Identification of gamma radionuclides using scintillator-based fiber-optic radiation sensor

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Abstract

In this study, we fabricated a fiber-optic radiation sensor (FORS) with four different kinds of scintillators. The equivalent dose rate is measured with a gamma survey meter, and light output is measured with a photon counting module Four kinds of radionuclides that emit different gamma energies are identified with the ratio of the light output of the scintillator. And they are quantified with light output and dose conversion factor.

Introduction & Experimental setup

- In gamma-ray spectroscopy, gamma-spectra induced by interactions of gamma-ray with materials can be used to identify and quantify the gamma-emitting radionuclides. Since scintillator-based radiation sensors are simple and cost-effective than semiconductor sensors, they are employed for gamma spectroscopy.
- FORS has many advantages, such as good flexibility, small sensing volume, remote sensing, and immunity to electromagnetic interference. However, it also has difficulties being used for gamma-ray spectroscopy due to modal dispersion.
- In this study, a FORS is fabricated with four different kinds of the scintillator to identify and quantify the gamma-radionuclides without measuring gamma-spectra.
- Based on physical properties, two different kinds of inorganic scintillators such as GAGG:Ce (Epic-Crystal), YSO:Ce (Epic-Crystal), and two organic scintillators such as BCF-12, BCF-20 (Saint-Gobain) were selected. Each selected scintillator had a cylindrical shape with a height of 15 mm and a diameter of 3 mm. 0.5 m-long plastic optical fiber (CK-80, Mitsubishi Rayon Co., Ltd) with a diameter of 2 mm was attached to the bottom part of each scintillator. ^{57}Co (0.122, 0.136 MeV), ^{133}Ba (0.081, 0.356 MeV), ^{137}Cs (0.662 MeV) and ^{60}Co (1.17, 1.33 MeV) are used as gamma-ray source.
- Figure 1 (a) shows the experimental setup for measuring light outputs from each scintillator using photon counting module (H11890-210, Hamamatsu), and (b) shows the experimental setup to measure dose-rate with a survey meter (RadEye-G-10, Thermo Scientific).

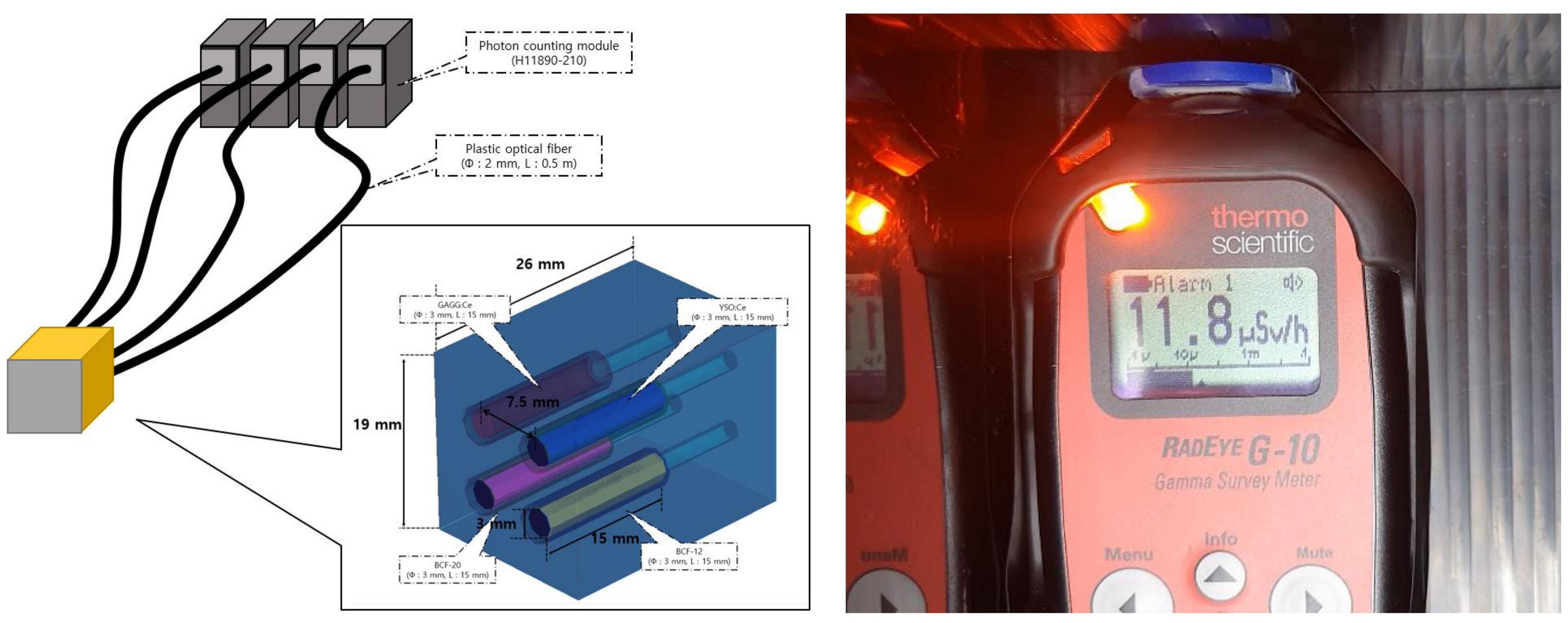

Fig. 1. (a). Experimental setup for measuring light outputs
(b). Experimental setup to measure dose-rate with a survey meter

Experimental results

- Figure 2 shows a plot of the count rate of each scintillator as a function of dose rate (μSv/h) at three different ^{137}Cs sources.

