The Characteristics Study on Detector for In-pipe Radioactive Contamination Counting

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SUMMARY

In this study, detectors characteristics for simultaneous counting of alpha and beta ray in a pipe were estimated. The detector were composed of thin ZnS(Ag) scintillator and plastic detector. The scintillator for counting alpha particles has been applied a polymer composite sheet, having a double layer structure of an inorganic scintillator ZnS(Ag) layer adhered onto a polymer sub-layer. The other for counting beta particles used a commercially available plastic scintillator. It was confirmed that the detectors were suitable for counting the in-pipe contamination.

1. INTORDUCTION

During the decommissioning, a large amount of radioactive wastes would be generated. These wastes are contaminated with various types of radioactive nuclides emitting alpha- and beta(gamma)-ray. These wastes have to be carefully managed, by being kept safe and secure from an environmental context. Therefore, the contamination level of the decommissioning wastes must be surveyed for free release in the future. A surface contamination is divided into removable and fixed contamination. Fixed contamination is measured by a direct method with a portable contamination monitor. And removable contamination is measured by an indirect method using smear paper and a low background proportional counter.

If the surface of the wastes to be measured is exposed on the outside, the measurement of the contamination level by direct and indirect methods can be easily measured. But, it is very difficult to count the radioactive contamination level of the pipe inside using conventional counting methods because of small diameter.

In this study detectors for simultaneous counting of alpha and beta ray in a pipe was developed. The phoswich detector is convenient for monitoring of alpha and beta contamination using only a single detector, which was composed of thin cylindrical ZnS(Ag) scintillator and plastic detector. The scintillator for counting a alpha particle has been applied a cylindrical polymer composite sheet, having a double layer structure of an inorganic scintillator ZnS(Ag) layer adhered onto a polymer sub-layer. The sub-layer in an alpha particle counting sheet is made of polysulfone, working as a mechanical and optical supporter. The ZnS(Ag) layer is formed by coating a ternary mixture of ZnS(Ag), cyano resin as a binder and solvent onto the top of a sub-layer via the screen printing method.

The other for counting a beta particle used a commercially available plastic scintillator. The plastic scintillator was simulated by using Monte Carlo simulation method for detection of beta radiation emitted from internal surfaces of small diameter pipe. Simulation results predicted the optimum thickness and geometry of plastic scintillator at which energy absorption for beta radiation was maximized. The characteristic of detector fabricated was also estimated. As a result, it was confirmed that detector capability was suitable for counting the beta ray.

The overall counting results reveal that the developed detector is efficient for simultaneous counting of alpha and beta ray in a pipe.

2. EXPERIMENTAL

2.1. The preparation of ZnS(Ag) scintillator for alpha-ray counting

Polysulfone phosphor sheet consisting of polysulfone(PSf) as polymer matrix and ZnS(Ag) as a phosphor were prepared through the solidification of polymeric solutions and application the ZnS(Ag) on the polysulfone sheet. To formulate a base sheet, PSf were dissolved in MC (methylene chloride) and then cast on the glass plate with doctor blade. Also, scintillator solution was prepared by dissolving cyano resin into Dimethylformamide (DMF) and adding the ZnS(Ag) scintillator. The prepared one was sifted on a base sheet with a screen printer. All of the preparation procedure was shown in Fig. 1.

An alpha-particles range in a material is very short. The alpha-particle-detection efficiencies of ZnS(Ag) layers are considerably more variable because this material is available only in the form of microcrystalline powder that must be deposited as a thin layer (often with a binder) to form a suitable detector. Therefore, the ZnS(Ag) layers thickness is critical for optimizing its detection efficiency. The thickness should be thick enough to react with most of the deposited alpha-particles, but also thin enough not to induce a significant absorption of the produced scintillation. Its optimum thickness of the ZnS(Ag) layer is about 15 m.

