Fabrication and scintillation characteristics of CsI:Tl scintillator for X-ray imaging system

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1. Introduction

The scintillator absorb X-ray and emit visible light. Thallium-doped cesium iodide(CsI:Tl) scintillator have been widely used in X-ray imaging system for medical and industrial because of high scintillation efficiency and proper emission wavelength (550nm) highly matching silicon-based photo-sensor[1].

In this study, Scintillation film was fabricated by using a thermal evaporation method. CsI:Tl films according to fabrication condition such as different doped Tl concentrations, heat treatment temperature, chamber vaccum pressure, deposition thickness and substrate structure onto a glass. Fabricated CsI:Tl scintillators were observed using scanning electron microscopy(SEM), and scintillation characteristics were evaluated such as wavelength, light output of CsI:Tl scintillators were obtained by an X-ray measurement system.

2. Methods and Materials

2.1 Preperation of the CsI:Tl filmr

We used the two-effusion cell source on thermal evaporator system to deposit CsI:Tl film. The heating coil in the holder supplies the heat to maintain the substrate temperature. The holder above 200mm distance from effusion cell source. The two effusion cell source were placed in each side to vaccum chamber and operated at different temperature according to the desired composition ration of Tl to CsI in side the scintillator. The deposition conditions such as deposition rate, chamber vaccum pressure, heat treatment temperature and Tl doping concentration affect the microstructures and scintillation properties from CsI:Tl film[2]. The good microstructures and high scintillation properties was obtained at a low deposition rate and substrate temperature about 150℃. We prepared chamber vaccum pressure 10^{-2} and 10^{-5}Torr, Tl doping concentration range from 0.3mol% to 1mol%, heat treatment temperature range 250℃ to 400℃ condition for 2Hr 30min , CsI powder charge weight range 100g to 300g and rotation for substrate plate.

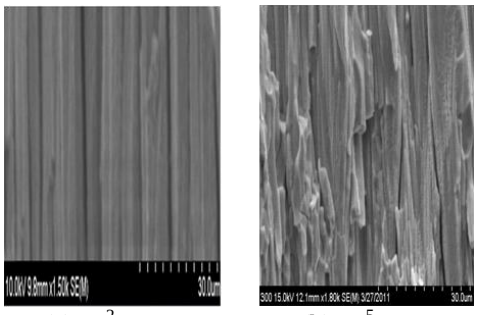
2.2 Measurement of the structures and characteristic

The microstructures of the fabricated powders through a thermal evaporation process and CsI;Tl scintillation films were observed by SEM. And the scintillation characteristics such as light output, intensities of the X-ray-induced luminescence(XL) spectra, spatial resolution(MTF) and X-ray images of a memory chip were measured and evaluated by UV-visible spectrometer (Spectra Academy, K-MAC) using an optical cable for emission spectrum measurement of the CsI:Tl film in dark box and lens-coupled CCD imaging device(Andor DV-434) connected to the PCI controller card and corresponding software for relative light output of CsI:Tl films by same X-ray exposure. The X-ray tube with 4.3mm spot size and inherent 0.8mm Al filter was used to measure X-ray response signals and X-ray images under 30mAs beam current and 80kVp X-ray energy[3]. The distance between X-ray tube and CsI:Tl films a fixed 400mm. The CCD consist of an 1024x1024 active pixels with a pixel pitch of 13μ m with a effective field of 13.2mmx13.2mm. The readout noise level can be kept low due to cooling of the CCD camera system. The MTF curve in terms of spatial frequency of the fabricated CsI:Tl film was a measured edge images by using a tungsten phantom with 1mm thickness [4].

3. Result and discussions

3.1 Images of structure

The CsI:Tl films fabricated by thermal evaporation method with 10^{-2} Torr, 10^{-5}Torr chamber vaccum pressure and 150℃ substrate temperature shows structure Fig. 2. The structure of the columnar(or needle shape) was seen at 10^{-2} Torr chamber vaccum pressure and 150℃ substrate temperature condition in Fig. 1(a) [5]. Fig. 1(b) shows the dense structure with some cracks at high vaccum pressure(10^{-5}Torr) and 150℃ substrate temperature.



