Journal of Alloys and Compounds, 213/214 (1994) 437–439
JALCOM 4114

Simultaneous counting of α, β and γ rays with phoswich detectors

Shigekazu Usuda, Hitoshi Abe and Akira Mihara
Japan Atomic Energy Research Institute, Tokai-mura, Naka-gun, Ibaraki-ken 319-11 (Japan)

Abstract

Phoswich detectors for simultaneous counting of α, β and γ rays have been developed, which were prepared by combining two or three scintillators, ZnS(Ag), NE102A and/or BGO or NaI(Tl), with different rise times from each other. In order to adjust the pulse height ascribed to each scintillator within a dynamic range, a sheet of Au–Mylar was used, if necessary, as an optical neutral density filter for lowering the transmittance of scintillation of the ZnS(Ag). Characteristics of these phoswiches were examined by a pulse shape discrimination technique. Excellent discrimination among the radiations was attained for the prepared phoswiches.

1. Introduction

A thin ZnS(Ag) film scintillator is sensitive only to α rays and its decay time is slow [1]. Organic scintillators, NE102A and stilbene, are especially sensitive to β rays and have a fast decay time. Therefore a combination of the ZnS(Ag) and one of the organic scintillators, i.e. a ZnS(Ag)/NE102A or ZnS(Ag)/stilbene phoswich detector, was prepared for simultaneous counting of α and β (including γ) [2]. The phoswich had much better properties of pulse shape discrimination (PSD) between α and $\beta(\gamma)$ rays (figure of merit (FOM), 8–11) than single scintillators. However, it was difficult for the phoswich to adjust the pulse height within a dynamic range when too large a difference in pulse height existed between the two scintillators composing the phoswich.

Inorganic scintillators, NaI(Tl) and BGO, are highly sensitive to hard γ rays. If the rise time of the inorganic scintillators differs to some extent from that of the ZnS(Ag) and organic scintillators, alternative combinations are designable. This paper deals with the PSD properties of the prepared phoswiches. A description is also given of how to adjust the pulse height within a given dynamic range when a large difference is encountered.

2. Experimental details

Four scintillators of interest, ZnS(Ag) for α counting, NE102A for β counting and BGO and NaI(Tl) for γ counting, were used (see Table 1). The NaI(Tl) was sandwiched between two quartz glasses of ∅2 in×3 mm thickness to transmit scintillation light from the ZnS(Ag). Figure 1 shows a schematic arrangement of ZnS(Ag)/NE102A/BGO with an Au–Mylar filter for simultaneous counting of α, β and γ rays. The Au–Mylar filter was ∅2 in and 0.88 mg cm^{-2} and was placed behind the ZnS(Ag) to adjust the intensity of the scintillation light. The measurement system was the same as reported before [3], by which rise time and pulse height distributions were obtained at the same time. The radiation sources used were ^{244}Cm for α counting, ^{137}Cs and ^{60}Co for β and γ counting, ^{241}Am for soft γ counting and ^{90}Sr for β counting.

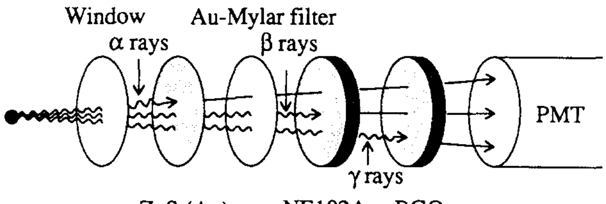

Fig. 1. Schematic arrangement of ZnS(Ag)/NE102A/BGO phoswich with Au–Mylar filter for simultaneous counting of α, β and γ rays.

