ELSEVIER

Journal of Alloys and Compounds 271–273 (1998) 58–61

Journal of ALLOYS AND COMPOUNDS

Simultaneous counting of radiation emitted from actinides with improved phoswich detectors by applying an optical filter

Shigekazu Usuda*, Kenichiro Yasuda, Satoshi Sakurai

Japan Atomic Energy Research Institute, Tokai-mura, Naka-gun, Ibaraki-ken 319-1195, Japan

Abstract

The effects of optical filters on rise times of output signals from a ZnS(Ag) scintillator have been examined, and phoswich detectors applying them were devised for more effective simultaneous counting of α and β (including γ) rays emitted from actinides. The optical sharpcut filters made the rise times slower and optical bandpass filters made them faster. In this paper, two improved phoswich detectors, ZnS(Ag)/sharpcut-filter/NaI(Tl) and ZnS(Ag)/bandpass-filter/CsI(Tl), are demonstrated. © 1998 Elsevier Science S.A.

Keywords: Phoswich detectors; Simultaneous counting; Optical filters; Rise times; Pulse shape discrimination

1. Introduction

To ascertain actinide behavior in nuclear fuel cycle facilities, it is meaningful to investigate simultaneous counting of different radiations emitted from actinides. The author and others have been working towards the development of efficient phoswich detectors suitable for actinide monitoring [1–6]. In Table 1, the phoswich detectors devised for simultaneous counting of radiations, including α rays, are summarized.

The phoswich detectors consist of plural scintillators having highly selective sensitivity to each radiation, and largely different decay times from one another, coupled to a single photomultiplier tube (PMT) [7]. The combinations of ZnS(Ag) for α rays and other scintillators, such as NE102A for β (including γ) rays and NaI(Tl) or BGO for γ (including β) rays have good properties for pulse shape discrimination among the respective radiations [1–4]. The combinations of ZnS(Ag), anthracene and/or ^{6}Li glass (NS8) were also demonstrated to have good properties among the radiations, plus fast and/or thermal neutrons, by using pulse height and/or pulse shape discrimination techniques [5,6].

Table 1
Phoswich detectors devised for simultaneous counting of radiations, including α rays

Phoswich detectors	Radiations	References
ZnS(Ag)/NE102A or stilbene	α, β(γ)	[1,2]
ZnS(Ag)/NaI(Tl) or BGO	α, γ(β)	[3,4]
ZnS(Ag)/NE102A/NaI(Tl)	α, β(γ), γ(β)	[3,4]
ZnS(Ag)/NS8	α, β(γ), n_{th}	[5]
ZnS(Ag)/anthracene, NE213 or BC501A	α, β(γ), n_f	[6]
ZnS(Ag)/NE102A/NS8	α, β(γ), n_{th}	[5]
ZnS(Ag)/anthracene/NS8	α, β(γ), n_{th}, n_f	[6]

n_{th}, thermal neutrons; n_f, fast neutrons.

Recently we have observed that rise times of output signals from ZnS(Ag) were somewhat changed by passing its scintillation light through an optical color filter. This phenomenon suggests that there is a possibility to prepare more effective phoswich detectors by controlling the rise times with the optical filter.

The present paper deals with the effects of optical filters, sharpcut and bandpass filters, on the rise times, and the application of the respective optical filters to the phoswich detectors, ZnS(Ag)/sharpcut-filter/NaI(Tl) and ZnS(Ag)/bandpass-filter/CsI(Tl), for more effective simultaneous counting of α and β(γ) rays.

2. Experimental details

The scintillators used were ZnS(Ag), NaI(Tl) and CsI(Tl), and their physical and optical properties [7] are shown in Table 2. To avoid deliquescence and to transmit scintillation light from the ZnS(Ag), the NaI(Tl) and CsI(Tl) were sandwiched between two pieces of optical glass of Ø50×3 mm*t*.