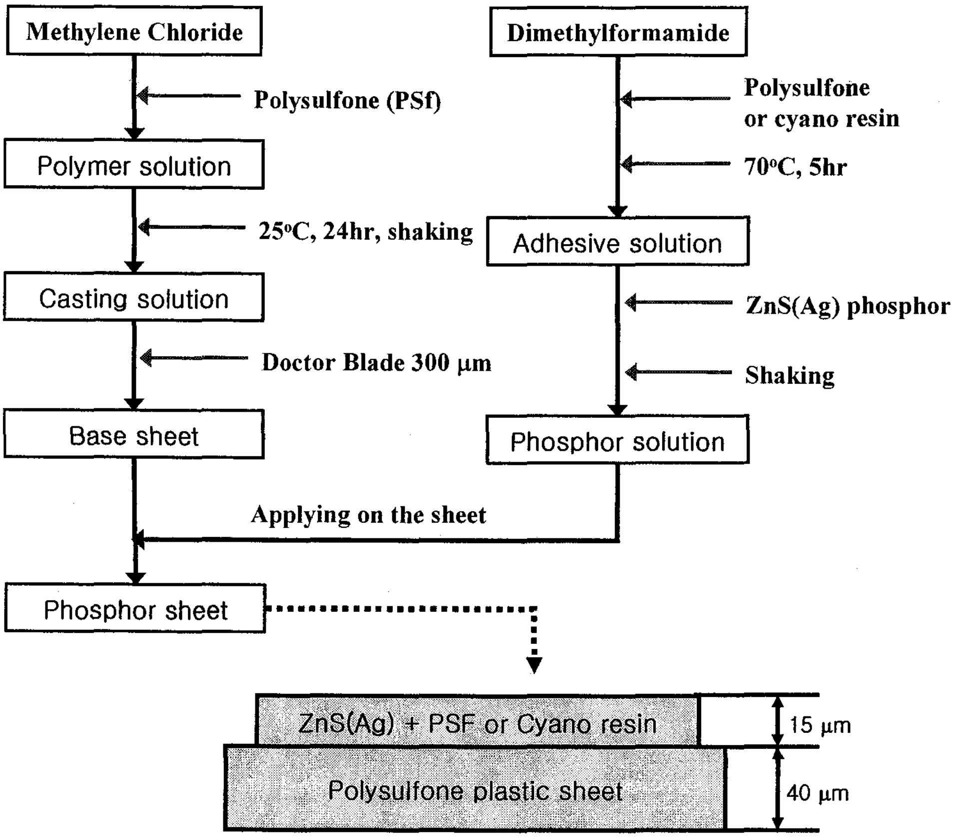


Figure 1. Preparation procedure of the polysulfone phosphor sheet using ZnS(Ag) scintillator.

2.2. The plastic scintillator and radiation counting

The used plastic detector for beta-ray counting is BC-400 and BC-408(Bicron). The general properties of the plastic detector are shown at Table 1. The plastic scintillator was cut into the dimensions of 26 mm (diameter) × 5.2 mm (thickness) and polished.

Am-241 and Sr/Y-90 standard solution with total activity of about 300 Bq/sample on the 5 cm diameter stainless steel planchet was slowly evaporated to fix the Am-241 and Y/Sr-90. After the evaporation, 4.5 cm diameter ZnS(Ag) and plastic scintillation detectors were placed on the planchet. This sample was faced toward the entrance window of the PMT.

Table 1. The general properties of the plastic scintillator

Parameter	BC-400	BC-408
Base material	Polyvinyltoluene	
Density	1.32 g/cc	
Light output, % Anthracene	65	64
Refractive index	1.58	
Rise time, ns	0.9	
Decay time	2.4	2.1
Wavelength of Max. Emission, nm	423	425

