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Evaluation of luminance performance of scintillating film for monitoring the position of a radioactive source in an NDT apparatus

Kyung-Jin Lee · Jeong-Ick Yun · Byung-Gi Park · Sin Kim* · Bong-Soo Lee**

Institute of Future Energy Technology · Cheju National University · Konkuk University***

— Abstract —

In domestic nondestructive testing(NDT) field, there have recently been radiation exposure accidents due to a disregard for confirmation of the position of radioisotope during the test. In order to prevent these kinds of accidents, a scintillating film has been developed. The scintillating film that can convert gamma-ray to visible light has a function of the position detection of radioisotope in a opaque guide tube of an NDT apparatus. The aim of this study is to enhance the visibility performance of the scintillating film and find out the best configuration of the scintillating film. In order to find appropriate materials for the scintillating film, various inorganic scintillating materials were evaluated in this work. An absolute luminance of the scintillating films was measured by luminance meter for evaluation of visibility performance. Ir-192 gamma projector was used for NDT apparatus. The experiment shows that the scintillating film with reflective layer was the more effective performance for visibility. The higher mixing ratio of scintillating material to binding material, the higher luminance was measured. $Gd_2O_2S(Tb)$ inorganic powder as the scintillating materials had the best performance for visibility of the scintillating film. The developed scintillating film helps to ensure safer environment to the operators.

Key words : radiation accident, ^{192}Ir source projector, guide tube, scintillating film, inorganic scintillator, radioactive source position detection, luminance performance

Ⅰ. INTRODUCTION

In the NDT field, there were radiation exposure accidents in Ulsan and in Gyeongnam province in November 2000 and in January 2003, respectively. Both accidents have been reported that the operators couldn't confirm the location of a radioisotope during their works. When the operators carry out the nondestructive test, they must make sure always of the position of the radioactive source with a private alarm meter and a survey meter according to the radiation safety regulations. The present NDT apparatus like a radioactive source projector can not indicate directly the location of source whether in container or not. If the apparatus has the function in itself, operators could recognize it

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책임저자 : 이경진, (151-818) 서울시 관악구 봉천 7동 산4-2 서울대학교 연구공원 본관 516호
(주)미래와도전 미래에너지기술연구소
Tel : 02-872-6415
E-mail : cagelee@fnctech.com

easily and it helps to prevent these kinds of accidents.

The aim of the study is to develop a scintillating film that can detect the position of a radioisotope in the guide tube of radioactive source projector. One of the primary works for configurations of the film is the choice of scintillation materials which remains one of the most useful materials available for the detection of radiations[1]. Various scintillating materials and structures for the scintillating film have been investigated to enhance the efficiency of light emission.

Ⅱ. MATERIALS AND METHODS

1. Guide tube and scintillating film

Ir−192 source projector is a gamma-ray NDT apparatus that consists of a source container, a controller, and a guide tube with source stop. During the test, the radioactive source goes back and forth between the container and the source stop through the guide tube by the remote controller. The guide tube plays a role of a flexible moving pass of the radioisotope and a prevention from a physical exposure of the radioisotope. The guide tube is made of a flexible stainless steel and PVC(Polyvinyl Chloride).

The scintillating film is adhered to the surface of the guide tube. It converts a gamma-ray to visible light which color is dependent on a scintillating material. When the radioisotope is passing through the guide tube, the scintillating film emits visible lights. Therefore, the position of the radioisotope is identified by detecting a light emission with naked eyes.

Fig. 1 shows a structure of the scintillating film with 4 layers: base layer, reflective layer, active layer, and protective layer. The base layer supports the structure of film. The reflective layer increases an intensity of light emission by reflection of the emitted light from the active layer. The active layer includes scintillating materials to react to radiations. And the protective layer protects active layer.

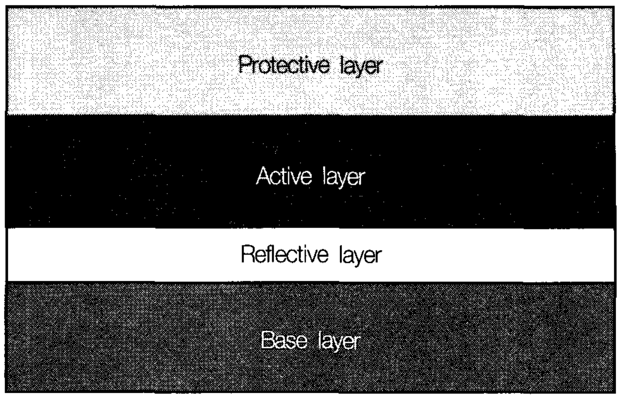

Fig. 1. Configuration of scintillating film

2. Scintillating materials

Scintillating materials have been produced for various applications by commercial manufacturers[2]. This work have focused on developing a scintillating film which has enough light emission to confirm the position of the radioactive source with naked eyes. Hence, the choice of the scintillating materials is one of the most important factors to develop the scintillating film. As a scintillating material, organic and inorganic materials has been used for various applications. The organic materials have generally lower intensity of light emission than the inorganic materials. However, the organic materials with a plastic form have an advantage to be easily fabricated to the film. Whereas the inorganic materials are not easy to fabricate to the film because their form exist as a powder[1]. Table 1 shows the properties of the used scintillation materials in this work.