Fig. 1 shows the principle of a phoswich detector applying an optical filter, which was positioned between

*Corresponding author. Tel.: +81 29 2826814; fax: +81 29 2826798; e-mail: usuda@sglsun.tokai.jaeri.go.jp

0925-8388/98/$19.00
PII: S0925-8388(98)00024-3

Table 2
Physical and optical properties of the scintillators used and the rise times observed (the figures in parentheses indicates the FWHM of each rise time peak)

Scintillator (dimension)	Density ($g\ cm^{-3}$)	Decay time (ns)	Light output[a] (%)	Wavelength of maximum emission (nm)	Rise time observed
ZnS(Ag)[b] (Ø50 mm, 10 mg cm^{-2})	4.09	200	130	450	429 (19) ns for α
NaI(Tl)[c] (Ø50×5 mm*t*)	3.67	230	100	415	296 (11) ns for β(γ)
CsI(Tl)[c] (Ø50×5 mm*t*)	4.51	1000	45	580	594 (57) ns for β(γ)

[a]Relative values to NaI(Tl).
[b]Coated on an acetylcellulose sheet (thickness, 12 μm).
[c]Sandwiched between two pieces of quartz glass (Ø50×5 mm*t*).

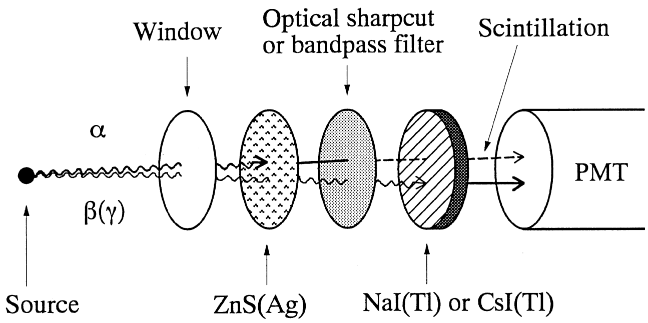

Fig. 1. Principle of phoswich detector applying an optical filter.

the ZnS(Ag) and another scintillator, NaI(Tl) or CsI(Tl). A thin Al-coated Mylar film (0.25 mg cm^{-2}) was used for shielding against ambient light. Scintillation light from the ZnS(Ag), which is attributable to α rays, passes through the optical filter and the other scintillator into the PMT. On the other hand, another scintillation light from the NaI(Tl) or CsI(Tl), which is attributable to β(γ) rays, directly enters into the PMT. The effects of the optical filters on the rise time of output pulses from the ZnS(Ag) were examined by measuring rise time distributions without the rear scintillator, NaI(Tl) or CsI(Tl).

As optical filters, sharpcut filters of Ø50×2.5-mm*t* glass and bandpass filters of Ø50×4-mm*t* glass were used. The sharpcut filters, sharply reducing the transmittance of the light in the short wave region, had a threshold transmission wavelength (λ_{lim}, the mean value of the two wavelengths at 5 and 72% transmittance) of 340–520 nm. The bandpass filters, transmitting only a band, had a wavelength of maximum transmittance (λ_{max}) of 340–480 nm, and a full width at half maximum ($\Delta\lambda_{1/2}$) of 7–10.5 nm and the transmittance at λ_{max} (T_{max}) of 35–69%. Properties of all the optical filters used were examined by measuring transmittance spectra using a spectrophotometer.

The rise time distributions (or pulse shape spectra) were measured by a pulse shape discrimination technique [8]. For counting of α and β(γ) rays, standard sources of ^{244}Cm and ^{137}Cs were used.

3. Results and discussion

3.1. Effects of optical filters on the rise time distribution

Fig. 2 shows the rise time distributions of α rays, which were observed with the ZnS(Ag) with and without the optical sharpcut or bandpass filter. The distributions in the