3. RESULTS AND DISCUSSION

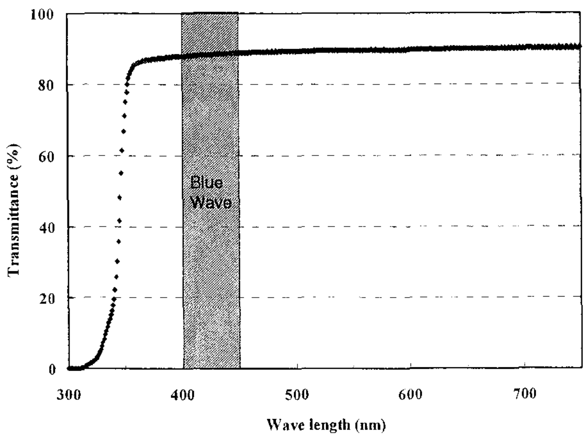
3.1. Properties of the ZnS(Ag) scintillator sheet for alpha-ray detection

In the previous study[1] the medium, scintillator-embedded polymer membrane for detecting the alpha-ray, was prepared by impregnating organic scintillators in a membrane structure. The plastic scintillator consists of PSf as a matrix with PPO as an organic scintillator and POPOP as a wave shifting agent dissolved in the matrix. But, an organic plastic scintillator was inadequate to detect the alpha particle in the alpha-beta mixing field because its light output is smaller than beta ray one. This phenomena is caused by the relatively small scintillation efficiency of the organic scintillators in a alpha particle detection, compared to the high efficiency of the inorganic scintillators, as indicated in Table 1. So, a thin inorganic scintillator sheet was prepared, which consisted of a very uniform deposit of ZnS(Ag) scintillator applied to on side of clear polysulfone plastic sheet.

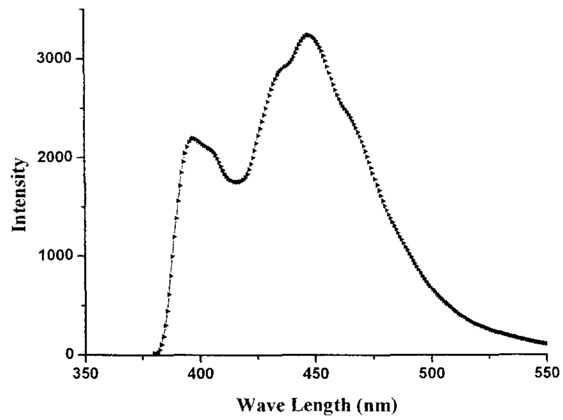
The light transmission rate through a base sheet has a very significant impact on its scintillation detection efficiency, since the scintillated light has to travel through the membrane structure to reach a PMT. Therefore, the scintillation membrane itself needs to be transparent or highly transmittable. As shown in Fig. 2(a), the transmission rate of the prepared sheet is about 90% near blue wavelength, thus revealing a high transparency. Also, the PMT, for detecting the produced scintillation, reacts effectively near a blue wave (wavelength : about 400 - 450 nm) . So, the wavelength of maximum emission of the ZnS(Ag) phosphor sheet was measured. It is shown Figure 2(b). The peak of ZnS(Ag) was detected near 450 nm, revealing that they can be highly efficient for a PMT measurement.

Table 1. Approximate relative scintillation efficiencies of the various scintillators. The relative light output of NaI(Tl) per unit energy deposited by beta-rays is taken as 1.0 [2]

Solid scintillator	alpha	Beta	alpha/beta
ZnS(Ag)	2.0	1.0	2.0
CsI(Tl)	0.4	0.5	0.8
NaI(Tl)	0.5	1.0	0.5
CsBr(Tl)	0.05	0.15	0.3
KBr(Tl)	0.01	0.04	0.25
CaF_2(Eu)	0.1	0.4	0.25
NaCl(Ag)	0.01	0.04	0.2
Organic	0.02	0.25	0.08
Ionization detector			1.0



(a)



(b)

Figure 2. The transmission rate of the base polysulfone sheet in the visible light range (a) and the light emission spectrum of the ZnS(Ag) scintillator sheet(b).

