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Comparison of functional parameters of CsI:Tl crystals and thick films

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HIGHLIGHTS

- Thick CsI:Tl columnar films were obtained by thermal evaporation in vacuum.
- Radiation stability of such CsI:Tl films appears to be better than that of crystal.
- CsI:Tl film parameters can be modified by annealing in different atmospheres.

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ABSTRACT

500 mkm thick CsI:Tl columnar films can be produced using thermal evaporation in vacuum by sublimation of the same bulk crystal. Comparison of afterglow and radiation stability of deposited CsI:Tl films with source crystal was the aim of current work. It is shown that the afterglow in the films is always below its level in initial single crystal. It was ascertained that the annealing atmospheres influence the processes leading to the activator depletion of the films during the thermal processing.

1. Introduction

Columnar morphology CsI:Tl and CsBr:Eu films are an optimal choice for scintillation and storage screens (Leblans et al. (2002); Nikl, 2006; Schmitt et al., 2002). Good light channelling inside column allows minimizing the light spread through the film and it is the base for the series of position sensitive films and screens applications (Eijk,van, 2002; Moy, 2000). At the same time registration of high energy X-ray photons needs thicker films for the optimal absorption efficiency. That is why thick film sensors could be competitive with thin crystals for radiation detection in general and for X-ray computed tomography (CT) in particular. In such case the radiation stability and afterglow level are the subjects for the study depending on the initial crystal purity, film structure and deposition conditions. It should be noted, that both radiation stability and afterglow are structure sensitive properties, i.e. all studies have to be based on extra pure materials available for the industrial application.

2. Experimental and methods

CsI:Tl films with 500 mkm thickness were obtained by thermal evaporation in vacuum on glass substrate by sublimation of the same bulk crystal at substrate temperature 573 K. Applied deposition method allows to reproduce the concentration of the activator equal to that in the source crystal and to provide its uniformity across the layer (Fedorov et al., 2006). Scintillation efficiency of such films can be compared with good quality CsI:Tl crystal (Fedorov et al., 2006). Thus sublimation of CsI:Tl crystal with $8.4 \cdot 10^{-2}$ mass% of thallium ensured the same Tl concentration in all film specimens. Deposition rate was varied in the range from 45 to 55 Å/s.

Morphology of films was observed using a JSM-6390 LV scanning electron microscope. As follows from Fig. 1a deposited CsI:Tl films possess a typical columnar morphology which is similar to that observed earlier (Cha et al., 2011; Nagarkar et al., 1998).

For modification of CsI:Tl films an annealing was performed in the argon and hydrogen atmospheres, and in vacuum at a

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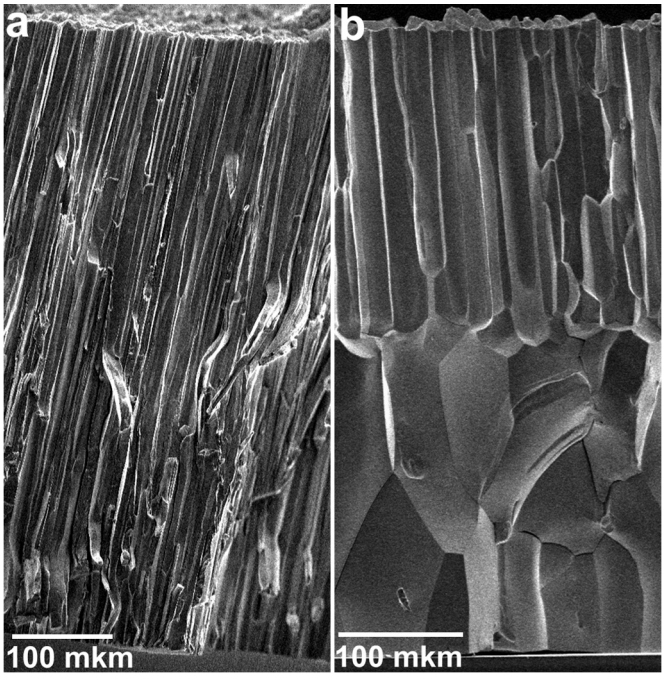

Fig. 1. SEM images of CsI:Tl layer cross-section: a) – as deposited film; b) – annealed in vacuum at 723 K during 5 h.

temperature of 723 K during 5 h. As it follows from Fig. 1b, the recrystallization during annealing is the cause of grains sizes increasing, and, as a result, of columnar morphology degradation.

Argon and hydrogen atmospheres were used in order to minimize the losses of the activator, as a result of Tl ions vaporizing from the surface. Chemical analysis showed that after the annealing in vacuum Tl concentration decreases from $8.4\cdot10^{-2}$ mass% to $1.2\cdot10^{-2}$ mass%. Similar annealing in argon and hydrogen atmospheres leads to changes in thallium concentration from $8.4\cdot10^{-2}$ mass% to $5.8\cdot10^{-2}$ and $6.8\cdot10^{-2}$ mass% respectively. These values are comparable with Tl concentration in the initial crystal and correspond to the "plateau" on the chart of the scintillations light output versus the activator concentration (Trefilova et al., 2002).

