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CsI(Tl)/plastic phoswich detector enhanced in low-energy gamma-ray detection

Koutaro Yamasoto*, Masahiro Tsutsumi, Tetsuya Oishi, Michio Yoshizawa, Makoto Yoshida

Department of Health Physics, Japan Atomic Energy Research Institute, Tokai-mura, Naka-gun, Ibaraki 319-1195, Japan

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Abstract

A phoswich detector composed of a thin plate CsI(Tl) scintillator and a plastic scintillator (BC-400) has been designed and evaluated in order to improve the sensitivity in the low-energy region of a large-area plastic scintillation detector. This newly designed phoswich detector can be applied to both gross gamma measurement and energy spectrometry for low-energy gamma-ray emitters. Judging by estimations of minimum detectable activity, the lower measurable energy of a large-area plastic scintillation detector can be expanded down to a few tens of keV by adding a thin plate CsI(Tl) scintillator.
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1. Introduction

Recently, the decommissioning of radioactive material handling facilities tends to be increased due to aging of the buildings. Because radioactive contamination of interiors and installations sometimes remains in such facilities, pre-survey of these objects is needed before the buildings are demolished. Since these objects have large dimensions, large-area radiation measuring instruments are required for surveying them efficiently.

Large-area plastic scintillation detectors are often used as gamma-ray monitors [1,2], due to their advantages in price and easy fabrication at large scale. However, plastic scintillators have less sensitivity to low-energy gamma-rays because their constituents have low atomic number. Their usages are limited to gross gamma measurement

*Corresponding author.
E-mail address: yamasoto@popsvr.tokai.jaeri.go.jp (K. Yamasoto).

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only of higher energy gamma-rays or for an object with a known composition of radionuclides. This demerit leads to an unsatisfactory detectable limit of activity on low-energy gamma-ray measurements. Hence, a plastic scintillation detector is inappropriate for the surveillance of contaminations potentially containing low-energy gamma-ray emitters.

In order to improve the low sensitivity in the low-energy region of a large-area plastic scintillation detector, we have contrived a new type of phoswich detector, which is composed of a plastic scintillator for the gross gamma measurement and a thin inorganic scintillator for gamma-ray spectrometry. Commonly used phoswich detectors use a pulse shape discrimination technique, which can be often applied to simultaneous counting of radiations and activity measurement of low-energy gamma-ray emitters [3–6]. Our newly developed detector also uses this technique, and is intended not only to count total gamma-rays by gross gamma measurement but also to identify low-energy gamma-ray emitters by energy spectrometry.

This paper describes the design of a CsI(Tl)/plastic phoswich detector and its signal processing system. The performance of pulse shape discrimination is experimentally evaluated. Its detection efficiency and minimum detectable activity are experimentally evaluated and also estimated by the EGS4 (Electron Gamma Shower version 4) Monte Carlo code [7].

2. Design of CsI(Tl)/plastic phoswich detector and signal processing system

The newly designed phoswich detector consists of a thin plate of CsI(Tl) scintillator optically coupled on a plastic scintillator (BC-400). General properties of both scintillators are given in Table 1. CsI(Tl) is selected as the front scintillator because its atomic number is so high as to attenuate low-energy gamma rays when formed in a thin plate, the mechanical strength is sufficient, and the decay constant of the scintillation is quite different from that for BC-400, allowing us to apply a pulse shape discrimination technique.

The structure of the detector is illustrated in Fig. 1. The front surface area of the combined scintillator unit is $200 \times 200\,mm^2$, and the thicknesses of CsI(Tl) and BC-400 are 3 mm and 50 mm, respectively. The thickness of CsI(Tl) was optimized for measurement of the activity of a radionuclide that emits gamma rays of around 120 keV taking account of the lowest measurable

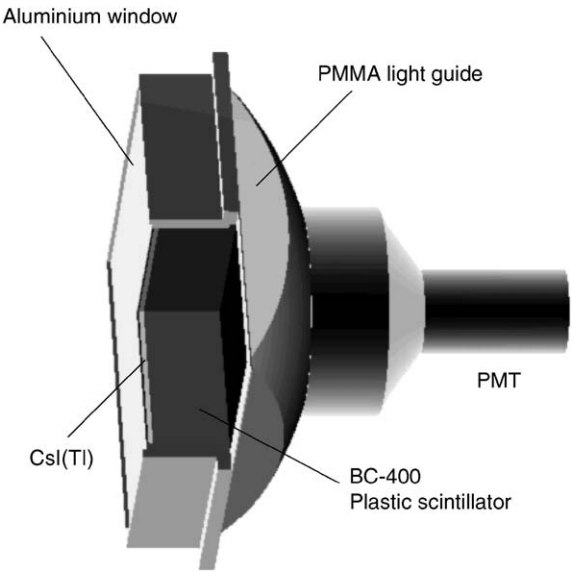

Fig. 1. Structure of the CsI(Tl)/plastic phoswich detector.

Table 1
Scintillator properties using in the CsI(Tl)/plastic phoswich detector [8]

Scintillator	Plastic scintillator (BC-400)	CsI(Tl)
Wavelength of max emission (nm)	423	540
Decay constant (μs)	0.0024	0.68(64%), 3.34(36%)
Specific gravity	1.103	4.51

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