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Poly (ether sulfone) as a scintillation material for radiation detection

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HIGHLIGHTS

- PES is characterised as a scintillation material for radiation detection.
- PES has an emission maximum at 350 nm.
- The effective refractive index for PES is 1.74 based on its emission spectrum.
- The light yield of PES is 2.21 that of PET and 0.31 times that of PEN.
- The PES response to 5486 (6118) keV alpha particles is 546 ± 81 (598 ± 83) keV electron equivalents.

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ABSTRACT

Considerable attention has been drawn to the advantages of using aromatic ring polymers for scintillation materials in radiation detection. Thus, it is important to identify and characterise those with the best potential. Here, we characterise poly (ether sulfone) (PES), which is an amber-coloured transparent resin that possesses sulfur as a main component and has a density of 1.37 g/cm^3. PES emits short-wavelength light with a 350-nm maximum. By taking into account its emission spectrum, we demonstrate that its effective refractive index is 1.74. Light yield distributions generated by ^{137}Cs and ^{207}Bi radioactive sources were obtained. PES has a light yield that is 2.21 times that of poly (ethylene terephthalate), and 0.31 times that of poly (ethylene naphthalate). The energy response to 5486 keV alpha particles emitted from ^{241}Am was 546 ± 81 keV electron equivalents (keVee), while the energy resolution was 17.0 ± 0.1%. The energy response to 6118 keV alpha particles emitted from ^{252}Cf was 598 ± 83 keVee, while the energy resolution was 16.0 ± 0.1%. Overall, PES has potential for use as a scintillation material in radiation detection.

1. Introduction

Aromatic ring polymers have been used as organic scintillation materials for radiation detection for many years (Beringer, 2012, Knoll, 2010; Leo, 1992). In many cases, they have been doped with various fluorescent guest molecules. Important characteristics that determine the performance of a scintillation material for radiation detection are its density, emission and excitation wavelengths, refractive index, and light yield. The refractive index is particularly important because it directly affects light propagation to the detector. Thus, there is a considerable effort worldwide to develop organic scintillation materials that have favourable characteristics (Nakamura et al., 2012a, 2013a). In addition, advanced refining techniques have provided high-purity aromatic ring polymers (Nakamura et al., 2013b).

In past few years, we have demonstrated that both undoped poly (ethylene terephthalate) (PET) and poly (ethylene naphthalate) (PEN) possess several properties suitable for radiation detection (Nakamura et al., 2010, 2011, 2012b). These results drew global attention to the advantages of undoped scintillation materials in radiation detectors (Kumar et al., 2012, Nakamura et al., 2013c, 2013d; Nagata et al., 2013a, 2013b; Sen et al., 2012). It is thus important identify potential scintillation materials by surveying the huge variety of aromatic ring polymers for suitable characteristics, and to summarise those characteristics. The performance of a survey metre using PEN has also been reported, as well as that of blended PET and PEN (Nakamura et al., 2013e; Nakamura et al., in press; Shirakawa et al., 2013a).

PET has a benzene ring and PEN has a naphthalate ring in each repeat unit. Poly (ether sulfone) (PES) possesses sulfur as its main

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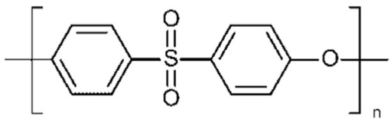
components and the repeat unit is:



Here, we assess undoped PES for radiation detection by characterising its emission and excitation spectra, refractive index, and light yields. We also characterise its response to alpha particles. Overall, undoped PES is a candidate as a scintillation material for radiation detection.

2. Materials and methods

A 31 × 31 × 5 mm PES plate (4100G; Sumitomo Chemical Co., Ltd.) was prepared. The amber-coloured PES emits slightly blue light as shown in Fig. 1. It is stable at high temperatures. The density of PES is 1.37 g/cm^3, which is higher than that of either PET or PEN (both 1.33 g/cm^3). Its emission and excitation spectra were obtained with a fluorescence spectrometer (F-2700; Hitachi High-Technologies Co.). Refractive indices were determined with a refractometer (PR-2; Carl Zeiss, Jena, Germany) at the C line of a hydrogen lamp (656 nm), the D line of a sodium lamp (589 nm), the F line of a hydrogen lamp (486 nm), and the g line of a mercury lamp (436 nm).

