Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 17-18, 2018

Development of radiation monitoring sensor using a digitizer in mixed radiation fields

Sang Hun Shin [a], Si Won Song [a], Hyun Young Shin [a], Young Beom Song [a], Bongsoo Lee [a*]
[a] *School of Energy Systems Engineering, Chung-Ang University, Heukseok-dong, Dongjak-gu, Seoul, 156-756, Republic of Korea*
[*] *Corresponding author: bslee@cau.ac.kr*

1. Introduction

Pulse Shape Discrimination (PSD) is a technique widely used to discriminate between different types of radiations. One of the most common PSD applications is to discriminate neutrons and gamma-rays in mixed radiation fields [1]. During the last years, PSD has been significantly developed due to the use of fast digitizers and digital pulse processing (DPP).

In general, the PSD techniques is used to distinguish the pulses which are generated from a photo-multiplier tube (PMT) according to the different light signals from a scintillator. In the case of discrimination between alpha and gamma radiations, the pulse shapes produced by both radiations are different. Thus, this difference can be used to discern which type of radiation generated the pulse.

In this study, we developed a radiation monitoring sensor using a digitizer to discriminate between alpha and gamma radiations in mixed radiation fields with PSD technique. The radiation monitoring sensor uses two kinds of scintillators to generate different pulses according to the different type of radiations such as alpha and gamma. Finally, PSD scatter plots of alpha and gamma radiations are measured and two types of radiations are discriminated by developed radiation monitoring sensor. Especially, this sensor can be used to monitor radiations to detect the species of radioactive isotopes and to measure the energy level of radiations in mixed low-level radioactive wastes (LLW) or intermediate-level radioactive wastes (ILW).

2. Methods and Results

The radiation monitoring sensor is composed of a sensing probe, a plastic optical fiber (POF), a PMT-amplifier, and a digitizer. For alpha/gamma discrimination, two kinds of scintillators such as a transparent CaF_2(Eu) inorganic scintillator and BCF-12 organic scintillator were employed as sensitive elements of the sensing probe. The first part, which is composed of a thin CaF_2(Eu) can detect alpha particles and the second part of the sensing probe consisting of a BCF-12 with 3 mm diameter is used to detect gamma-rays [2].

2.1 Alpha particle detection

In general, CaF_2(Eu) is a transparent material used for detecting gamma-rays with energies of up to several hundred kilo electron volt (keV), as well as charged particles. In this study, a CaF_2(Eu) was used for detecting alpha particles because its low atomic number can minimize interactions with background gamma-rays and because its chemical inertness can allow direct contact with samples without any radiation entrance window. The scintillation decay time of the CaF_2(Eu) inorganic scintillator is about 940 ns [3].

2.2 Gamma-ray detection

As a sensing element of the radiation monitoring sensor, a BCF-12 (Saint Gobain S.A., France) was used for gamma-ray detection. The colorless and transparent BCF-12 has many advantages including low cost, high light output, fast decay time, and good energy resolution. In addition, it has a non-hygroscopic characteristic and high sensitivity against gamma-rays. The peak emission wavelength and the decay time of a BCF-12 are about 435 nm and 3.2 ns, respectively. Table I shows the physical properties of the CaF_2(Eu) and BCF-12 used in this study.

Table I: physical properties of the CaF_2(Eu) and BCF-12

	CaF_2(Eu)	BCF-12
Type	Inorganic scintillator	Organic scintillator
Density (g/cm^3)	3.18	1.05
Luminescence (nm)	435	435
Decay time (ns)	940	3.2
Light yield [photons / MeV]	30,000	~8,000

2.3 Light-measuring device and digitizer

As a light-measuring device, a compact side-on PMT module (H11461-03, Hamamatsu Photonics) with a high-voltage power supply is employed to convert real-time scintillating light signals into electrical signals. In general, a PMT is used for measuring very weak scintillating light signals, owing to its high internal gain and reasonable quantum efficiency. The measurable wavelengths by the PMT is from 185 nm to 900 nm and the peak wavelength is about 450 nm. Typical and maximal dark currents of this PMT are about 2.0 nA and 10.0 nA, respectively, when the control voltage was fixed at +1.2 V. The output current signals generated by the PMT were measured using a digitizer and monitored using emulation software. A 8-Channel 14-bit 250 MS/s digitizer (DT5725, CAEN) was used to discriminate pulses generated from two scintillators such as a CaF_2(Eu) and a BCF-12, through a PMT.

