Visual Performance of Scintillating Film for Monitoring the Position of Radiation Source in Nondestructive Testing

Kyung-Jin Lee

Institute of Future Energy Technology, FNC Technology Co., Seoul, Korea
cagelee@fnctech.com

1. Introduction

Radiation technology is clean and reliable so that is widely used for nondestructive testing (NDT). Recognizing its advantage, many countries have invested a considerable amount of efforts in improving the performance and safety of NDT. However, radiation exposure accident in NDT is became an obstacle to its progress. In the domestic NDT field, the accident has occasionally happened more than once a year according to the Korea Institute of Nuclear Safety (KINS) reported. The major cause of the accidents was that the operators could not actively perceive the radiation source being escaped from a safe area while working. Some accidents are resulted from an equipment failure or a discharged battery. It is necessary to prevent the radiation exposure accidents and reduce radiation exposure dose with a trouble-free monitoring system. Therefore, our objective is to develop a trouble-free monitoring system with the scintillating material that can indicate the position of the radiation source. The scintillating film indicates the position of radiation source as emitting visual light at the position of the radiation source. In this work, we fabricated various scintillating film with different compositions and thickness, and estimated their visual performances as a function of luminance.

2. Material and method

Scintillating materials produce light by interaction with ionizing radiation. Scintillating film has basically the same mechanism of the scintillation detector. We introduced a special design for the film to focus on monitoring the position of a radioisotope source and enhancing its visual performance.

The film was composed of 4 layers: base, reflective, active, and protective layer. In the active layer, radiation interacts with scintillating material and is transformed into visual light. Reflective layer increases light output by reflecting some of light forward. Protective layer protects the active layer and film's surface. The base layer supports the structure of film.

One of the most important tasks for fabrication of the scintillating film is the choice of scintillation materials composed of the active layer. In our previous research on comparing their performances between organic and inorganic scintillating film, inorganic scintillating materials are better than the organics in the view of luminance performance(1). Gd_2O_2S:Tb, Gd_2O_2S:Eu, Gd_2O_2S:Pr, La_2O_2S:Eu, La_2O_2S:Tb, and CsI:Tl were tested in the study. The film was fabricated by mixing the scintillating powders and binding materials. A mixing ratio of the mixtures (scintillator: binding material) was changed from 1:1 to 5:1 in weight ratio. A thickness of the film was also changed.

In order to evaluate visual performance of the film, the visibility was introduced. Visibility defines how well a target can be seen by the naked eye. Many factors influence visibility. One of the most important factors affecting visibility is luminance (brightness) contrast. The higher luminance is, the better visibility is obtained if the environment luminance is not changed(2). The brightness of the film was estimated with luminance meter. The samples of the film stuck on the surface of the guide tube and were irradiated with an Ir-192 gamma-ray projector. While the Ir-192 is moving forward and backward, the emitting light from the samples was observed and estimated with a camcorder and a luminance meter.

3. Results and discussion

The most important role of the film is to indicate the position of the radiation source in the opaque guide tube. To confirm it by the naked eye, the emitting light has to have a detectable brightness and contrast to the background luminance.

The relative brightness of the film with various inorganic scintillating materials was measured and listed in Table 1. As listed in Table 1, a scintillating film with Gd_2O_2S:Tb

Figure 1. Light emitted from scintillating films along with the moving radiation source Ir-192, 10.5 Ci) in the opaque guide tube

showed the best among them. An emitting peak wavelength among Gd_2O_2S:Tb is 545nm that is known to be good for visible sensitivity(3). A scintillating material of Gd_2O_2S:Tb was selected for the scintillating film in order to indicated the position of the radiation source.

As a binding material, an acrylic and a polyvinyl-chloride (PVC) dispersant were used for constructing thin film layers. The film samples were fabricated with mixing the powder of Gd_2O_2S:Tb and the binding materials.

Figure 1 shows that the scintillating film emits visual light when the source moves forward and backward. The bright area with

Table 1. Comparison of measured luminance performance of the various scintillation materials (Ir-192, 20 [Ci])

Scintillation material	Relative brightness	Light yield (Photons/MeV) (3)
Gd_2O_2S:Tb	1.00	60,000[a]
Gd_2O_2S:Eu	0.50	-
Gd_2O_2S:Pr	0.41	50,000[a]
Gd_2O_2S:Pr,Ce,F	0.52	35,000[a]
La_2O_2S:Eu	0.12	-
La_2O_2S:Tb	0.51	-
CsI:Tl	0.67	66,000[b]

[a] Measured at 60~80 [keV]

[b] Measured at 662 [keV]

diameter of about 25mm was observed and moved simultaneously along with the moving source. As the bright area exists locally, the scintillating film can discriminate the source position in the opaque guide tube.