3. Results and discussion

Rise time distributions of α and $\beta(\gamma)$ rays from ^{244}Cm and ^{137}Cs sources and the background (BG) were measured with the respective scintillators under the same PSD conditions. Table 1 gives the measured results. The ZnS(Ag) was quite insensitive to β and γ rays, its rise time (the maximum peak channel T) was the slowest and its BG level was very low. The NE102A had the fastest rise time and its full width at half-

0925-8388/94/$07.00
SSDI 0925-8388(94)04114-J

TABLE 1. Measured results with four single scintillators under the same PSD conditions

Scintillator	Source	Rise time (ns) T	Rise time (ns) $W_{1/2}$	Count rate (Hz)
ZnS(Ag)	^{244}Cm	429	19	815
(Ø2 in, 10 mg cm^{-2})	^{137}Cs	–	–	0.002
	BG	–	–	0.002
NE102A	^{244}Cm	194	5.4	818
(Ø2 in×5 mm thick)	^{137}Cs	186	5.4	817
	BG	186	4.6	5.3
BGO	^{244}Cm	326	22	862
(Ø2 in×5 mm thick)	^{137}Cs	338	33	5282
	BG	347	40	42
NaI(Tl)	^{137}Cs	296	11	1893
(Ø2 in×5 mm thick)	BG	298	14	30

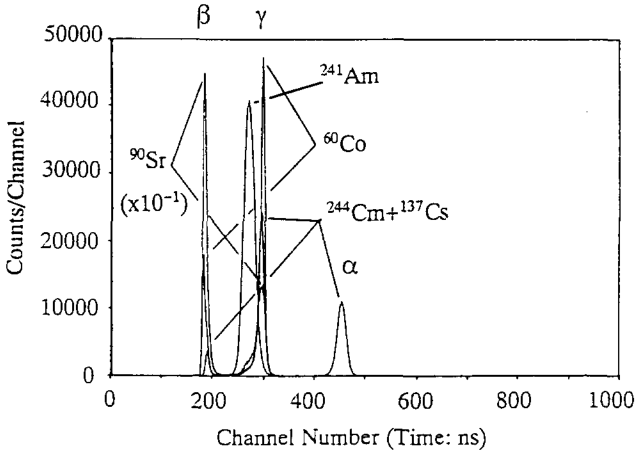

Fig. 3. Rise-time distributions of α, β and γ rays with ZnS(Ag)/NE102A/NaI(Tl) phoswich without Au–Mylar filter (sources ^{244}Cm + ^{137}Cs, ^{244}Cm, ^{137}Cs, ^{60}Co, ^{241}Am and ^{90}Sr).

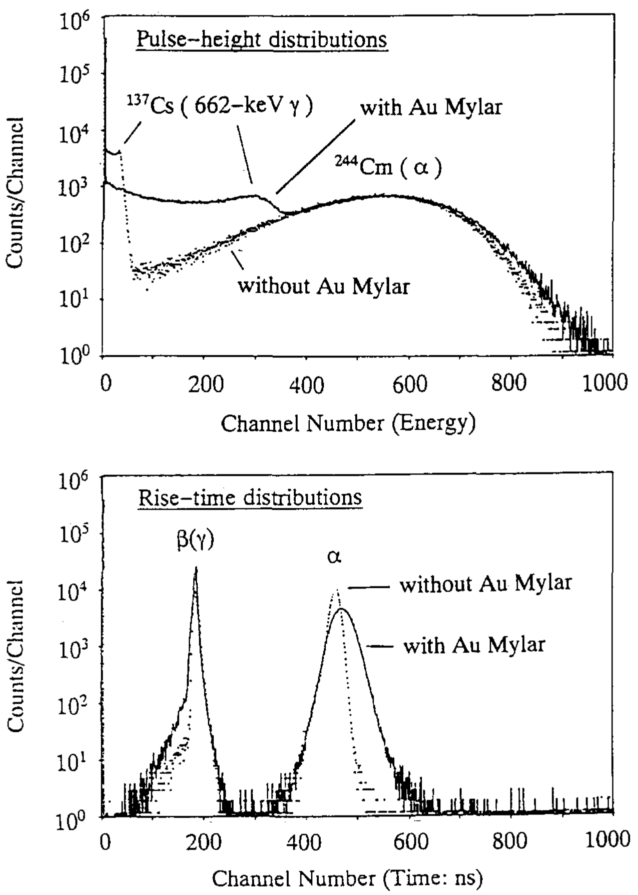

Fig. 2. Pulse height and rise time distributions of α and β(γ) rays with ZnS(Ag)/NE102A phoswiches with and without Au–Mylar filter (sources ^{244}Cm and ^{137}Cs).

