Arrangement of detectors (a), and the position of HPGe, NaI(Tl) crystals of case 1 (b) and case 2 (c).

3. Experiment

The arrangement of detectors is shown in Fig. 1, (a). Main γ-ray detector is n-type HPGe detector whose energy resolution of 1.88 keV (FWHM) at 1.33 MeV and a relative efficiency of 31.7%. Suppression detectors for the detection of Compton scattered γ-ray are six 3″× 3″ NaI(Tl) detectors. HPGe detector is fixed by an aluminum mount, and the height of suppression detectors can be changed. ^{137}Cs source is mounted in front of HPGe detector, and source-to-detector distance is 25 cm.

The block diagram of the Compton suppression system is shown in Fig. 2. The input timing of a pulse is analyzed by using CFD (Constant Fraction Discriminator), and the time interval between the signal of HPGe and NaI(Tl) detector is measured by TAC/SCA (Time-to-Analogue Convertor/ Single Channel analyzer). When the time interval is below tens of nanoseconds, a logic signal is generated by TAC/SCA and goes to ADC/MCB (Analogue-to-Digital Convertor/Multi-Channel Buffer) to reject the energy signal of HPGe detector.

To check the change of the suppressed range of Compton continuum, the height of windows of NaI(Tl) detectors are set to 2 cm higher than the window of HPGe detector (case 1) and 8 cm lower (case 2) as shown in Fig 1, (b) and (c). In case 1, NaI(Tl) crystal is higher than HPGe crystal, hence, it is expected that Compton continuum near the Compton edge is suppressed more than lower energy range. In case 2, lower energy range of Compton continuum is suppressed effectively because NaI(Tl) crystal covers small scattering angle of incident γ-ray.

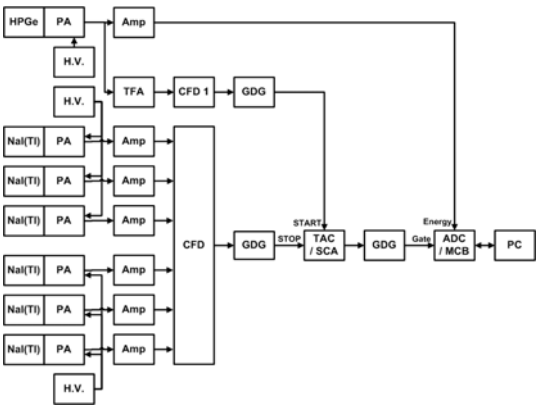

Fig. 2. Block diagram of the Compton suppression system using a HPGe and NaI(Tl) detectors.

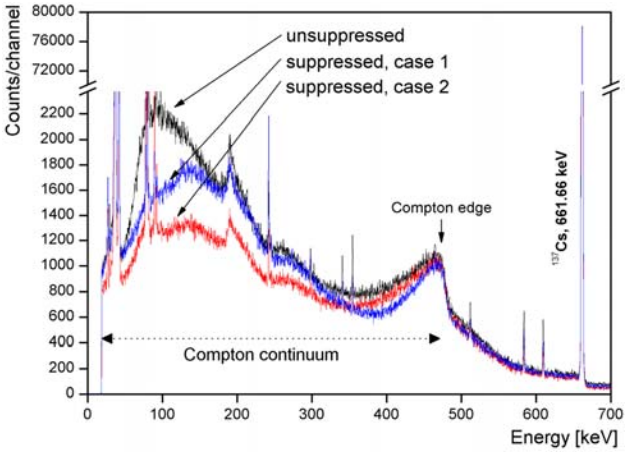

Fig. 4. Pulse height spectra from ^{137}Cs γ-ray source in single mode and Compton modes varying the height of the suppression detector.

3. Results

γ-ray spectra of ^{137}Cs obtained for 3600 seconds by using single HPGe detector and Compton suppression system in case 1 and 2 are shown in Fig. 4. Compton continuum is suppressed on the whole energy range under Compton edge (about 477 keV). Reduction factors [2] at intervals of 100 keV in the range of 100 to 400 keV are shown in Table 1. The reduction factor is defined as the ratio of counts of the unsuppressed spectrum to the suppressed spectrum at the certain energy. At the energy of 400 keV, near the Compton edge, reduction factor of case 1 is bigger than case 2. At lower energy range, reduction factor of case 2 is bigger than case 1. Hence, the adjustment of the height of NaI(Tl) detector is required to suppress Compton continuum around the γ-ray peak to analyze.

Table 1. Reduction factors of spectra obtained by Compton suppression system.

	Reduction factor			
	100 keV	200 keV	300 keV	400 keV
Case 1	1.29	1.13	1.05	1.30
Case 2	1.75	1.45	1.22	1.11

4. Conclusion and further work

The characteristic of Compton suppression system according to the position of suppression detectors is checked. Compton continuum near the Compton edge is suppressed when windows of NaI(Tl) detectors are positioned higher than the window of HPGe detector. To extend the range of application of Compton suppression system, the performance test by using a few MeV γ-ray is required.

Acknowledgement

This research was supported by the Ministry of Education, Science & Technology (MEST) of Korea and also supported by Brain Korea 21 project.

REFERENCES

[1] G. F. Knoll, Radiation Detection and Measurement, John Wiley & Sons, New York, 2000.
[2] K. Fukuda, J. Ohkuma, T. Asano and Y. Satoh, Performance of a Ge-BGO Compton-suppression spectrometer and its application to photon activation analysis, Nuclear Instrument and Method B, Vol 114 , p.379, 1996.