2.4 Alpha and gamma radioisotopes

To evaluate the performance of the fabricated radiation monitoring sensor, a ^{210}Po and a ^{137}Cs were used as an alpha and a gamma emitter, respectively. The energy of an alpha particle is 5.304 MeV and the energy of a gamma ray is 0.662 MeV. Also, the radioactivity of ^{210}Po and ^{137}Cs radioisotope was 0.1 and 46 μCi, respectively. In this study, the alpha particle and gamma-ray were measured simultaneously and separately using the radiation monitoring sensor to discriminate species of radioisotopes.

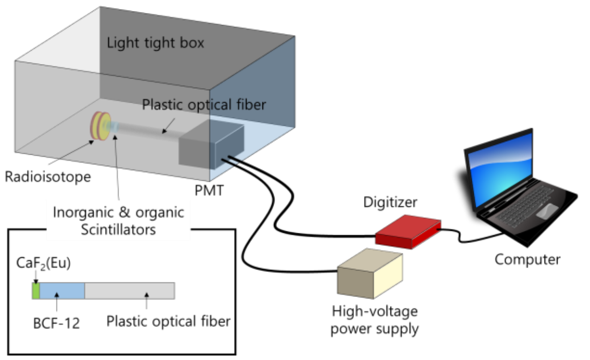

Fig. 1. Schematic diagram of radiation monitoring sensor.

Figure 1 shows the structure of the sensing probe and detailed experimental setup using the radiation monitoring sensor.

2.6 Results

In this study, to discriminate alpha and gamma radiations generated from combined radioisotope, we performed PSD technique. Figure 2 shows measured PSD scatter plots of an alpha particles and gamma rays using the radiation monitoring sensor.

Using a digitizer in the radiation monitoring sensor, we collected a large number of decay traces and analyzed them to extract information about alpha or gamma energy levels. The summed energy, pulse shape, and time stamp were collected in real-time. Figure 2 shows two distinct regions for alpha particles and gamma rays with different energies.

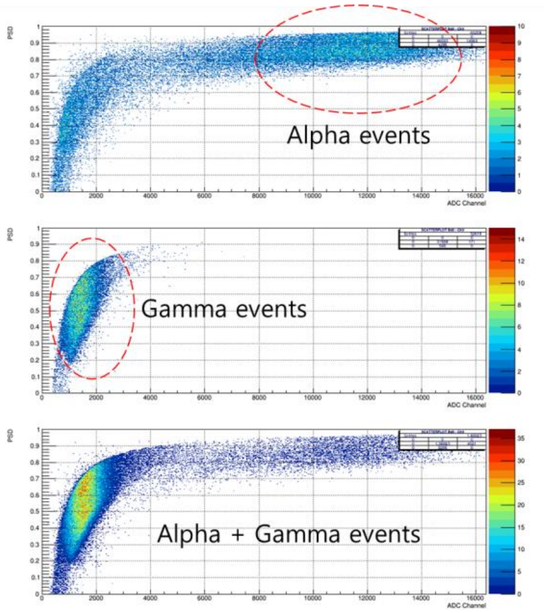

Fig. 2. PSD scatter plot of alpha and gamma radiations and the particular region selected for typical alpha and gamma events.

3. Conclusions

The objective of this study is to fabricate a radiation monitoring sensor that can be used for the management of radioactive waste by detecting the species and by measuring the level of radioactive isotopes.

In this study, we developed a radiation monitoring sensor to discriminate alpha and gamma radiations simultaneously using the PSD technique. It is expected that the developed radiation monitoring sensor can be used to detect radioactive species and to measure contamination level in the mixed radioactive wastes.

REFERENCES

[1] F.D. Brooks, A scintillator counter with neutron and gamma-ray discrimination, Nuclear Instruments and Methods, Vol. 4, p.151, 1959.

[2] R. L. Heath, R. Hofstadier and E. B. Huges, Inorganic scintillators: A review of techniques and applications, Nuclear Instruments and Methods. Vol. 162, p.431, 1979

[3] S. H. Shin, S. B. Song, B. Lee and S. Kim, Simultaneous measurement of alpha and beta particles using dual-type fiber-optic, Journal of the Korean Physical Society, Vol.71, p. 923, 2017.

ACKNOWLEDGEMENT

This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Science, ICT and future Planning (No. 2017R1A2B2009480) and This research was supported by National Nuclear R&D Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Science, ICT and future Planning (No. 2016M2B2B1945255).