maximum ($W_{1/2}$) was narrow. The BGO and NaI(Tl) had an intermediate rise time between the ZnS(Ag) and NE102A and the sensitivity to γ rays was very high. On basis of the results, the following phoswiches were designed: ZnS(Ag)/NE102A [2], ZnS(Ag)/BGO and ZnS(Ag)/NaI(Tl) for α and β(γ) counting; ZnS(Ag)/NE102A/BGO and ZnS(Ag)/NE102A/NaI(Tl) for α, β and γ counting.

Since the light output of the ZnS(Ag) is much larger than that of the NE102A or BGO [1], it was necessary to control each pulse height within a given dynamic range. In this case a sheet of Au–Mylar was suitable for an optical neutral density (ND) filter to lower the transmittance of scintillation light from the ZnS(Ag), because the transmittance of the Au–Mylar was roughly constant (within 10%–20%) for visible light of wavelength greater than 310 nm. This means that the pulse height ascribed to the ZnS(Ag) only can be lowered by a factor of 5–10 by interposing the Au–Mylar behind the ZnS(Ag) as shown in Fig. 1.

Figure 2 shows the pulse height and rise time distributions of α and β(γ) rays measured with the ZnS(Ag)/NE102A with and without the Au–Mylar filter. The signals from the phoswich with the filter were amplified by a factor of about 7 compared with the phoswich without the filter. Consequently, the phoswich without the filter did not enable simultaneous counting of α and soft γ rays, but the phoswich with the filter did. Although the $W_{1/2}$ value for the α ray peak was enlarged by the filter and the FOM value was diminished to 5.7 from 10, the degree of real separation between two peaks was apparently similar.

Another sheet of Au–Mylar was also interpolated in the ZnS(Ag)/BGO for α and β(γ) counting. The resolution of the phoswich with the Au–Mylar filter was not so good (FOM 2.5), but the counting efficiency for γ rays was greatly improved because of the high density of BGO. Since the light output of the NaI(Tl) is comparable with that of the ZnS(Ag) [1], the ZnS(Ag)/NaI(Tl) did not required the Au–Mylar filter. It was possible for the phoswich to count simultaneously α rays and not only hard γ rays but also soft γ rays. Its resolution was good (FOM 4.0).

The PSD properties of the ZnS(Ag)/NE102A/BGO and ZnS(Ag)/NE102A/NaI(Tl) with and without the Au–Mylar filter respectively for α, β and γ counting were examined. Figure 3 shows the rise time distributions with the latter phoswich. It was found that α, β and hard γ rays were detected with both phoswiches. For soft γ rays the detection was difficult with the ZnS(Ag)/NE102A/BGO but efficient with the ZnS(Ag)/NE102A/NaI(Tl). The resolution among α, β and γ rays for the ZnS(Ag)/NE102A/NaI(Tl) was superior to that for the ZnS(Ag)/NE102A/BGO.

The authors have been aiming at the development of detectors suitable for flow monitoring of actinide solutions [4]. The prepared phoswiches will also serve as detectors for other monitoring systems of α, β and γ rays. If other combinations of scintillators with different rise times from each other and with selective sensitivity to each radiation of interest are found, other types of phoswich detectors may be developed.

References

1 G.F. Knoll, *Radiation Detection and Measurements,* Wiley, New York, 1989.
2 S. Usuda, *J. Nucl. Sci. Technol., 29* (1992) 927.
3 S. Usuda, A. Mihara and H. Abe, *Nucl. Instrum. Methods A, 321* (1992) 274.
4 S. Usuda and H. Abe, *Nucl. Instrum. Methods A, 321* (1992) 242.