Afterglow in millisecond range was measured after X-ray excitation. All samples were excited by X-ray tube operated at 140 kV and 0.6 mA, duration of excitation pulse was 6 s. To investigate the manner in which the afterglow is depends on duration of the excitation pulse, the similar measurements were performed over a range of excitation time duration from 1 to 60 s (afterglow signal was measured in 100 ms after stopping of the excitation pulse).

3. Results

Fig. 2 shows the afterglow in millisecond range of the CsI:Tl crystal with thickness of 2 mm and of the film obtained on its basis.

It is obvious from Fig. 2 that in 3 ms after the end of the irradiation, the afterglow of film was 1.2 times lower than that in the initial crystal. In 20 ms this proportion made up 2.5. In 95–150 ms after the end of the excitation pulse, the afterglow of the film is 1.5 time lower than that in the crystal. It should be noted that scintillation response of the film on the excitation pulse before afterglow measuring was 1.6 times higher than that in the crystal.

For estimation of radiation stability of CsI:Tl films, the similar measurements were performed under different durations of excitation pulse. The obtained afterglow dependence on the duration of excitation pulse is shown in Fig. 3.

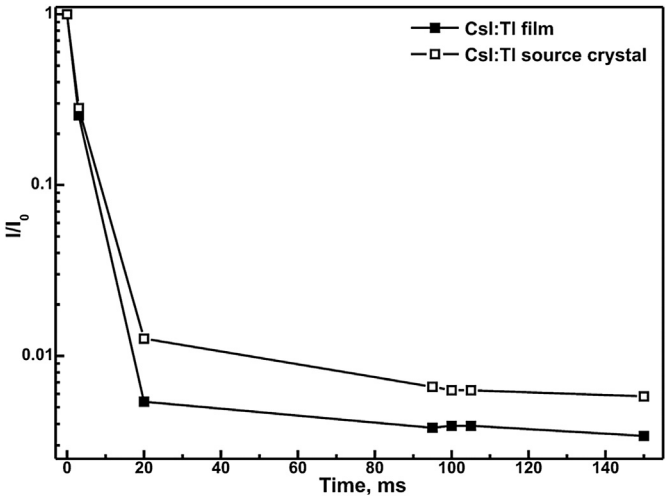

Fig. 2. CsI:Tl crystal and 500 mkm film afterglow in millisecond range.

Changes in the afterglow as a result of the film structure modification by its annealing are shown in Fig. 4.

According to Fig. 4 the atmosphere of annealing also influences the afterglow of the samples. Thus, annealing in argon, hydrogen and vacuum leads to increasing of the afterglow in 3 ms by about 1.8 times. In 20 ms the afterglow level of the films annealed in argon and hydrogen is 1.25 and 1.15 times higher than that in the initial film. At the same time, the film, annealed in vacuum, demonstrates the increasing of the signal by 2.6 times. Within the interval of 100–150 ms the afterglow levels of the annealed in argon and hydrogen films coincide with the initial film. The afterglow level of the film annealed in vacuum, within this time span exceeds by 2 times the similar value of the initial film.

Similar behaviour is also observed in the case of the increasing of the irradiation time (see Fig. 5).

Fig. 5 shows that only the annealing in the argon atmosphere leads to the decreasing of the afterglow under long radiation pulse. Thermal processing in the hydrogen atmosphere slightly increases the afterglow level. At the same time, the annealing of the sample in vacuum increases the value of the afterglow level up to the signal level similar to that of the crystal.

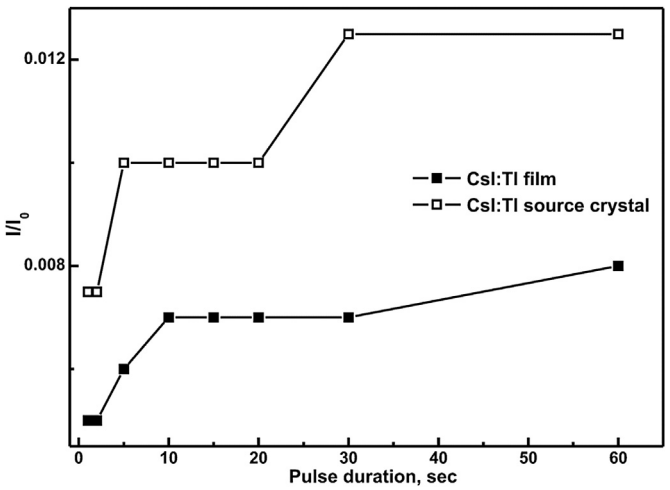

Fig. 3. Afterglow level dependence on the duration of excitation pulse of the CsI:Tl crystal and 500 mkm film. Afterglow signal was measured in 100 ms after stopping of the excitation pulse.