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ScienceDirect

Physics Procedia 84 (2016) 245 – 251

Physics Procedia

International Conference "Synchrotron and Free electron laser Radiation: generation and application", SFR-2016, 4-8 July 2016, Novosibirsk, Russia

Performance and characterization of CsI:Tl thin films for X-ray imaging application

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Abstract

High spatial resolution thin CsI:Tl scintillator films was prepared by thermal deposition method for X-ray imaging applications. We fabricated CsI:Tl scintillators ranging from 2 μm to 14 μm in thickness. We measured spacial resolution and light yield as a function of input photons energy (5-40 keV) and film thickness. To improve spatial resolution of films carbon post-deposition treatments was performed.

Peer-review under responsibility of the organizing committee of SFR-2016.

Keywords: high-resolution, CsI:Tl, thin scintillator films, X-ray imaging, vacuum deposition method, carbon layer

1. Introduction

CsI:Tl scintillator films are widely applied as the conversion screens for the indirect X-ray imaging. The CsI:Tl is characterized by one of the highest conversion efficiencies of any known scintillator (Nikl (2006)). There are a lot of researches where authors consider different approaches to the performance of the scintillator films. The methods to fabricate thin scintillators using a vacuum deposition process have been developed since the 1960s by Bates (1969). In general, there are two approach to improve spatial resolution of the X-ray image obtained using the scintillators. The first one consists in the growth of CsI:Tl scintillator with micro-columnar structure (Nagarkar et al. (1998, 2001); Yao et al. (2013)). The micro-structure of the crystals of the scintillator decreases the lateral spreading of scintillating light. The second approach consider post-deposition additional coating by carbon to decrease multiple scattering of photons inside scintillator volume (Zhao-Dong et al. (2015)). It is observed that the intrinsic properties of the structured CsI:Tl screens are heavily influenced by post deposition carbon coating. In the research we study the influence of carbon layer to spatial resolution and light output of the films with different thicknesses and energy of input X-ray photons. Additionally, the paper is dedicated to demonstrate the X-ray imaging applications of thin scintillator films.

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Peer-review under responsibility of the organizing committee of SFR-2016.
doi:10.1016/j.phpro.2016.11.042

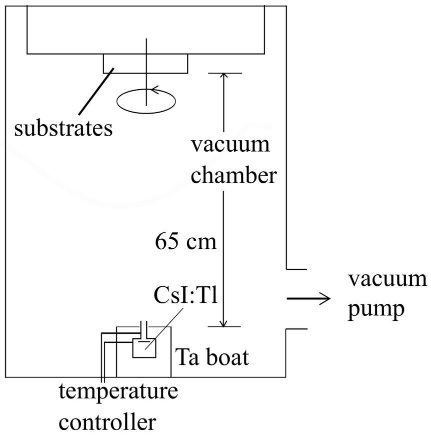

Fig. 1. Schematic of the thermal evaporation setting.

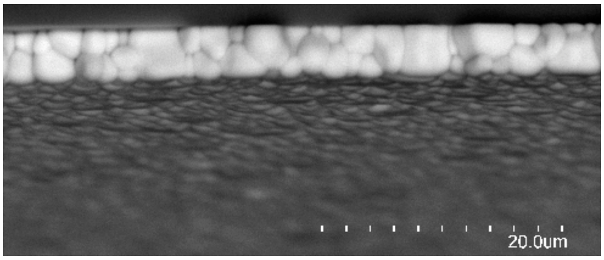

Fig. 2. Scintillator morphology of CsI:Tl film deposited on glass substrate with thickness 4.1±0.3 μm.

2. Experimental

2.1. Preparation of CsI:Tl Scintillation Films

CsI:Tl scintillation films were manufactured by the thermal deposition method. We use glass substrates with 150 μm thickness and 25x25 mm^2 area. The source material - CsI:Tl held in a tantalum boat. The doping concentration of Tl was about 0.08 mol%. During deposition process the tantalum boat temperature was set at 680°C as a nominal value. To achieve homogeneous coverage of substrate by scintillator a relatively low deposition rate (17 ± 2 Å/s) was used. All samples were prepared at pressure of $5{\cdot}10^{-3}$ Pa and substrate temperature at 25°C as was recommended by Thornton Zone Model (Thornton (1974)). A rotated disk with substrates was situated at distance 65 cm from tantalum boat (see Fig. 1). Four thicknesses of CsI:Tl films were prepared: about 2, 4, 8 and 14 μm.

It was observed that Tl concentration decreases with the increase of deposition time. The Tl density in 8 μm sample is less by 1.2÷1.3 times relatively to 2 μm sample, due to larger evaporation velocity of Tl relatively to CsI. So, the deposited on substrate CsI:Tl scintillator is characterized by acceptable Tl concentration for the thicknesses less than 10 μm. For larger thicknesses we need apply serial deposition procedure step-by-step increasing the CsI:Tl layer. Scintillator morphology of CsI:Tl film deposited on glass substrate was investigated by a scanning electron microscope and is shown in Fig. 2. The film consists of well-defined grain structure with typical size of the grain about 2÷5 μm.

In order to improve spatial resolution of obtained scintillator screens we perform additional carbon layer on CsI:Tl surface by magnetron deposition method using AUTO 500 Vacuum Coater (BOC EDWARDS corp.). All images that will be shown below was generated using CsI:Tl films with 70 nm carbon layer, unless otherwise stated.