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A model survey meter using undoped poly (ether sulfone)

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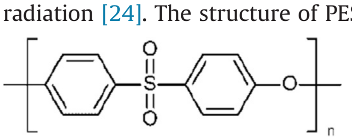
ABSTRACT

The large region surrounding the damaged Fukushima Daiichi Nuclear Power Plant has necessitated the use of numerous radiation survey meters with large, robust substrates. The survey meters require efficient scintillation materials that do not require doping and have dimensional stability, such as poly (ether sulfone) (PES) resins. Here, we demonstrate the performance of a model survey meter that uses large PES plates with polished, mirrored surfaces and rough, scattering surfaces. Light collection efficiencies from plates having one or more of these surfaces were quantitatively Characterised with ^{36}Cl-, ^{60}Co-, ^{137}Cs-radioactive sources. The count rates of plates having a combination of mirrored/scattering-surfaces are >1.6 times that for plates having two mirrored surfaces. In addition, a significant amount of radiation-induced light generated in the PES is trapped inside the plate because of its relatively high refractive index. The results indicate that large, undoped PES plates can be used in radiation survey meters.

1. Introduction

The massive accident at the Fukushima Daiichi Nuclear Power Plant caused the release of significant amounts of radioactive materials into the surrounding environment [1,2]. Efficient decontamination requires stable, robust monitoring by a considerable number of survey meters with large scintillation base substrates [3–6]. Modern refining techniques have made it possible for undoped aromatic ring polymers to be used as scintillation materials [7,8]. Examples include polycarbonates and poly (ethylene terephthalate) [2,9–21]. Moreover, optical characteristics of high-purity polystyrene and poly (vinyltoluene) have been subsequently re-examined [22,23].

We Characterise poly (ether sulfone) (PES), which is a robust resin with a relatively high density for increasing radiation interaction, as well as heat, creep, hydrothermal, acid, and alkali resistance. These features, along with its dimensional stability, make it potentially useful for stable monitoring of environmental radiation [24]. The structure of PES is:



Because of delocalised electrons over the sulfonyl groups, it absorbs visible light and has an amber colour. The emission maximum is 350 nm and the effective refractive index (based on the emission spectrum) is 1.74. PES responses to alpha and beta particles, internal conversion electrons and gamma-rays have been previously reported [24,25]. In addition, it can be used as a component substrate in polymer blends to alter the optical characteristics of other scintillation materials [26–28].

Here, we examine the performance of a model survey meter that uses large PES plates with polished mirror surfaces and roughened, scattering surfaces. The effects of the surface treatments are compared and quantified by using standard, wide-area radioactive sources. Overall, we demonstrate that large undoped PES plates can be used as scintillation materials in survey meters.

2. Material and methods

Three $140 \times 72 \times 1$ mm^3 plates were cut from extrusion-moulded PES resin (4100G; Sumitomo Chemical Co., Ltd.). One sample had two mirrored surfaces, one had two scattering surfaces, and one had a combination of mirrored/scattering surfaces. As shown in Fig. 1, the plate with two mirrored surfaces is transparent, while the plate with two scattering surfaces appears opaque. Initially, asperities on all of the surfaces were removed by a series of six waterproof sandpapers having different particle sizes (320, 400, 600, 800, 1000, and 1500; Kohnan Shoji Co., Ltd.). The surfaces

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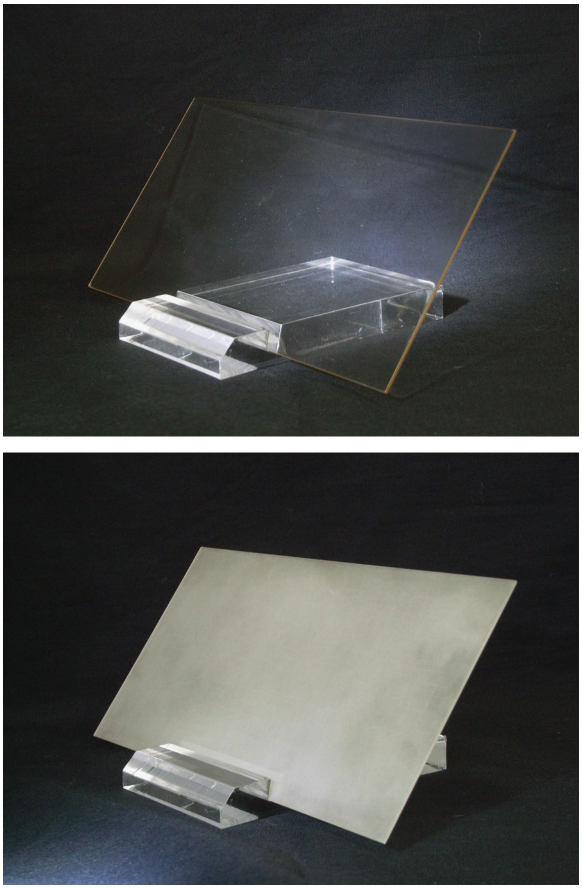

Fig. 1. $140 \times 72 \times 1\text{-mm}^3$ PES plates. The plate with two mirrored surfaces is transparent (*Top*), while the plate with two scattering surfaces is opaque (*Bottom*).