3. Experiment set-up

In order to evaluate a performance of the scintillating film, Ir−192 source projector was installed according to the NDT process. The remote controller and the guide tube were connected into the source container. The activities of Ir−192 were about 7∼30[Ci]. The scintillating films fabricated for a per-

Table 1. Properties of inorganic scintillating materials

Scintillator	Emission peak [nm]	Density	Emission color
$Gd_2O_2S(Tb)$	544	7.50	Green
$Gd_2O_2S(Eu)$	626	7.50	Red
$Gd_2O_2S(Pr)$	513	7.50	Green
$Gd_2O_2S(Pr,CE,F)$	513	7.50	Green
$La_2O_2S(Eu)$	624	5.70	Red
$La_2O_2S(Tb)$	543	5.70	Green
CsI(Tl)	540	4.50	Yellow

Fig. 2. Experiment set-up

formance evaluation were put on the surface of the guide tube as shown in Fig. 2.

Experiment was monitored and recorded with digital camcoder to make sure of light emission of the scintillating films when the source was moving from the container to the source stop. A luminance of the emitted light from the scintillating films was measured by a luminance meter(Minolta LS-100).

Ⅲ. RESULTS AND DISCUSSION

The most important role of the scintillating film is to identify the position of the radioisotope in the guide tube. To confirm it by naked eye, the emitted light from the scintillating film has to have a detectable brightness and contrast to the illumination environment. Fig. 3 shows that the scintillating film have emitted light at the position of the radioisotope in the guide tube. Bright area with a diameter of about 25[mm] moved simultaneously along the radioisotope in the guide tube. As the bright area exists locally by radioactive source, the film can detect the source position in the guide tube.

1. Performance of the reflective layer

A luminance performance of the scintillating film depends a reflective layer. To evaluate performance of the reflective layer of the scintillating film, TiO_2 white paint was introduced for the reflective materials. The sample is made of PE(Polyethylene) thin film, TiO_2 white paint and scintillation materials

Fig. 3. Emitting scene from the scintillating film on the guide tube

Table 2. Configuration of the scintillating film sample for reflection performance test

Layers	Material	Thickness[㎛]
base	PE thin film	100
reflective	TiO_2 white paint	65
scintillating	$Gd_2O_2S(Tb)$:Binder (3:1)	100

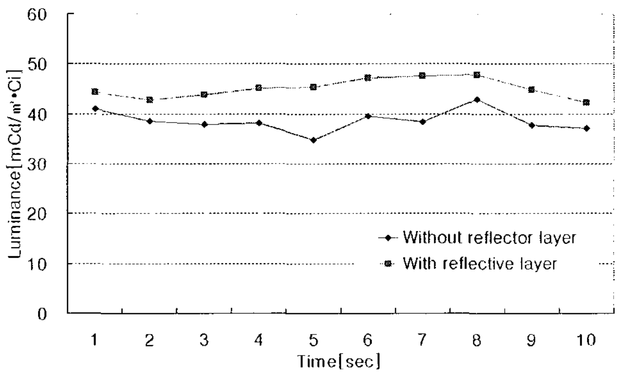

Fig. 4. Luminance comparison for the performance test of reflective layer of scintillating film

(Table 2). In order to compare the performance of reflective layer, we made two types of samples. one has the reflective layer, and the other doesn't. Fig. 4 shows that the luminance of the sample with reflective layer maintains higher on the average than that of the sample without reflective layer.

2. Composition of the scintillating layer

The inorganic scintillators are supplied by powder. So the samples were fabricated by mixing the powder and organic binding solvent to form a thin film layer. Binding material should be transparent and have a good dispersion ability. Fig. 5 illustrates luminance performance to mixing rate between scintillator powder and binding material. As increasing the ratio, the performance goes up. But the maximum rate restrains due to alleviation of degree of dispersion and flexibility.

3. Types of Scintillation materials

The choice of inorganic scintillation materials is the most important factor to effect on the luminance performance of scintillating film. Especially, their fluorescence efficiencies set the maximum value of the luminance of the scintillating film[3]. Table 3 shows the measurement results of the various inorganic scintillating films. It shows that the doping material, which determines emitting wave length, has an effect on the luminance performance even though the basic scintillating material is the same. Because light wave length affects in visual performance[4]. The luminance of $Gd_2O_2S(Tb)$ samples were appeared to be the best.

