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Blended poly (ether sulfone) and poly (ethylene naphthalate) as a scintillation material

Hidehito Nakamura [a,b,*], Yoshiyuki Shirakawa [b], Nobuhiro Sato [a], Hisashi Kitamura [b], Sentaro Takahashi [a]

[a] Kyoto University, 2, Asashiro-Nishi, Kumatori-cho, Sennan-gun, Osaka 590-0494, Japan
[b] National Institute of Radiological Sciences, 4-9-1, Anagawa, Inage-ku, Chiba 263-8555, Japan

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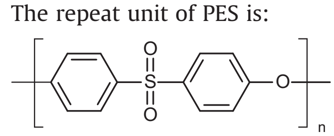
ABSTRACT

The advantages of blending two aromatic ring polymers for use as a scintillation substrate for radiation detection have attracted considerable attention. Here, we have characterised the blending of poly (ether sulfone) (PES) and poly (ethylene naphthalate) (PEN), which have dissimilar repeat units. The blended substrate is a faint-amber-coloured resin, and its density is between that of PES and PEN (1.34 g/cm^3). Its excitation spectrum has a maximum at 370 nm and differs from the component substrates. However, the emission spectrum is similar to that for PEN substrates, and does not exhibit short-wavelength light from the PES component, even when excited by the excitation maximum of PES. These results reveal that excitation energy is being transferred to a lower energy level before it is emitted as light, with a maximum at 420 nm. By taking into account its emission spectrum, an effective refractive index was determined to be 1.70. Light yield distributions generated by ^{137}Cs and ^{207}Bi radioactive sources indicated that the blended substrate had a yield 2.23 times that of PES, and 0.68 times that of PEN. Overall, the results demonstrate that polymer blends can have scintillation characteristics that differ in some ways from those of the base substrates, with a potential advantage in being able to control them.

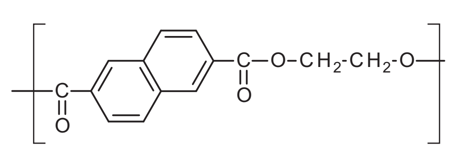
1. Introduction

Organic scintillation materials developed from aromatic ring polymers, and doped with various fluorescent guest molecules, possess important characteristics in radiation detection such as high densities, suitable excitation and emission wavelengths, refractive indices, and high light yields [1,2]. Refractive indices strongly depend on the wavelength of the propagated light [3,4]. Thus the emission wavelength must be considered in detail with regard to refractive indices and light propagation in scintillation materials. Through advanced refining techniques, high purity aromatic ring polymers can now be manufactured and made into high performance scintillation materials [5–7]. Furthermore, undoped substrates based on these polymers may now be considered as alternatives. Specifically, poly (ethylene terephthalate) (PET) and poly (ethylene naphthalate) (PEN) have several advantages [8–10] and have stimulated searches for other potential materials within the enormous variety of aromatic ring polymers [11–18]. In this context, we have reported on blending PET and PEN to develop an optimised substrate [19]. However, the similar PET and PEN repeat units complicated our understanding of the altered characteristics of the blend.

We also recently reported that poly (ether sulfone) (PES) is a good candidate for use as an undoped scintillation material [20]. The repeat unit of PES is:



It has heat stability, transparency, and resistance to hydrolysis and chemical stress. Its density is 1.37 g/cm^3. The amber-coloured PES emits short-wavelength light with an emission maximum at 350 nm. The repeat unit for PEN differs considerably from that of PES:



It has shock resistance and a density of 1.33 g/cm^3, and emits blue light with a maximum at 425 nm.

* Corresponding author at: Kyoto University, 2, Asashiro-Nishi, Kumatori-cho, Sennan-gun, Osaka 590-0494, Japan. Tel./fax: +81 72 451 2463.
E-mail address: hidehito@rri.kyoto-u.ac.jp (H. Nakamura).

