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A potential base substrate for deformable scintillation materials

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ABSTRACT

Deformable scintillation materials for radiation detection are an original concept that will impact many applications. Here we reveal the optical characteristics of readily available, transparent grease that consists of adhesive aromatic ring polymers. The aromatic ring polymer is methyl phenyl polysiloxane, commonly used in cosmetics, lubrication, heat conduction, and mechanical damping. It has a 285-nm excitation maximum and emits short wavelength light that peaks at 315 nm. The stopping power for 1 MeV electrons is 1.78 MeV cm^2/g. The light-yield distribution has distinct peaks at 976 keV from internal conversion electrons and at 5486 keV from alpha particles. In addition, this particular methyl phenyl polysiloxane is safe for use and disposal, which is an excellent advantage. These aromatic ring polymers are potential base substrates for deformable scintillation materials and make an important addition to the categories of scintillation materials.

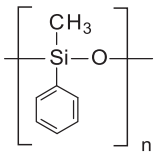
1. Introduction

Plastic scintillation materials made of aromatic ring polymers have been used as substrates for radiation detection for many years [1,2]. In those materials, we recently revealed an unusual mechanism of wavelength conversion that removes restrictions on the types of fluorescent guest molecules that can be used to convert short wavelength emission from the polymers into longer wavelengths [3]. Some aromatic ring polymer substrates having no guest molecules were found to be effective for radiation detection, and were recognised as an alternative to typical scintillation materials [4–10]. In addition, blending of aromatic ring polymers can favourably alter optical characteristics [11,12]. Thus, there are many available options for scintillation materials for radiation detection [13–24].

The use of deformable scintillation materials is an entirely original approach for radiation detection. For example, large assemblies of detectors having intricate shapes could be fabricated by filling or coating ductworks or tubes with deformable scintillation materials. Here, we characterise transparent grease that consist of adhesive aromatic ring polymers. The results demonstrate that the adhesive aromatic ring polymers can be used as a deformable base substrate for scintillation materials.

2. Materials and methods

Methyl phenyl polysiloxane is an aromatic ring polymer used in familiar cosmetics, lubrication, heat transport, and mechanical damping [25]. The structural formula is:



Grease (EJ-550, Eljen Technology) consisting of 80–85% methyl phenyl polysiloxane as the main active component (see manufacturer's material safety data sheet) was used.

UV–vis absorption spectrum of the grease was acquired with a UV–vis photometer (V-670, JASCO Co.). The grease was contained in a quartz cell having two transparent faces and a 2-mm light path.

Fluorescence spectrum was acquired with a spectrometer (F-2700, JASCO Co.). The grease was contained in a quartz cell having four transparent faces and a 10-mm light path. The stopping power of the grease for 1 MeV electrons was calculated with the ESTER program (National Institute of Standards and Technologies, USA) [26].

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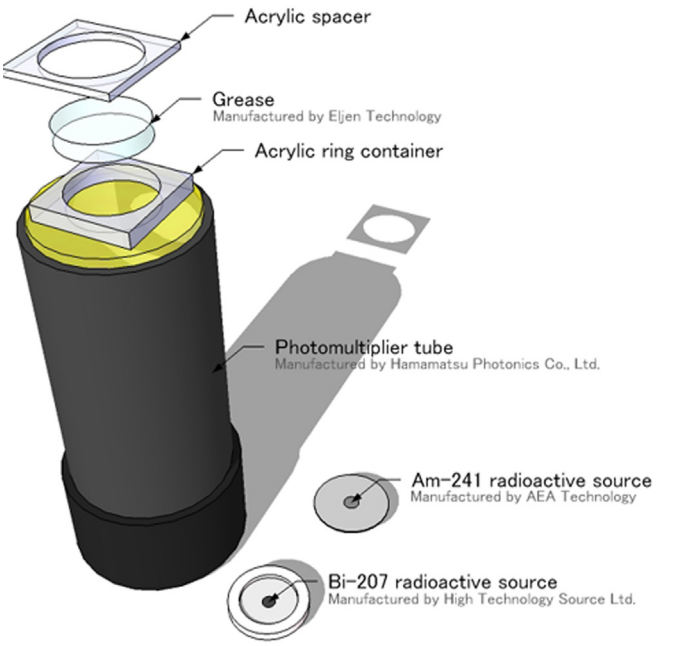

Fig. 1. Schematic of arrangement for determining light yields in grease contained by a φ25 × 5-mm acrylic ring. The bottom face of the grease is on the PMT window. A 2-mm-thick acrylic spacer with a 25-mm-diameter hole is used to prevent contact between the top face of the grease and the radioactive sources.