For the alpha-ray detection test of the prepared scintillator sheet, a radioactive solution of a Am-241 emitting alpha particles was spotted onto a ZnS(Ag) scintillator sheet. The amount of scintillation produced by the interaction between ZnS(Ag) and alpha particle was measured using a PMT. The alpha-ray spectra measured using the ZnS(Ag) scintillator sheet and PMT was shown Fig. 3. The measured spectra showed the good detection ability for the alpha particles.

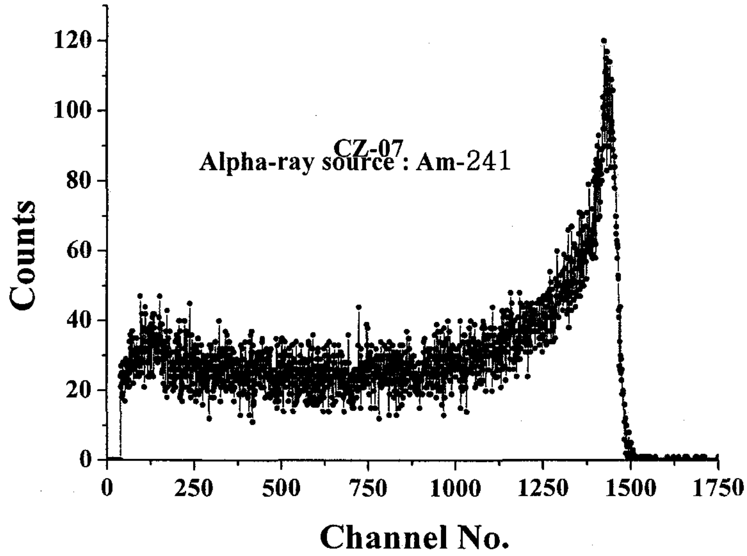


Figure 3. The alpha-ray spectrum of the thin ZnS(Ag) scintillator sheet measured using Am-241 alpha source.

3.2. Alpha- and beta-ray counting in the internal pipe

The solution of a radiation source was slowly evaporated to fix the Am-241 and/or Sr/Y-90 on the ZnS(Ag) screen in the dryer to evaluate a possibility of simultaneous detection of alpha- and beta-rays. This sample was faced toward the entrance window of the plastic scintillator at 13mm distance. The result was illustrated in Fig. 4. Alpha-ray events were observed in the latter channel attributable to the energy of alpha-particles but events attributable to beta-particles were observed in the lower channel than that for alpha events. Therefore alpha or beta events were distinguishable from the other by optimizing the pulse height discrimination level. The distance between a plastic scintillator and a ZnS(Ag) scintillator has to be considered because of the limit of a system size, detection efficiency varied with an incidence angle of a scintillation light toward to the entrance window of a plastic scintillator and a scintillation light loss in the air between a plastic scintillator and a ZnS(Ag).

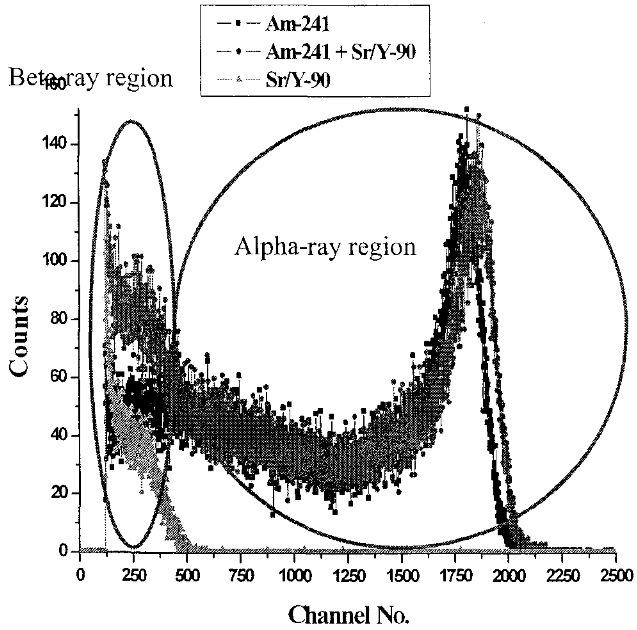


Figure 4. Pulse height spectrum of the ZnS(Ag) and plastic detector for Am-241 and Sr/Y-90.