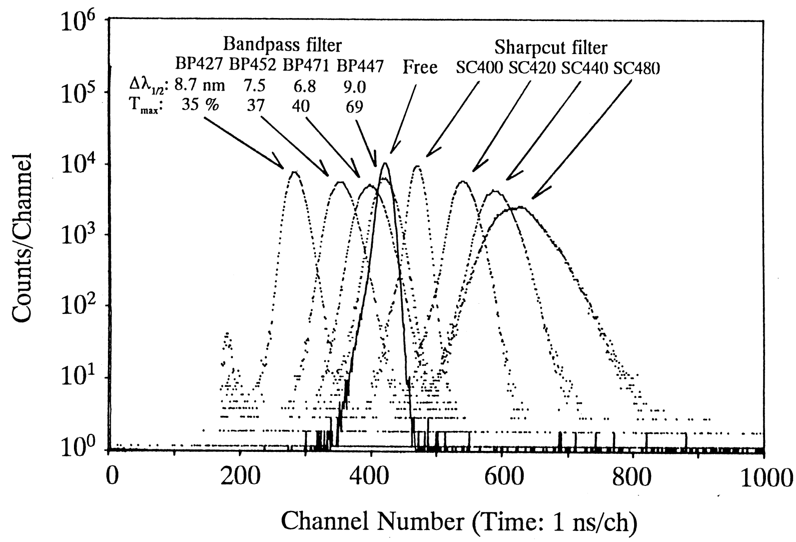

Fig. 2. Effects of optical filters on rise time distributions of α rays observed with ZnS(Ag).

right side of the filter-free distribution were influenced by the sharpcut filters of λ_{lim}=400–480 nm (SC400-SC480). The rise times became slower with increasing λ_{lim}, and the full width at half maximum (FWHM) for each rise time peak became wider depending on the reduction of transmittance of the scintillation from ZnS(Ag). Negligible variation in the distributions was observed for the filters with λ_{lim}=370 nm or less. On the other hand, it was difficult for the filters of λ_{lim}=500 nm or more to observe the normal distributions with the counting system used. These results suggest that a slow component of decay time exists in the longer wave region of the scintillation light from the ZnS(Ag).

The distributions in the left side of the filter-free distribution in Fig. 2 were observed by bandpass filters with λ_{max}=427–471 nm (BP427-BP471). The rise times became rather faster and it was, however, difficult to reveal the tendency for the λ_{max}. For the filters of $\lambda_{max}<390$ nm and $\lambda_{max}>480$ nm, it was impossible to produce the normal distributions owing to the low transmittance of the scintillation from ZnS(Ag). This suggests a fast component of decay in the shorter wave region of the scintillation light from the ZnS(Ag).

3.2. Application of the respective optical filters to phoswich detectors

The first demonstration is a ZnS(Ag)/NaI(Tl) phoswich applying a sharpcut filter of λ_{lim}=420 nm. Fig. 3 shows typical rise time distributions of α and β(γ) rays observed with the ZnS(Ag)/NaI(Tl) with and without the sharpcut filter. The rise time peak for α rays was moved from 400 to 520 channels by the sharpcut filter, while the peak for β(γ) rays was little affected. A figure of merit (FOM) [9], which expesses resolution between the peaks for α and β(γ) rays, was improved from 4.5 to 5.2, and the tailings of the other peaks became negligible due to the sharpcut filter.

The second demonstration is a ZnS(Ag)/CsI(Tl) phoswich applying a bandpass filter of λ_{max}=410 nm. Fig. 4 shows the rise time distributions of α and β(γ) rays observed with the ZnS(Ag)/CsI(Tl) with and without the bandpass filter. Only the rise time peak for α rays was moved from 400 to 260 channels, and FOM was improved from 2.1 to 4.3. As shown in Table 2, the rise times of output signals from single ZnS(Ag) and CsI(Tl) were 429 and 594 nm, respectively. Because of some overlapping with the other rise time distributions, the combination of ZnS(Ag) and CsI(Tl) was considered to be less valid. By applying the bandpass filter, this phoswich will be available for practical use. Since rise times of α signals became faster, this phoswich must be useful for higher α count rate.

4. Conclusion and future perspective

This study is now in progress and concluding results and future subjects are as given below.

(1) It was found that sharpcut filters made the rise times of output signals from ZnS(Ag) slower to a certain degree, while bandpass filters made them faster. These facts are very convenient for preparation of improved phoswich detectors for more effective simultaneous counting of α rays and other radiations.

(2) The respective optical filters were applied to two types of phoswich, ZnS(Ag)/sharpcut-filter/NaI(Tl) and ZnS(Ag)/bandpass-filter/CsI(Tl).

(3) It is important for the preparation of such phoswich detectors to know the optical properties of each decay component of the front scintillator, ZnS(Ag) in this study.

