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

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Motivation

CsI:Tl is a well known scintillator as a bulk media for scientific, industrial and security applications, and columnar films (flat panels) for medical and screening applications.

It is important to study the transfer of thick CsI:Tl columnar film to a thin bulk crystal. Having all advantages of CsI:Tl material, thick columnar layers enable to improve detector spatial resolution, simplifying radiation imaging process.

The aim of the present work is to obtain the thick (about few hundred micrometers thickness) films of CsI:Tl scintillator and compare their functional parameters with the bulk crystal.

Experimental

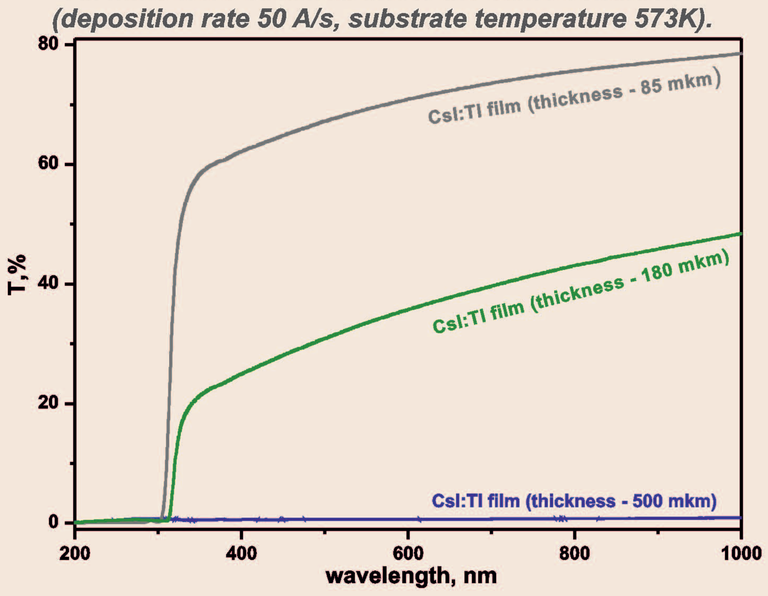
CsI:Tl films were produced by sublimation of the bulk CsI:Tl crystal in vacuum better than 10^{-3} Pa. Film crystalline structure was examined using X-ray diffraction in Cu Kα radiation. The film morphology was tested by SEM. Spectral characteristics of luminescence were studied by the FLS920 spectrometer. Radioluminescence spectra were measured using γ-radiation (Am^{241}) and X-ray excitation (Cu, 40kV). Scintillation processes were excited by γ-radiation (source Am^{241}).

Results and Discussion

It is well known that CsI:Tl films produced by PVD possess a columnar morphology. These columns act as a light guide that increases the spatial resolution of scintillation detector. What is the “price” for the increase of film thickness?

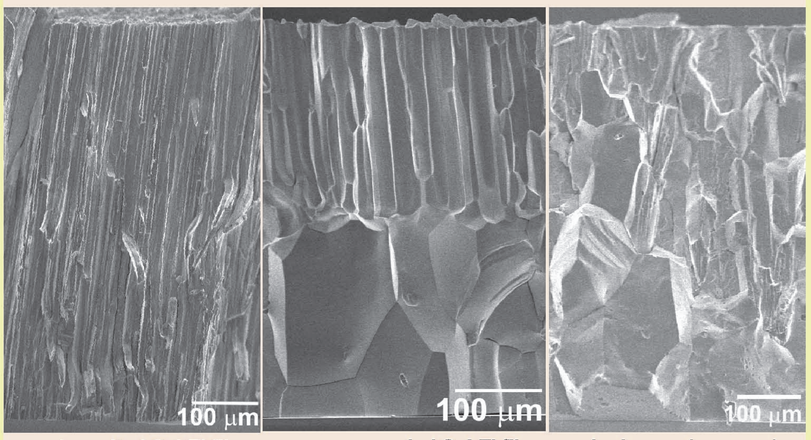
Transmission & morphology

Transmission of CsI:Tl films with different thickness. All films were obtained under the same conditions (deposition rate 50 A/s, substrate temperature 573K).