Fig. 5 shows the pulse height spectrum as a function of the distance between a plastic scintillator and a ZnS(Ag). The maximum counting was observed when distance was 2cm. This indicates that the light loss occurring on the transmission to the entrance window of a plastic scintillator is smallest. But, unlike Fig. 4 the peak attributable to energy of alpha-particles was not observed and the maximum channel No. counted was small. In the case of Fig. 5, it is because a ZnS(Ag) layer applied to one side of polyester plastic sheet was faced toward the entrance window of a plastic scintillator. On the other hand, the light loss was occurred by the polyester sheet since the polyester sheet was faced toward the entrance window of a plastic scintillator. In spite of the light loss alpha or beta events were distinguishable from the other because the maximum channel No. counted attributable to the beta-rays was much smaller than that for alpha-rays.

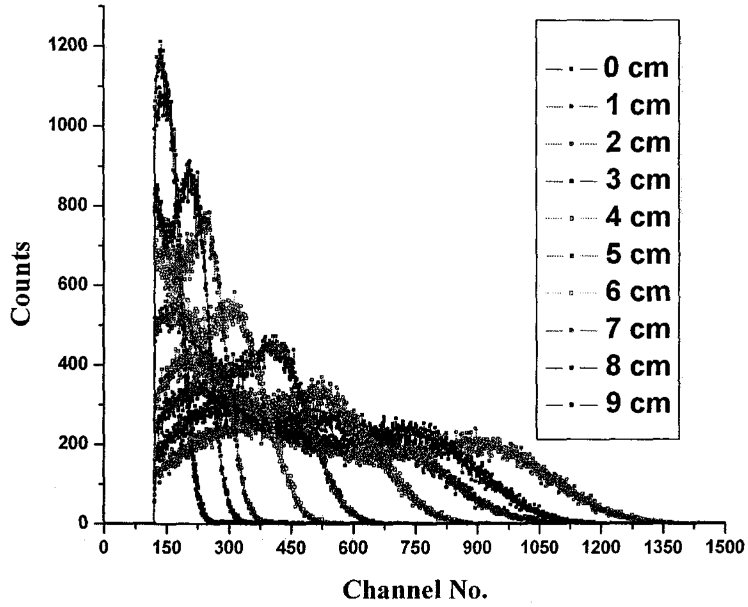


Figure 5. Pulse height spectrum of Am-241 according to distance.

4. CONCLUSION

Thin phosphor polysulfone sheet were prepared to detect an alpha-particle. The phosphor sheet is composed of a polysulfone sheet coating an inorganic phosphor, ZnS(Ag), and the base polysulfone sheet being solidified from a homogeneous casting solution. And then, the ZnS(Ag) phosphor was adhered on the base sheet using screening method. Its optical property as a scintillation detector is excellent. And, the efficiency of the alpha-particle detection of the prepared ZnS(Ag) sheet is measured with alpha-ray source Am-241. The thin ZnS(Ag) polysulfone sheet shows a reliable capacity for the detection of the alpha-particle, and can be applied to the measurement of a alpha-ray. The plastic scintillator with 26mm diameter and 5 mm thickness was applied to the PMT for measuring the in-pipe beta-ray. It was confirmed that this detection system was suitable for measuring the contamination of pipe inside.

REFERENCE

[1] B. K. Seo, Z. H. Woo, G. H. Kim, W. Z. Oh, K. W. Lee, and M. J. Han, Preparation and Property of the Polymer Scintillator for the Alpha Contamination Monitoring, WM05 Conference, Feb. 27~Mar. 3, 2004, Tucson, AZ.

[2] J. M. R. Hutchinson, NIST Measurement Services : Alpha-Particle Calibration (2004), NIST Special Publication 250-5a, p. 14, 2004.