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Thus it is a straightforward extension of our previous work to characterise the 1:1 by weight blending of PES and PEN as a scintillation material in terms of density, excitation and emission spectra, refractive index, and light yield. Overall, the results presented here enrich the understanding of polymer blends as scintillation materials, and demonstrate that blends can increase the variety of potential substrates.

2. Materials and methods

A 1:1 by weight blend of PES and PEN (Teijin Ltd.) was prepared as a $31 \times 31 \times 5\ \text{mm}^3$ substrate. The characteristics of the blended substrate were compared with that of similar plates for PES (Sumitomo Chemical Co., Ltd.) and PEN (Teijin Ltd.). The blended substrate has a faint amber colour, as shown in Fig. 1, which indicates an absorbance of visible light. A fluorescence spectrophotometer (F-2700; Hitachi High-Technologies Co.) was used to acquire excitation and emission spectra. The wavelength dependence of the refractive index was determined at four wavelengths with a refractometer (PR-2; Carl Zeiss, Jena, Germany): g line of a mercury lamp (436 nm), F line of a hydrogen lamp (486 nm), D line of a sodium lamp (589 nm) and C line of a hydrogen lamp (656 nm). Light yields from the substrate when it is excited by radiation from a radioactive source were measured by a photomultiplier tube (PMT; R878-SBA, Hamamatsu Photonics Co., Ltd.), as depicted schematically in Fig. 2. The radioactive source was positioned at the centre of a wide face ($31 \times 31\ \text{mm}^2$) of the substrate. A ^{137}Cs source (CS21; Japan Radioisotope Association)

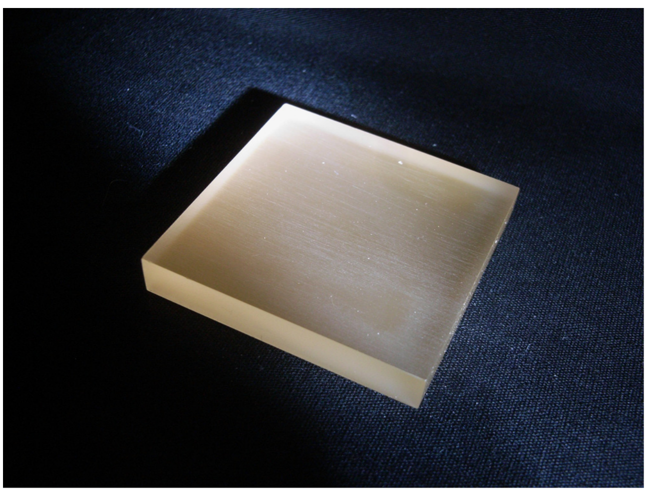

Fig. 1. Photograph of a $31 \times 31 \times 5\text{-mm}^3$, faint amber-coloured PES–PEN blended substrate.

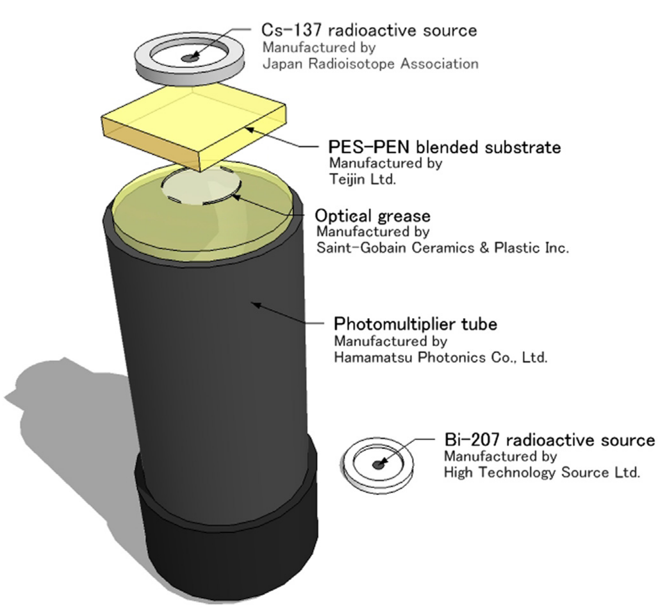

Fig. 2. Schematic view of the arrangement for measuring light yields in the PES–PEN blended substrate.