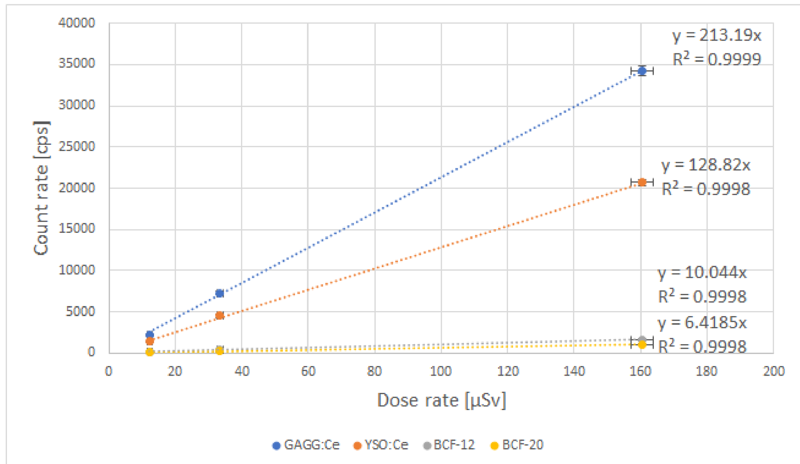

Fig. 2. Count rate (cps) as a function of dose rate (μSv/h) with ^{137}Cs

- Figure 3 shows a plot of the count rate of each scintillator as a function of dose rate (μSv/h) at three different ^{60}Co sources.

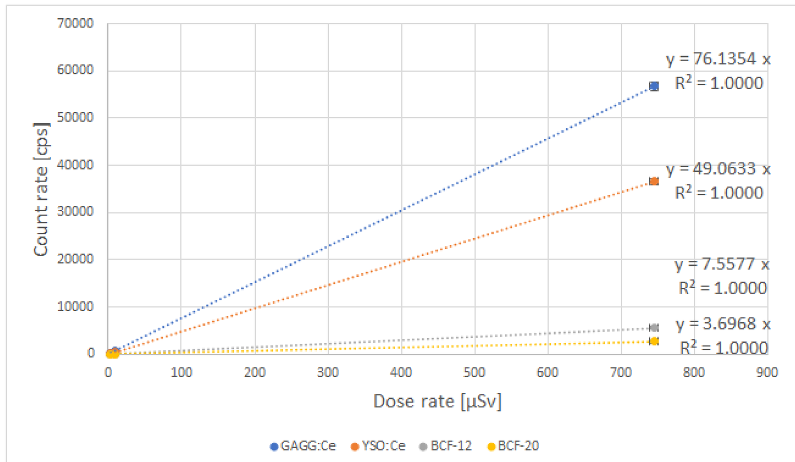

Fig. 3. Count rate (cps) as a function of dose rate (μSv/h) with ^{60}Co

- Theoretically, the scintillator emitted visible photons proportional to deposited energy in the scintillator. The count rate is proportional to the dose rate. From the slopes, the dose conversion factors can be derived, and gamma-emitting radionuclides can be quantified.
- Figure 4 shows a plot of the ratio of light output in the inorganic scintillator and the organic scintillator to the energy of incident gamma-ray. It can be noticed that with the increase of energy of incident gamma-ray, the ratio of light-output decreases. As a result, it is expected that the ratios of light output can be used to identify the gamma-emitting radionuclide.

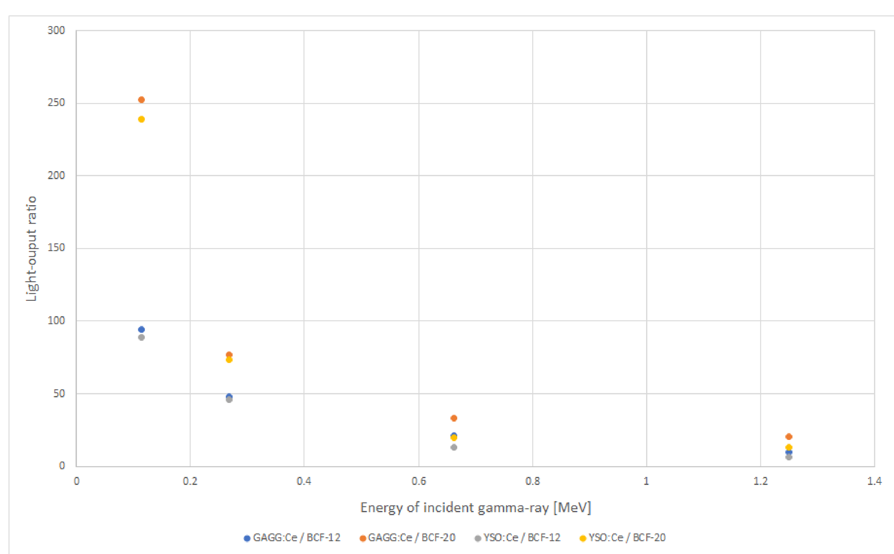

Fig. 4. Ratio of light-output as a function of energy of incident gamma-ray

Conclusions

- In this study, the FORS is fabricated with four different kinds of scintillators. With dose conversion factor, gamma-emitting radionuclide can be quantified using light output. And four different radionuclides such as ^{57}Co, ^{133}Ba, ^{137}Cs, and ^{60}Co can be identified with the ratios of light output of the scintillators.

Acknowledgements

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