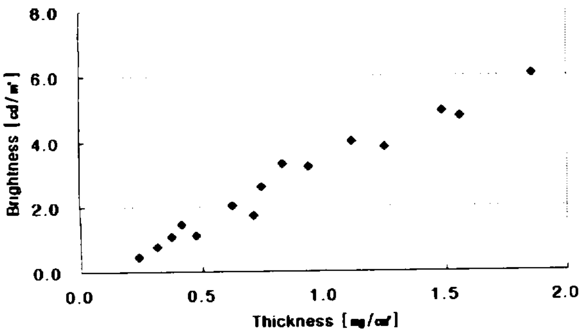

Figure 2. Measurements of brightness of the scintillating films mixing with acrylic dispersant (Ir−192, 12.0[Ci])

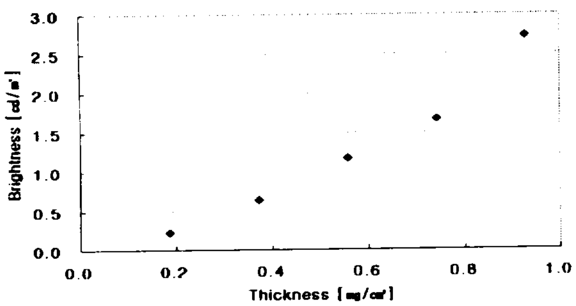

Figure 3. Measurements of brightness of the scintillating films mixing with PVC dispersant (Ir−192, 15.7[Ci])

Figures 2 and 3 show an effect of the film thickness on the brightness of the scintillating film with the acrylic and PVC dispersant, respectively. The thicker film resulted in the higher brightness of the scintillating as shown in Figure 2 and 3, respectively. However, the mixing ratio and the thickness of the scintillating film were restrained because the limits of dispersivity of the scintillating powder and flexibility of the scintillating film.

4. Conclusion

A scintillating film was developed in order to indicate visually the position of a radioactive source in an opaque guide tube of NDT apparatus. The various samples were fabricated to find out the best composition between scintillating material and binding materials. The experimental results showed that the scintillating film with Gd_2O_2S:Tb had the best performance on luminance.

The brightness of the scintillating film with Gd_2O_2S:Tb was proportional to the thickness of the film. The position of the radiation source in the opaque guide tube could be observed by the naked eye. Therefore, the scintillating film will be helpful to alleviate radiation exposure accident by visual observation of the position of radiation source from a distance.

REFERENCES

1. K. J. Lee, J. I. Yun, Y. S. Kim, S. Kim and B. S. Lee, "Experimental Evaluation of Luminance Performance of an Organic and an Inorganic Scintillating Film for Locating Radioactive Source in an NDT Apparatus", Proceeding of the Autumn Symposium of the Korean Association for Radiation Protection, pp.247, 2004.
2. C. D. Wickens, S. E. Gorden, Y. Liu, "An Introduction to Human Factors Engineering", Addison Wesley, pp.81~109, 1997.
3. Carel W E van Eijk, "Inorganic scintillators in medical imaging, Physics in Medicine and Biology", Vol 47. pp.89, 2002.

비파괴검사 장치 내 방사선원의 위치 탐지용 섬광필름의 가시 성능 평가

이 경 진

미래에너지기술연구소, (주)미래와 도전

국문요약

최근 비파괴검사 현장에서 검사 중 장치 내 방사선원의 위치 미확인으로 인한 방사선 과피폭 사고가 종종 발생하고 있다. 이러한 방사선원의 노출여부나 위치 미인지로 인한 방사선 사고를 예방하기 위한 방사선원의 위치를 감시할 수 있는 소재를 개발하는 것이 본 연구의 목표이다. 연구를 통해 방사선 비파괴 검사 장비의 가이드튜브 내에 존재하는 선원의 위치를 육안으로 탐지할 수 있는 섬광필름을 개발하였고, 또한 다양한 소재와 형태로 섬광필름을 제작하여 이에 따른 발광성능을 평가하였다.

필름 개발에 사용된 발광물질은 무기 섬광체를 주로 이용하였으며, 필름의 발광성능은 광도계(Minolta LS-100)를 이용하여 측정하였다. 필름은 비파괴 검사장비 Ir-192 감마선 조사기의 선원 전송관 표면에 부착하여, 선원을 이동시켜 가며 필름의 가시성능과 발광량 등을 측정하였다. 실험결과, 섬광필름의 발광량은 일정거리(약10 m)에서 육안으로 선원의 위치를 충분히 인지할 수 있었으며, 선원의 이동에 따라서 발광영역도 동시에 이동하면서 형성되는 것을 확인하였다. 특히, 섬광층의 두께에 비례하여 발광성능이 증가하는 것으로 평가되었다. 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.

중심어 : 비파괴 검사, Ir-192 방사선원, 섬광필름, 무기섬광체, 가시성능

key words : nondestructive testing, Ir-192 radioisotope, scintillating film, inorganic scintillator, visual performance