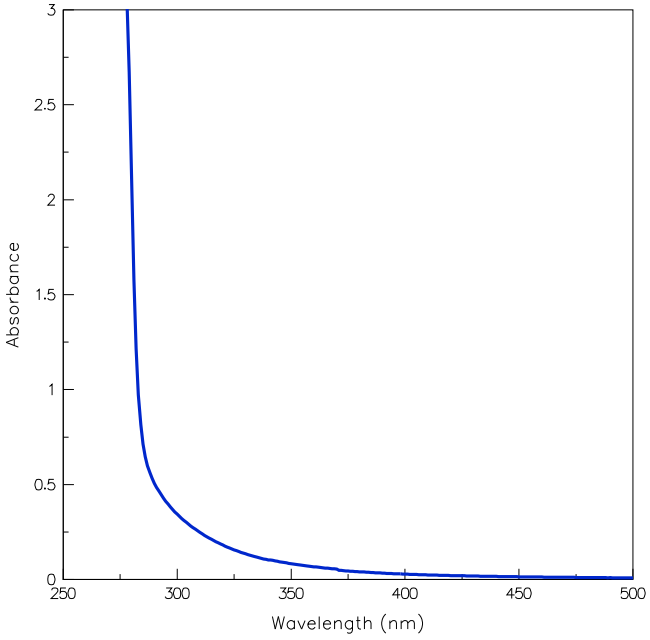

Fig. 2. UV–vis absorption spectrum for 2-mm-thick grease.

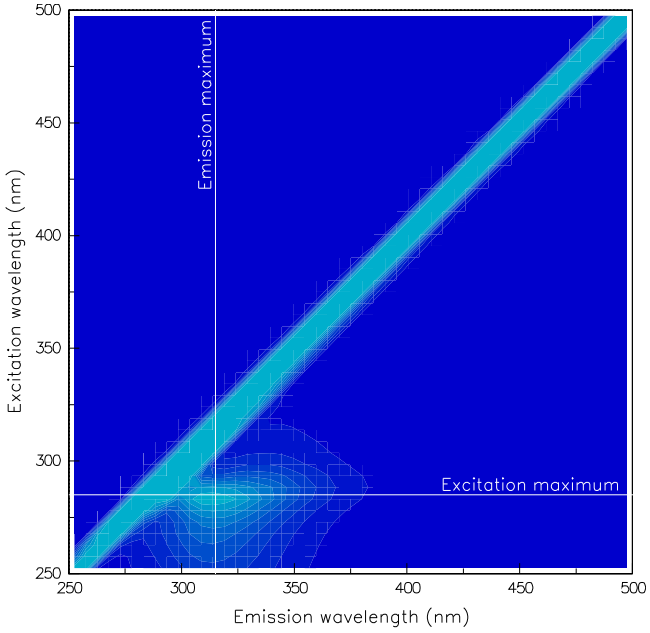

Fig. 3. Two-dimensional correlation between excitation and emission wavelengths for fluorescence emitted from the grease. The diagonal line is caused by stray light in the fluorescence spectrometer.

A schematic of the experimental arrangement for determining the light yield of the grease is shown in Fig. 1. The grease was contained in a φ25 × 5-mm acrylic ring. The bottom face of the grease was in contact with the window of a photomultiplier tube (PMT; R878-SBA, Hamamatsu Photonics Co., Ltd.). A ^{207}Bi radioactive source that emits internal conversion electrons and a ^{241}Am radioactive source that emits alpha particles were used to excite the grease. To prevent contact of the sources with the top face of the grease, a 2-mm-thick acrylic spacer with a 25-mm hole was used to mount the sources. A charge-sensitive analogue-to-digital converter module (PC-022, REPIC Co.) was used to digitise the PMT signals.

3. Results and discussion

The UV–vis absorption spectrum of the 2-mm-thick grease (Fig. 2) is dominated by absorption at short wavelengths. The fluorescence spectrum in Fig. 3 is plotted as a two-dimensional correlation between excitation and emission, where the fluorescence maximum is located at the intersection of the two white lines in the distribution drawn with the light colour. Stray light generated in the spectrometer appears along the diagonal line. Excitation and emission spectra extracted from Fig. 3 are displayed in Fig. 4. The excitation maximum is at 285 nm, and the emission maximum is at 315 nm. Thus part of the emission is self-absorbed.

The specific gravity of the grease is 1.04, and its composition is 5.5×10^{22} atom/g hydrogen, 1.8×10^{22} atom/g carbon, 4.6×10^{21} atom/g oxygen, and 9.1×10^{21} atom/g silicon. When these values were used in the ESTER program, the stopping power of the grease for 1 MeV electrons was determined to be 1.78 MeV cm^2/g.

The light yield distribution from a 5-mm-thick grease sample generated by the ^{207}Bi radioactive source is shown in Fig. 5. There is a peak induced by 976 keV internal conversion electrons in the high yield region. Counts in the low light yield region arise mainly from gamma-rays emitted from the ^{207}Bi radioactive source. The light yield distribution generated by the ^{241}Am radioactive source is shown in Fig. 6. The response to alpha particles is significantly less than the response to electrons. However, a sharp peak induced by 5486-keV alpha particles is observed.

These results demonstrate that the adhesive aromatic ring polymer is a potential deformable base substrate for scintillation materials. Up to now, there have been only solid and liquid organic scintillation materials [2,27,28]. Now we have an original deformable substrate category. Disposal of scintillation materials is an issue facing many users. However, this is not a concern for methyl phenyl polysiloxane, which is safe for use and disposal.