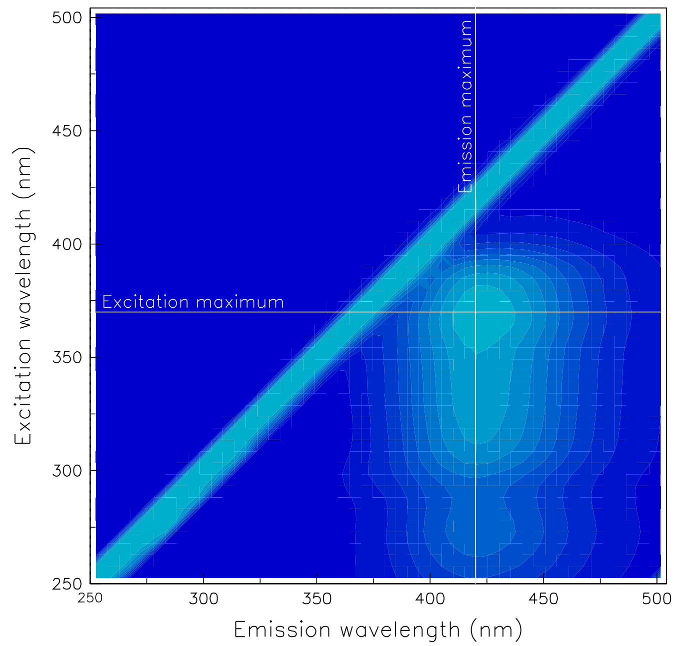

Fig. 3. Fluorescence distribution for the PES–PEN blended substrate. The correlation between the excitation and emission wavelengths is shown. The excitation and emission maximum peaks are 370 and 420 nm, respectively. White lines in each axis denote the peaks.

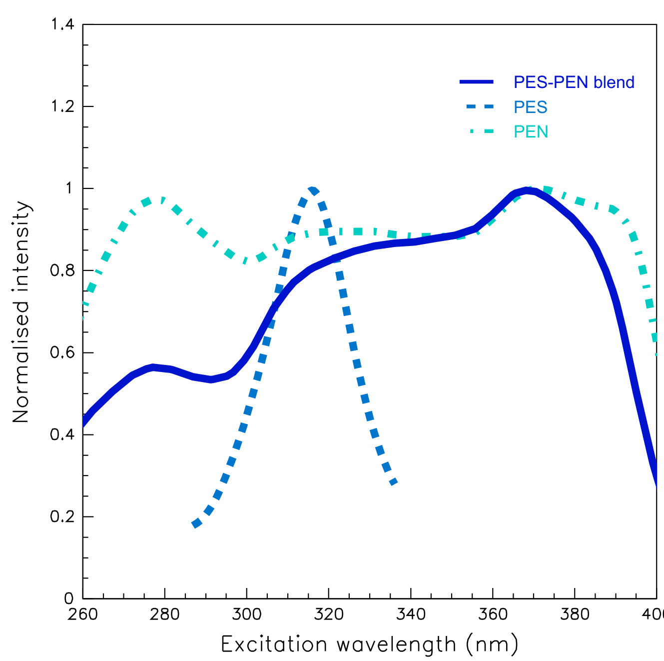

Fig. 4. Excitation spectrum (solid line) for the PES–PEN blended substrate monitored at the 420-nm emission maximum. The dotted line is the PES excitation spectrum monitored at its 350-nm emission maximum. The dashed line is the PEN excitation spectrum monitored at the 425-nm emission maximum.