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Analysis of Changes in Response of CsI(Tl) Detector according to the Gamma Radiation Fields

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1. Introduction

In nuclear power plants and other nuclear-related fields, in order to prevent radiation accidents and ensure safe operations, it is essential to use radiation detectors to monitor the accumulated dose and dose rate at the location where workers are present.

Relation to this, we are currently developing radiation detectors that can swiftly and accurately identify dose rates, accumulated doses, and specific radionuclides. In the working environment, we aim to derive radiation dose rates through the analysis of radiation detector responses. To achieve this, it is essential to establish response data of the detector corresponding to varying dose rates.

Therefore, in this study, experiments were conducted to analyze how the responses of the developing detector changes with gamma radiation fields. Additionally, a data table of the detector's responses based on varying gamma radiation fields was established.

2. Methods and Results

In this experiment, a radiation detector based on CsI(Tl) scintillator was utilized. The reasons for using CsI(Tl) detector in the experiment are as follows. Cesium iodide is widely popular as a scintillation material and it is less brittle than sodium iodide. Also, when making thin forms, it can be bent into various shapes without fracturing, compared to NaI(Tl), and it is less hygroscopic than NaI(Tl) scintillator [1]. For these reasons, the experiment was conducted using CsI(Tl) detector.

2.1 Composition of CsI(Tl) Detector

The CsI(Tl) detector used in this study composed of CsI(Tl) scintillator wound with Teflon reflector, MicroFC 60035 SiPM(Silicon photomultiplier) manufactured by ONSEMI, USA, pre-amplifiers, amplifiers, ADC(Analog-to-Digital Converter), FPGA(Field Programmable Gate Array) [2].

2.2 Experiment setup and process

The experiment to analysis of changes in response of the CsI(Tl) detector according to the gamma radiation field was conducted using gamma-ray irradiator at the Radiation Device Test Center of the Korean Association for Radiation Application(KARA). The beam quality of the gamma-ray irradiator is Cs-137 and Mean energy is 0.662 MeV. The gamma-ray irradiator utilizes two Cs-137 sources with activities of 10 mCi and 100 mCi. From 1 to 20 μSv/h, 10 mCi Cs-137 source was used, and from 40 to 150 μSv/h, 100 mCi Cs-137 source was used. To irradiate various dose rates on the detector, the distance between the irradiator and the detector was adjusted. The dose rates and distances between the irradiator and the detector are presented in Table 1.

Table I: The Dose rates according to distance between gamma-ray irradiator and CsI(Tl) detector.

Dose rate(μSv/h)	Distance(mm)
1	5639
2	4003
5	2545
10	1806
20	1282
40	2830
60	2316
80	2009
100	1800
120	1645
150	1474

The dose rates(μSv/h) in Table I are obtained by multiplying the exposure dose rate (μGv/h) with the conversion coefficient of 1.21. The value of 1.21 provided by ISO-4037-3 is the conversion coefficient used to convert air kerma to personal dose equivalent.

For each dose rate, irradiation was taken twice for 120 seconds to observe changes in the detector's response. In this study, response refers to the count rate obtained by dividing the total count detected by the detector under a specific dose rate condition by the measurement time of 120 seconds. The experiment setup where the gamma-ray irradiator and CsI(Tl) detector are positioned is depicted in Fig. 1. The CsI(Tl) detector is positioned above the white box in the middle-left, and the gamma-ray irradiator is located inside the yellow box in the middle-right of Fig. 1.

Fig. 1. CsI(Tl) detector and gamma-ray irradiator at the Radiation Device Test Center of the Korea Association for Radiation Application(KARA).

2.4 Results

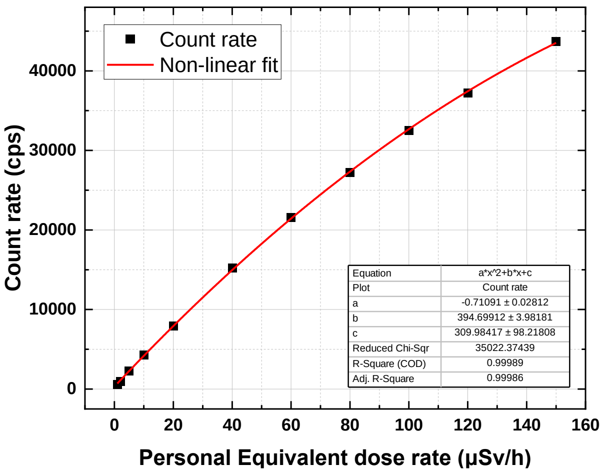

Fig. 2. The count rate values of the CsI(Tl) detector according to the personal equivalent dose rate and is a graph obtained by non-linear fit of the data.

The responses of the detector according to the dose rates were fitted using the quadratic function (1). In Fig. 2, the responses with respect to the dose rates show an overall increasing trend. However, it can be observed that as the Cs-137 source intensity becomes stronger, the rate of increase in the responses gradually decreases. It was confirmed that the gamma sensitivity (cps/μSv/h) of the CsI(Tl) detector used in this study was approximately 376 cps/μSv/h.

The quadratic function for non-linear fit is as follows:

$$(1)\quad \mathrm{y} = \mathrm{ax}^2 + bx^2 + c$$

The count rate values corresponding to the dose rates shown in Fig. 2 can be confirmed in Table II.

Table II: Count per second(cps) of CsI(Tl) detector according to Dose rate

Dose rate(μSv/h)	Distance(mm)	cps
1	5639	554.7
2	4003	989.9
5	2545	2260.7
10	1806	4265.7
20	1282	7952.9
40	2830	15256.8
60	2316	21567.0
80	2009	27256.5
100	1800	32490.1
120	1645	37208.7
150	1474	43724.8

3. Conclusions

In this study, the experiment was conducted to analyze the changes in response of the CsI(Tl) detector according to the gamma radiation fields. In the Results section, it was observed that the count rate showed a gradual decrease. It is inferred that the decreasing count rate trend may be attributed to changes in the baseline used as a reference when accepting pulse signals. Also, it could be a consequence of pile-up phenomenon where signals from subsequent radiation events are superimposed before the processing of signals from previous incidents is complete, leading to a decrease in the count rate.

In order to increase the gamma sensitivity(cps/μSv/h) value of the CsI(Tl) detector used in the experiment, additional experiments are needed to find and apply the appropriate gain and threshold values.

REFERENCES

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