The Relation between the Light Output the Distribution of Thallium Concentration in the Polycrystalline CsI(Tl) Layers

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1. Introduction

Inorganic scintillators are employed in most of the current radiation imaging modalities using x-rays or gamma rays. This is explained by the comparatively good detection efficiency of inorganic scintillators for hard radiation. Especially, the color of the emitted light from CsI(Tl) scintillators is well matched to the spectral sensitivity of silicon photodiodes, which show excellent long term stability, CsI(Tl) scintillators with photodiode readouts are now widely used for detecting both light charged particles and gamma rays[1].

It was published already in the 1960s that the thallium concentration in CsI(Tl) crystals influences the scintillation characteristics[2]. A similar emission has been found in polycrystalline CsI(Tl) layers and is assumed to be responsible for some important characteristics of the CsI(Tl) scintillator[3].

We have been fabricating polycrystalline CsI(Tl) layers by simple evaporation process, which can not affirm the uniformity of thallium concentration because of the difference of melting temperature between CsI(660°C) and TlI(440°C). Most of TlI particles are supposed to be evaporated before CsI powder melts.

In this study, we observe the distribution of thallium concentration according to heat treatment after the evaporation and report the relation between the light output and the distribution.

2. Methods and Results

2.1 Thermal Evaporation

To deposit polycrystalline CsI(Tl) layers on glass substrate, thermal evaporation which is a kind of physical vapor deposition(PVD) technology was used because it provides a high deposition rate and also produces high density structure when certain parameters are controlled well[4]. The parameters are process pressure controlled by injection of inert gas(Ar) and substrate temperature and so on.

We observed the microstructure of polycrystalline CsI(Tl) layer by SEM(Fig. 1). The process pressure is 4×10^{-6}torr and the substrate temperature is 250°C.

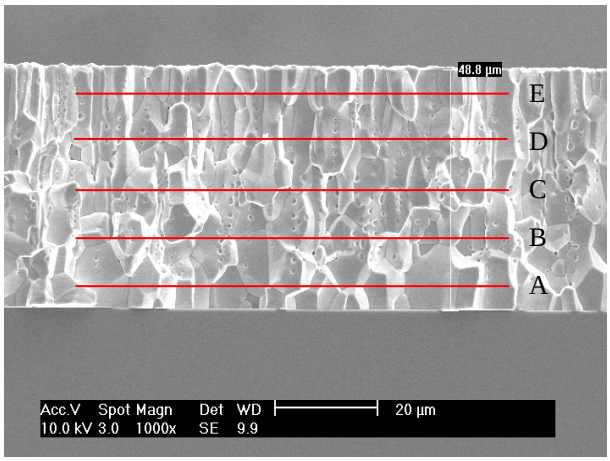

Figure 1. SEM photograph of the polycrystalline CsI(Tl) layer.

2.2 Heat Treatment

Diffusion in solid is well-explained by P. Shewmon[5]. The behavior could be expressed with a coupled of equations which are dominated by temperature and time.

As deposition of the layers, the concentration of thallium centered on the interface between the layer and the substrate(position A in Fig. 1).

2.3 Distribution of Thallium Concentration

Energy Dispersive Analysis(EDS) is method of elemental analysis of materials by scanning backscattered X-rays from high voltage electron bombardment, usually in a Scanning Electron Microscope. Characteristic emission peaks enable identification of most elements.

We prepared 4 samples in the one process which were heavily doped with thallium(20%) for the demonstration of the change. Each sample was heat-treated for respective times(0, 10, 100, 200 hour) at 250°C and the concentration of thallium at the depth positions (A, B, C, D, E in Fig. 1) have been analyzed by EDS. Fig. 2 shows the result of the analysis. The concentration of thallium at the surface of the layer(position E in Fig.1) increased in proportion to time(Fig. 3) because of the diffusion.

The heat treatment at 250°C for 200 hour was promising a measure of uniform concentration of thallium.

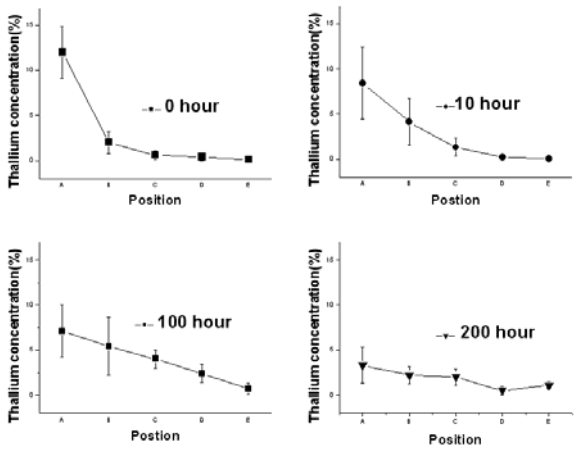

Figure 2. Distribution of thallium concentration as depth position and heat treatment time.

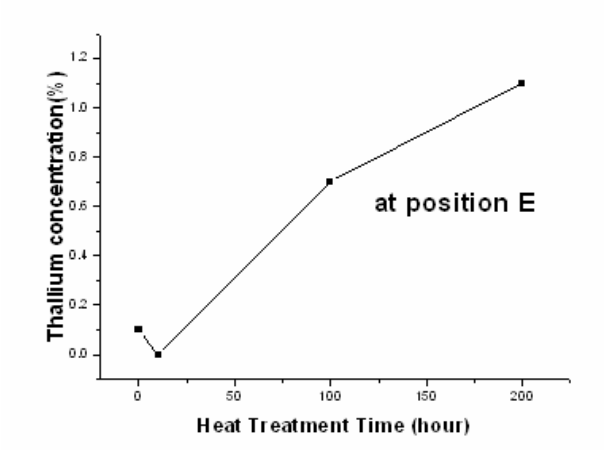

Figure 3. Change of the concentration of thallium at the surface of the layer as the heat treatment time.

2.4 Light output

A number of research about CsI(Tl) reported that a concentration of 0.1-0.2 mol percentage is required for an optimal light output[6].

We prepared 4 samples in the one process which were slightly doped with thallium(0.1%). Each sample was heat-treated for respective times(0, 10, 100, 200 hour) at 250°C.

The light output of the scintillators at X-ray(100kVp, 41.3mAs) was measured by the spectrometer(Ocean Optics OOIBase32)(Fig. 4). The sample heat-treated for 200 hour shows ~40% light intensity of single crystal.

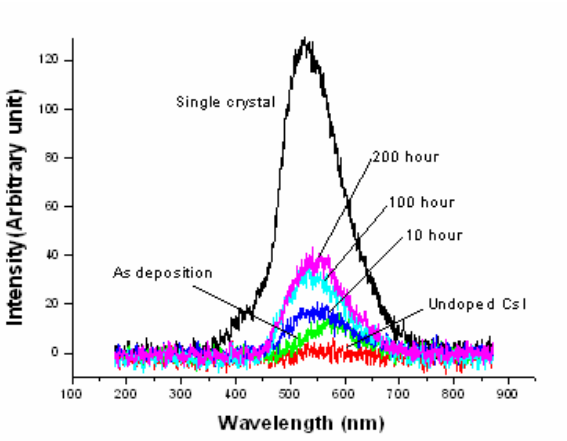

Figure 4. Light emission spectra of the CsI(Tl) scintillators

3. Conclusion

The light intensity of the scintillation increases according to the heat treatment and the reason is thallium diffusion.

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