Transactions of the Korean Nuclear Society Autumn Meeting
Yeosu, Korea, October 25-26, 2018

Fiber-Optic Radiation Sensor Using an Inorganic Scintillator for Measuring Dose Distributions in the Mixed Radiation Fields

H. Y. Shin [a], S. W. Song [a], H. Byun [a], J. H. Park [a], S. H. Shin [a], B. Lee [a*]
[a]*Energy System Engineering, The Chung-Ang Univ, 84, Heukseok-ro, Dongjak-gu., Seoul*
**Corresponding author: bslee@cau.ac.kr*

1. Introduction

Safety of radioactive waste disposal is essential for stable and continuous development of nuclear industry, thus the accuracy and reliability of the radiation measurement system for radioactive wastes should be improved. To ensure safe disposal of radioactive wastes, the provision of information on the nuclear inventory and the distribution of radioactivity in the radioactive waste drum is the most important precondition, in which the concentration of radionuclides, total amount of radioactivity and other properties must meet the safety standards [1]. Although High-purity Germanium (HPGe) detectors are widely used in non-destructive nuclide analysis of radioactive waste, they are expensive and difficult to handle due to their large volume and heavy weight [2]. In order to overcome these problems, the development of a new detector which is inexpensive, easy to handle and has rapid measurement is required [3].

In this study, we fabricated a fiber-optic radiation sensor (FORS) using an inorganic scintillator, a plastic optical fiber (POF) and a photon counter (H11890-210, Hamamatsu Photonics) for remote sensing of the dose distributions in the radioactive waste. Using the FORS, the dose distributions of mixed radiation fields were measured and the distribution curves were compared with the results of a survey meter (TGS-121, Aloka science & humanity).

2. Materials and experimental setup

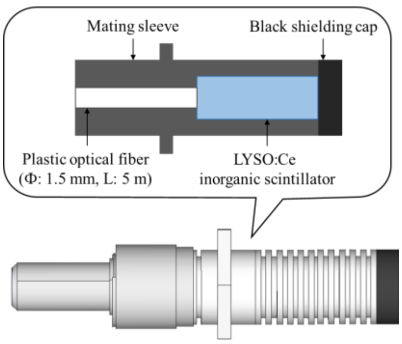

Fig. 1. Schematic diagram of a sensing probe of a FORS.

A sensing probe of the FORS is composed of a square-type cerium-doped lutetium yttrium orthosilicate (LYSO:Ce) inorganic scintillator and a POF as shown in Fig. 1. The size of inorganic scintillator is 3 × 3 × 15 mm^3 and the refractive index is 1.82. The primary decay time and the maximum wavelength of emission are 40 ns and 420 nm, respectively. The outer surface of the inorganic scintillator was surrounded by an aluminum foil to increase the scintillating light-collection efficiency. Furthermore, a black shielding cap and a mating sleeve were used to intercept ambient light noise.

To transmit scintillating light signals, a POF (SH6001, Mitsubishi Rayon) with diameter of 1.5 mm was used. The refractive index of the core is 1.49 and the numerical aperture (NA) is 0.5, respectively.

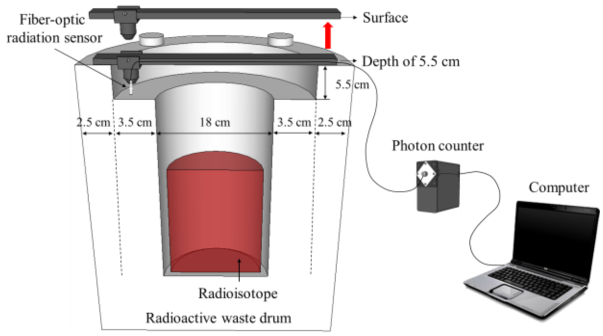

Fig 2. Experimental setup for measuring the dose distributions of the radioactive waste using the FORS according to the depth.

Fig. 2 shows the experimental setup for measuring the dose distributions in the mixed radiation fields using the FORS. The sensing probe is located at the left end of the radioactive waste drum and shifted to the right by 1 cm. When the sensing probe is irradiated by the mixed radiation, scintillating light signals with different light intensities are generated and transmitted to the photon counter via one transmitting optical fiber with a length of 5 m. Photon counter (H11890-210, Hamamatsu Photonics) has high sensitivity in a spectral response range from 230 to 700 nm and a peak sensitivity wavelength of 400 nm.