Resume The increasing of the CsI:Tl columnar films thickness deteriorates their transmission due to rise of a light scattering centers number in the columns volume .

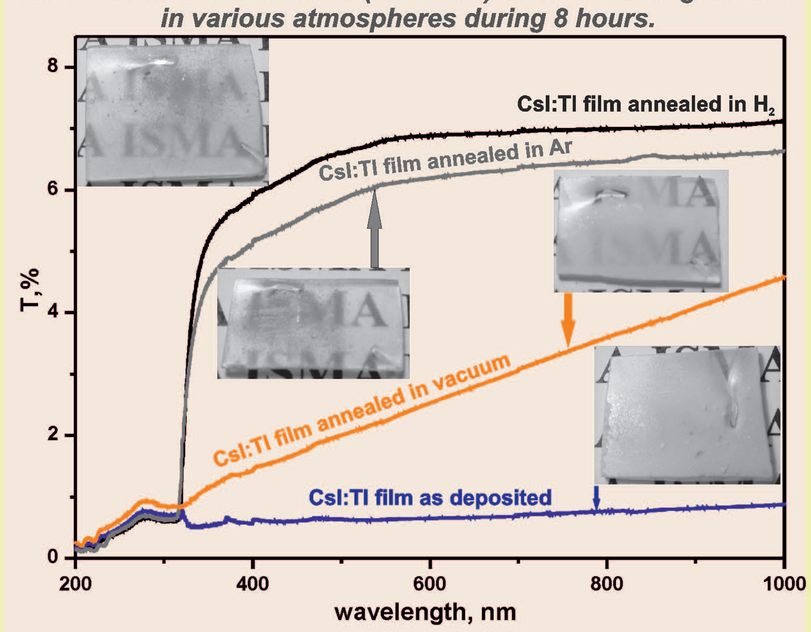
SEM images of CsI:Tl films cross-section



as deposited CsI:Tl film | *vacuum annealed CsI:Tl film* | *hydrogen (or argon) annealed CsI:Tl film*

Resume Film annealing transforms the columnar morphology to the arbitrary oriented blocks due to recrystallization.

Transmission of CsI:Tl films (500 mkm) after annealing at 723K in various atmospheres during 8 hours.



Resume The enhancement of films transmittance can be achieved by post deposition temperature treatment.

Acknowledgments

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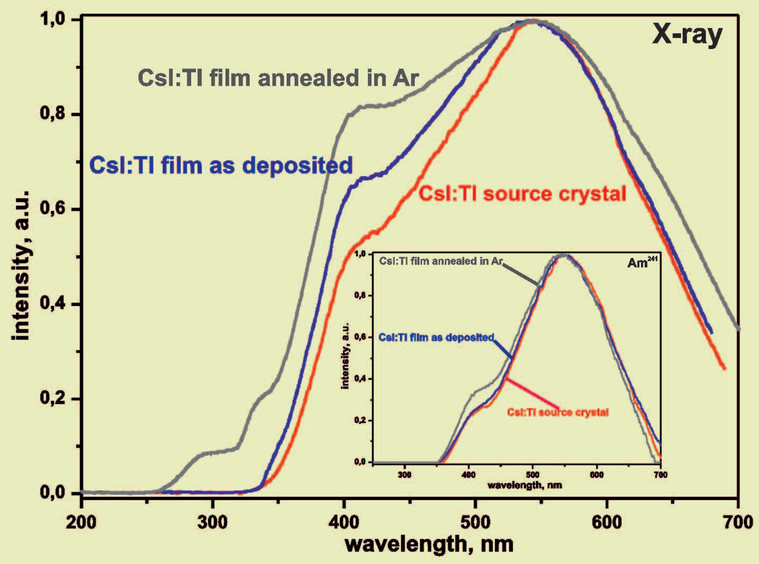
Luminescence & scintillation

X-ray luminescence spectra of CsI:Tl source crystal and films. Insert : radioluminescence spectra.