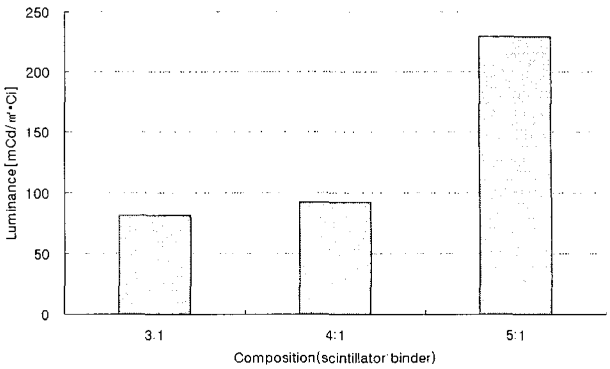

Fig. 5. Luminance measurement for scintillating film with various mixing rates

Table 3. Luminance measurements for the various inorganic scintillating films

Scintillator	Luminance [mCd/m^2 · Ci]
$Gd_2O_2S(Tb)$	87.0
$Gd_2O_2S(Eu)$	43.7
$Gd_2O_2S(Pr)$	36.6
$Gd_2O_2S(Pr,CE,F)$	44.9
$La_2O_2S(Eu)$	8.0
$La_2O_2S(Tb)$	33.8
CsI(Tl)	34.8

Ⅳ. CONCLUSION

Scintillating film is a new device for detecting the radioactive source position in an opaque guide tube of NDT apparatus. As the film indicates the radioactive source position by visual light, it can locate a radioactive source in an opaque object. To find out the best composition of the film, various samples were made and evaluate in their luminance performance. The test samples was fabricated with various inorganic scintillation materials and with various structure of layers. The brightness of the inorganic scintillating films was enough to figure out the source position by naked eyes. The experimental results showed that the reflective layer was more effective in enhancing to utilize the emitting light. And mixing rate between scintillator and binding material was important. Generally the higher rate of scintillating material, the higher luminance was measured. $Gd_2O_2S(Tb)$ inorganic powder of scintillation materials had the best performance. Applying in NDT field, this technology helps to ensure safer environment to the operators.

V. ACKNOWLEDGEMENTS

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• 국문요약

비파괴검사 장치 내 방사선원 위치감시용 섬광필름의 발광성능 평가

미래에너지기술연구소 · 제주대학교[*] · 건국대학교[**]

이경진 · 윤정익 · 박병기 · 김 신[*] · 이봉수[**]

최근 비파괴검사 현장에서 검사 중 검사장치 내 방사선원의 위치를 확인하지 못하여 방사선 과피폭 사고가 종종 발생하고 있다. 본 연구는 방사선원의 노출여부나 위치 미인지로 인한 방사선 사고를 예방하기 위해 방사선원위치를 감시할 수 있는 섬광필름을 개발하는데 있다. 섬광필름은 방사선 비파괴 검사 장비의 가이드튜브 내에 존재하는 선원의 위치를 육안으로 탐지할 수 있는 신소재이다. 연구를 통해 섬광필름의 발광성능을 평가하고 최적의 필름 설계를 꾀하였다. 필름에 적용된 발광물질은 무기 섬광체를 이용하였고, 다양한 층을 갖는 형태의 필름을 제작하여 성능을 평가하였다. 필름의 발광성능은 광도계를 이용하여 측정하였고, 비파괴 검사장비는 Ir-192 감마선 조사기를 사용하였다. 실험결과, 섬광필름의 발광은 육안으로 선원의 위치를 감시할 수 있었으며, 선원의 이동에 따라서 발광영역도 동시에 이동하면서 형성되었다. 또한, 섬광필름에 반사층을 두는 것은 광 이용률의 증대시켜 발광성능을 높이는 데 매우 효과적이었다. 섬광체와 분산용제의 혼합비에 따라서도 성능변화가 나타났으며, 일반적으로 섬광체의 양이 높을수록 발광성능은 높게 나타났다. 그러나 분산 특성이 변화로 혼합비는 일정 농도 이하로 제한되었다. 섬광체 중에서는 $Gd_2O_2S(Tb)$ 무기섬광체가 가장 높은 발광성능을 보여주었다. 개발된 섬광필름을 비파괴 검사 장비에 적용하게 된다면 방사선종사자에게 보다 안전한 작업환경을 제공할 수 있을 것이다.

중심단어 : 방사선 피폭사고, Ir-192 감마선조사기, 가이드튜브, 섬광필름, 무기섬광체, 방사선원 위치탐지, 발광성능