(a)10^{-2} Torr (b)10^{-5} Torr

Fig. 1. SEM images of CsI:Tl films at different chamber vaccum pressure.

3.2 Optical property and MTF

The light output of the CsI:Tl films was measured by lens-coupled CCD imaging device connected to the PCI controller card and corresponding software for relative light output of samples by same X-ray exposure. The CsI:Tl film fabricated with 10^{-5} Torr chamber vaccum pressure was even higer than the 10^{2} Torr chamber vaccum pressure. The CsI:Tl film fabricated with high chamber vaccum pressure, low Tl doping concentration and many CsI powder charge weight showed the highest light output.

The modulation transfer function(MTF) of the CsI;Tl films was measured by using obtained edge images. The measured MTF curves of the fabricated with different CsI powder charge weight is shown in Fig. 2. The MTF of the sample decreased as the thickness of CsI:Tl films increases.

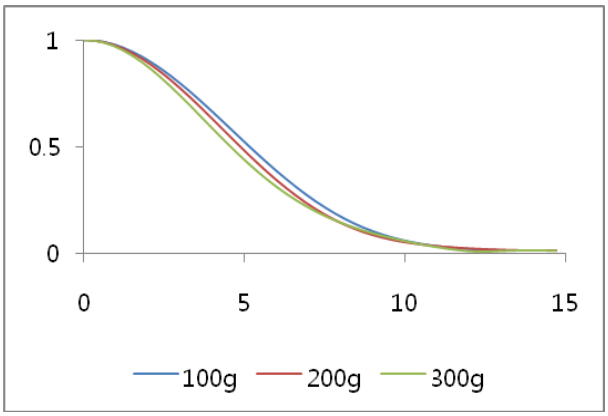


Fig. 2. The measured MTF curves of various CsI powder charge weight.

3.3 X-ray image

The X-ray images of a memory chip measured by CsI:Tl film-coupled CCD camera system and an X-ray tube. The X-ray images of the CsI:Tl films with different Tl concentrations are shown in Fig. 3. The CsI:Tl films fabricated at 0.3mol% Tl concentration shows the highest image contrast. And 1mol% Tl concentration shows the high resolution.

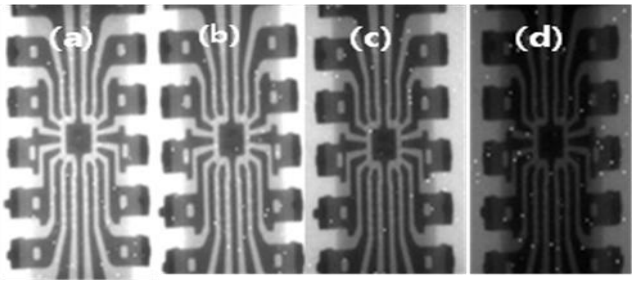


Fig. 3. X-ray images:(a) 0.3mol%/Tl; (b) 0.5mol%/Tl; (c) 0.7mol%/Tl;(d) 1mol%/Tl

4. Conclution

In this study, Scintillation film was fabricated by using a thermal evaporation method and measured the sample characteristics and X-ray image as the function df the fabrication condition as like chamber vaccum pressure, Tl doping concentration, CsI powder charge weight and Tl doping concentration for X-ray imaging system. The CsI;Tl film with columnar structure was observed at low chamber vaccum . The CsI:Tl film fabricated high chamber vaccum pressure, low Tl doping concentration showed high light output. In conclusion, CsI:Tl films with high resolution and high light output can be fabricated by deposition conditions.

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REFERENCES

[1] R. Gwin, R.B. Murray, Phys. Rev. 131 (1963) 508.
[2]B.Schmitt, M. Fuchs, E. Hell, W. Knüpfer, P. Hackenschmied, A. Winnacker, Nucl. Instr. And Meth. B 191 (2002) 800
[3] Bo kyung Cha, Jeong-Hyun Shin, et al., Nucl. Instr. And Meth. A 604, 224 (2009)
[4] Bo kyung Cha, Jongyul Kim, et al., Radiation Measurements 45, 742 (2010)
[5] A.L.N Stevels, A.D.M. Schrama-de pauw, Philips Res. Rep. 29 (1974) 340