Report

Position Dependence for Count Rates in a Polyethylene Naphthalate Survey Meter

Philip NGUYEN,^{*1} Hidehito NAKAMURA,^{*1,2} Yoshiyuki SHIRAKAWA,^{*2} Tatsuya YAMADA^{*1} and Sentaro TAKAHASHI^{*1}

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A thin polyethylene naphthalate (PEN) sheet ($72 \times 140 \times 0.5$ mm) with one face enhanced with prism treatment was used for a survey meter. PEN has a relatively high effective refractive index of 1.70, which directly affects light propagation generated in the sheet. We show its radiation counting response at a 9×23 array of different locations on the detection window of the PEN survey meter, when irradiated with beta particles from a ^{90}Sr radioactive source. The variability in radiation counts on the detection window, obtained by dividing the maximum value by the minimum value, was 1.23 along the Y-axis and 1.05 along the X-axis. This knowledge can be useful in the design of radiation detectors mounting PEN sheets.

KEY WORDS: polyethylene naphthalate, survey meter, position dependence, strontium-90.

I INTRODUCTION

In the environment around Japan's Fukushima Daiichi Nuclear Power Plant, the enormous area of damage requires extensive surveying to investigate the ambient dose rate and radioactive surface contamination.¹⁻⁴⁾ Thus, the number of survey meters must be dramatically increased,^{5,6)} and detector costs must be kept low.

Aromatic ring polymers are attractive scintillation materials for radiation detectors because they are inexpensive and can be easily produced.⁷⁻¹⁵⁾ We have previously developed a scintillation substrate from common polyethylene naphthalate (PEN), and evaluated its overall performances for radiation detection.

An important characteristic of a scintillation substrate is the refractive index for light generated in the material.¹⁶⁾ For PEN, light with a 425-nm emission peak is emitted and the effective refractive index is 1.70 over its emission spectrum.¹⁷⁻²⁰⁾ Additionally, it has other attractive properties such as transparency, heat tolerance, gas and moisture impermeability, chemical inertness, and a density of 1.33 g/cm^3 . Energy spectra of some radiations were recently demonstrated for PEN.²¹⁻²⁷⁾

For a survey meter with a large detection window, we created a thin sheet of scintillation material from PEN and demonstrated its radiation counting response at different

locations on the detection window. This knowledge will be useful for designing a full-scale radiation detector.

II MATERIALS AND METHODS

A $72 \times 140 \times 0.5$ mm thin PEN sheet (Teijin, Ltd.) with one face enhanced with prism treatment to propagate more light emitted from the PEN sheet to reach the photodetector was created. The structure possesses a naphthalate ring:

To get optimum results, the sheet was mounted to the detection part of a common survey meter (SPS-210Z, Ohyo Koken Kogyo Co., Ltd.). **Figure 1** shows the schematic of the detection part and the defined coordinates. The treated PEN face was oriented away from the photomultiplier tube (PMT). There is no bulking agent in the detection part of the survey meter.

The experimental setup for measuring radiation counts is shown in **Fig. 2**. The PEN sheet was irradiated by beta particles emitted from a ^{90}Sr radioactive source (149 Bq, 9 October 2008; Nuclitec GmbH) via an acryl collimator. The center of the source was placed over a 9×23 array of different locations on the detection window. The time constant of the survey meter was set to 30 s, and the count rates were read after 90 s from the start of irradiation. At each location on the detection window, the data taking was performed 10 times and the results were averaged.

^{*1} Kyoto University Research Reactor Institute; 2, Asashiro-Nishi, Kumatori-cho, Sennan-gun, Osaka 590-0494, Japan.
E-mail: philip@rri.kyoto-u.ac.jp

^{*2} National Institute of Radiological Sciences; 4-9-1, Anagawa, Inage-ku, Chiba-shi, Chiba 263-8555, Japan.

Fig. 1 Schematic of the detection part and defined coordinates (a) Bottom view after removing the PEN sheet. (b) Side view. There is no bulking agent.

Fig. 2 Schematic of the setup for measuring radiation counts. Beta particles emitted from a ^{90}Sr radioactive source via an acrylic collimator irradiate a 9×23 array of points on the detection window.

III RESULTS AND DISCUSSION

Figure 3 shows the count rate distribution on the detection window. This position dependence was primarily caused by the relatively high refractive index of PEN and the geometry between the PEN sheet and the PMT. The refractive index determines the critical angles of total reflection. Thus, more light emitted from the PEN sheet is directly detected at the high count rate region in **Fig. 3**, the location near the center of the PMT light receiving section ($X = 0 \text{ mm}$, $Y = 25 \text{ mm}$) in **Fig. 1**. The low count rate regions occur because the propagation length for the emitted light is longer.

Figure 4 plots the count rates along the Y-axis monitored at $X = 0 \text{ mm}$, while **Fig. 5** plots the count rates along the X-axis at $Y = 25 \text{ mm}$. The variability for the count rates along each axis was obtained by dividing the maximum value by the

Fig. 3 Count rate distribution along the detection window. The center of the PMT light receiving section is placed at the coordinates $X = 0 \text{ mm}$ and $Y = 25 \text{ mm}$.

Fig. 4 Count rates along the Y-axis monitored at $X = 0 \text{ mm}$.

minimum value, respectively. Along the Y-axis, the variability was 1.23. In contrast, the variability was 1.05 along the X-axis.

These results should be useful for designing a radiation detector based on PEN. Thus, a position-sensitive detector should take into account the count-rate position dependence. It is advantageous to keep the PEN sheet perpendicular to the light receiving section of the photodetector in order to directly detect the emitted light.

IV CONCLUSION

We have mounted a thin sheet from the aromatic polymer PEN in a survey meter. The radiation counting response was obtained from a 9×23 array of different locations on the detection window of the PEN survey meter. The radiation

Fig. 5 Count rates along the X-axis monitored at Y = 25 mm.

count variability on the detection window of the survey meter was 1.23 along the X-axis and 1.05 along the Y-axis. These results could be useful for the design of radiation detectors mounting PEN sheets.

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