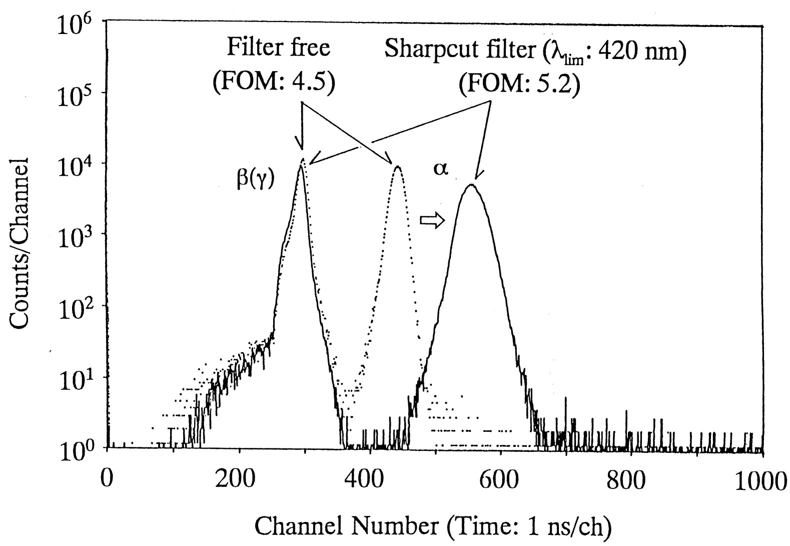

Fig. 3. Rise time distributions of α and β(γ) rays observed with ZnS(Ag)/NaI(Tl) phoswich with and without a sharpcut filter.

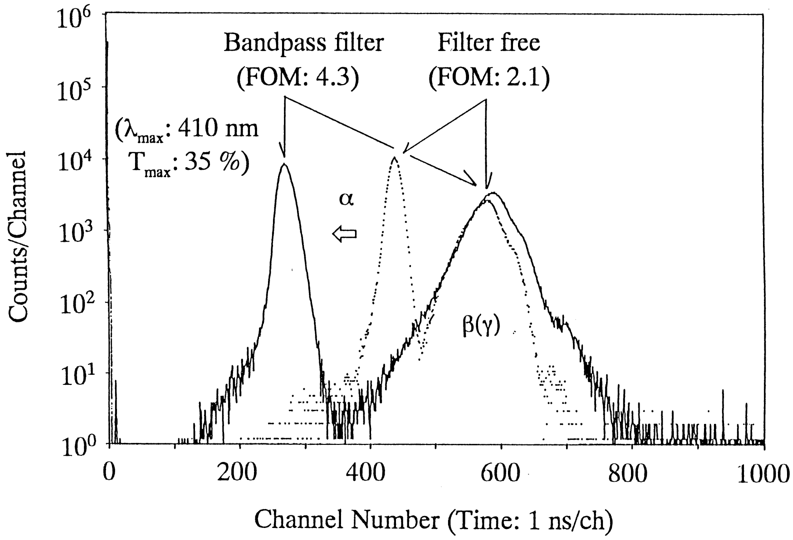

Fig. 4. Rise time distributions of α and β(γ) rays observed with ZnS(Ag)/CsI(Tl) phoswich with and without a bandpass filter.

It will certainly be necessary to measure emission spectra of scintillation light from ZnS(Ag).

(4) Our final interest is focussed on developing a practical and effective phoswich system suitable for actinide monitoring by applying optical techniques.

References

[1] S. Usuda, J. Nucl. Sci. Technol. 29 (1992) 927.
[2] S. Usuda, H. Abe, J. Nucl. Sci. Technol. 31 (1994) 73.
[3] S. Usuda, A. Mihara, H. Abe, Nucl. Instrum. Methods A 340 (1994) 540.
[4] S. Usuda, A. Mihara, H. Abe, J. Alloys Compounds 213–214 (1994) 437.
[5] S. Usuda, Nucl. Instrum. Methods A 356 (1995) 334.
[6] S. Usuda, S. Sakurai, K. Yasuda, Nucl. Instrum. Methods A 388 (1997) 193.
[7] G.F. Knoll, Radiation Detection and Measurements, 2nd ed., John Wiley & Sons, New York, 1979 and 1989.
[8] S. Kinbara, T. Kumahara, Nucl. Instrum. Methods 70 (1969) 173.
[9] R.A. Winyard, J.E. Lutkin, G.W. McBeth, Nucl. Instrum. Methods 95 (1971) 141.