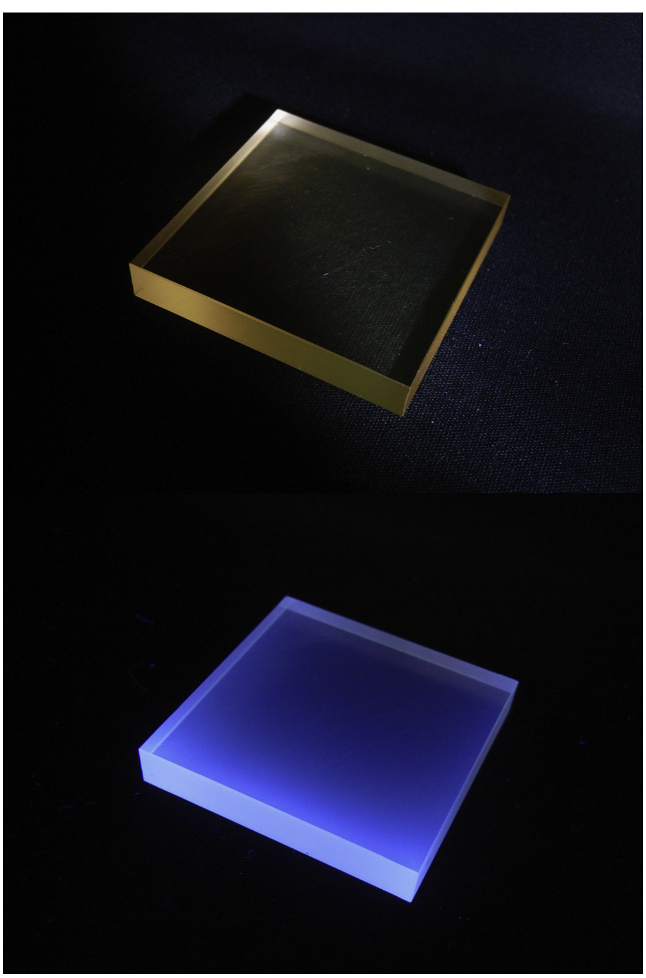


Fig. 1. A 31 × 31 × 5 mm poly (ether sulfone) plate. PES is an amber-coloured transparent resin (*top*). PES emits slightly blue light when excited by ultra-violet light (*bottom*).

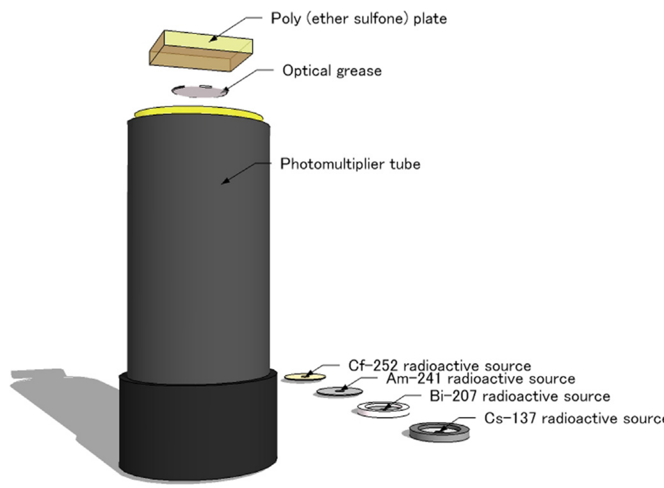


Fig. 2. Schematic of the arrangement for measuring light yields in PES.

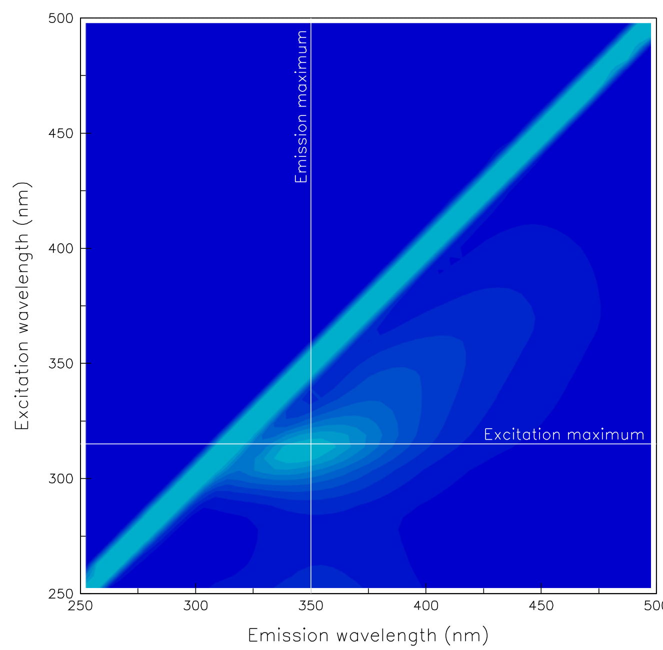


Fig. 3. Fluorescence from PES. The correlation between the emission and excitation wavelengths is shown. The maximum peaks in the emission and excitation spectra are denoted by white lines in each axis.

The experimental arrangement for measuring light yields is shown in Fig. 2. A photomultiplier tube (PMT; R878-SBA, Hamamatsu Photonics Co., Ltd.) was used as a photodetector. One 31 × 31 mm PES face was interfaced with the PMT window *via* a very thin layer of optical grease (BC-630; Saint-Gobain Ceramics & Plastic Inc.), while a radioactive source was positioned in the centre of the opposite face. Two radioactive sources, ^{137}Cs and ^{207}Bi, both of which emit monoenergetic internal conversion electrons, were used to obtain the relationship between the light yield in PES and the radiation energy. The light yield for alpha particles was then evaluated with ^{241}Am and ^{252}Cf radioactive sources that do not emit background beta particles or gamma-rays. A data acquisition system was constructed from several CAMAC and NIM modules. The output signals from the PMT were directly digitised by a charge-sensitive analogue-to-digital converter module (RPC022, REPIC Co.).