3. Results

When the sensing probe of the FORS was shifted horizontally to the right by 1 cm from the left end of the radioactive waste drum, the light intensity distributions of the scintillation signals generated from the inorganic scintillator were similar to the distributions obtained using the survey meter at the same operating conditions as shown in Fig. 3.

As expected, the light intensity distribution of the scintillation signals was not uniform since the radioactive wastes are not piled up regularly. In the region of lead shielding, the light signals measured by the FORS show a sharper falloff than those of survey meter because of the large sensing volume of the survey meter.

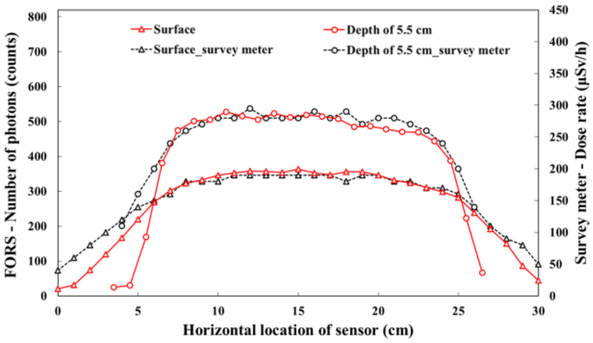

Fig. 3. Light intensity distribution of the scintillation signals measured by the FORS at the surface and depth of 5.5 cm.

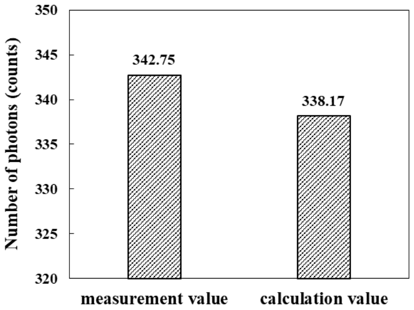

Fig. 4. Comparison of light intensity between measurement and calculation.

$$\phi_{\gamma} = \frac{S}{4}\ln\left(1 + \frac{R^2}{x^2}\right) \tag{1}$$

Calculation value for disk sources was derived using the equation 1 and compared with measurement value obtained by the FORS as shown in Fig. 4. Based on the surface, an error of 5.5 cm is 1.35% compared to the calculation value.

4. Conclusion

In this study, we fabricated a FORS using an inorganic scintillator, a POF and a photon counter for remote sensing of the dose distributions in the radioactive waste. To obtain dose distributions in the radioactive drum, we measured the light intensities of scintillation signals from the FORS at each measuring point.

From the experimental results of this study, we confirmed that the light intensity distributions of the scintillation signals measured by the FORS were similar to the reference distributions obtained by the survey meter. Further studies are planned to develop the distributed multi-channel fiber-optic radiation sensor system using a multi-pixel photon counter (MPPC) array module as a light measuring device to increase the detection efficiency of the scintillating lights. It is expected that a radiation sensor using optical fiber can be developed for inspection and testing of radioactive waste as a quality assurance.

REFERENCES

[1] K. R. Rao, Radioactive waste: The problem and its management, Current Science, Vol. 81, No. 12, pp. 1534-1546, 2001
[2] I. Hossain, N. Sharip and K. K. Viswanathan, Efficiency and resolution of HPGe and NaI(Tl) detectors using gamma-ray spectroscopy, Scientific Research and Essays, Vol. 7, No.1, pp. 86-89, 2012.
[3] H. Jeon, W. J. Yoo, S. H. Shin, G. Kwon, M. Kim, H. J. Kim, Y. B. Song, K. W. Jang, W. S. Youn, B. Lee, Performance Evaluation of a Multichannel All-In-One Phantom Dosimeter for Dose Measurement of Diagnostic X-ray Beam, Sensors, Vol. 15, No.11, pp. 28490-28501, 2015

ACKNOWLEDGEMENT

This research has supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT) (No. 2017R1A2B2009480, 2016M2B2B1945255) and this research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (No. 2018R1D1A1B0704115).