Fig. 2. Detection section of the model survey meter. (*Top*) Entrance window, (*Bottom*) light collection box with walls covered with white reflector plates. The yellow hemisphere is the PMT window. (For interpretation of the references to Colour in this figure legend, the reader is referred to the web version of this article.)

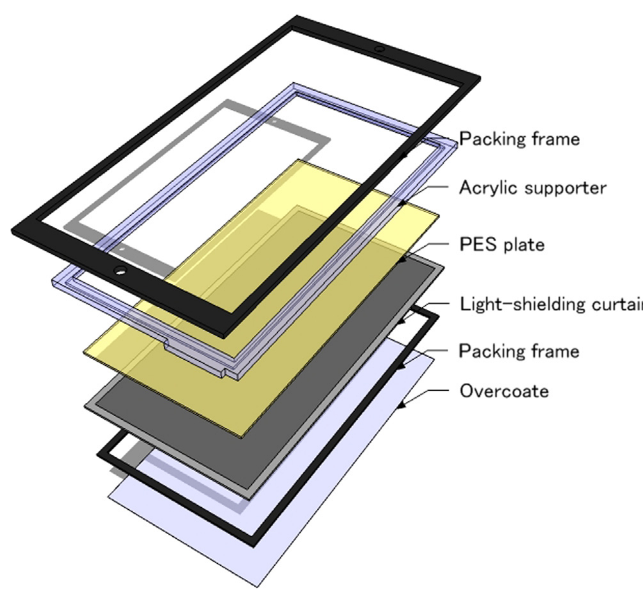

Fig. 3. Schematic of the entrance window. It is constructed with an overcoat, a packing frame, a light-shielding curtain of three Mylar films with evaporated aluminium, a PES plate, an acrylic supporter with a rectangle hole, and a second packing frame. There is no optical connection between parts.

were mirrored surfaces where fine scratches were removed by buffing with four abrasive soaps with different particle sizes (501MC-16, 506MC-16, 5605S-16AU; Sankei Co., Ltd. and Acrysunday; Acrysunday Co., Ltd.). The scattering surfaces were created by roughening the mirrored surfaces with waterproof sandpaper (400; Kohnan Shoji Co., Ltd.).

The detection section of the model survey meter is shown in Fig. 2. It consists of an entrance window and a light collection box equipped with white reflector plates and a hemispherical photomultiplier tube (PMT). As shown in Fig. 3, the entrance widow is constructed with an overcoat, a packing frame, a light-shielding curtain of three Mylar films of evaporated aluminium, a PES plate, an acrylic support, and a second packing frame. As discussed below, the PES plate with the mirrored/scattering combination can be oriented with either side facing the light box. The light emitted from the PES overlaps the absorption spectrum of the acrylic supporter (acquired with a UV–vis photometer; V-670 JASCO Co., see Fig. 4). Therefore, a $136 \times 69\text{-mm}^2$ rectangular hole was made in the acrylic support to directly transmit the short-wavelength light from the PES to the PMT.

The response of the model survey meter was Characterised by exposing it to three standard, wide-area radioactive sources. The first was a $150 \times 100\text{-mm}^2$ ^{36}Cl source with an endpoint-energy of 709 keV (CLR07022; AEA Technology QSA GmbH), which is used to calibrate common plastic scintillation survey meters. The second was a $150 \times 100\text{-mm}^2$ ^{60}Co source that emits predominantly beta particles with an endpoint-energy of 318 keV, as well as 1173 and 1332 keV gamma-rays (CKR07032; Eckert & Ziegler Nuclitec GmbH), and is used to evaluate typical radioactive materials in reactor cooling water. The third was a $100 \times 100\text{-mm}^2$ ^{137}Cs source (CS221; Japan Radioisotope Association) that emits predominantly beta particles with an endpoint-energy of 514 keV, 662 keV gamma-rays, and 624 keV internal conversion electrons, and is used to detect long-half-life radioactive materials that have leaked from the Fukushima power plant.