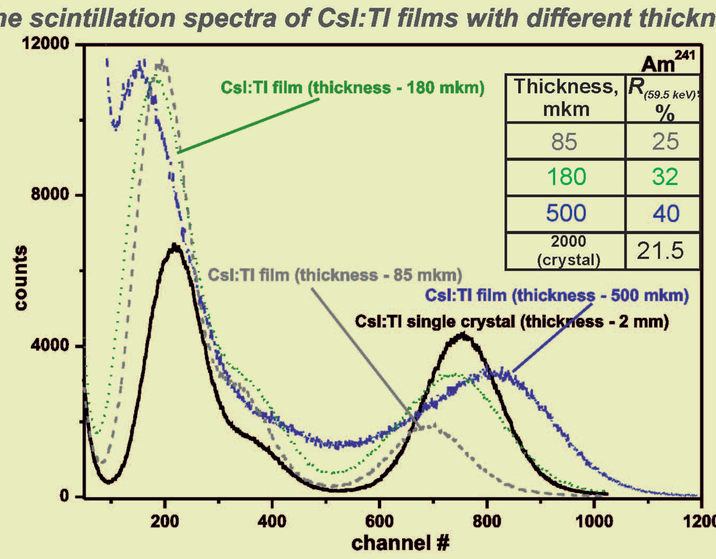


Resume X-ray – and radioluminescence spectra are always the same

Comments:

the appearance of emission band at 300 nm in X-luminescence spectra of annealed films indicates that meaning depletion of dopant (Tl) takes place in the surface layer (about 100 mkm) of samples (mean free path of quantum with energy 40 keV is about 100 mkm and for energy 59.5 keV this value is about 270 mkm).

The scintillation spectra of CsI:Tl films with different thickness



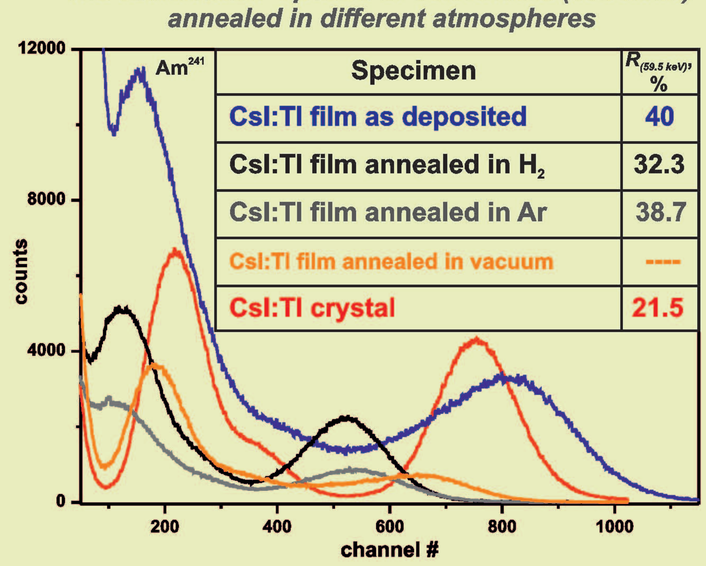
Thickness, mkm	$R_{(59.5\ keV)}$, %
85	25
180	32
500	40
2000 (crystal)	21.5

Resume So, we have a disbalance between light collection (channeling) and scattering

Comments:

- *the enhancement of a light scattering in the film results in degradation of energy resolution (R) (for energy 59,5 keV);*
- *the defects in the columns act as scattering centers and suppress an effective light channeling in the microcolumnar structure. It leads to the light output decreasing in low energy range;*
- *under high energy γ-radiation the increasing of scattering in film sets conditions for a light output enhancement*

The scintillation spectra of CsI:Tl films (500 mkm) annealed in different atmospheres



Specimen	$R_{(59.5\ keV)}$, %
CsI:Tl film as deposited	40
CsI:Tl film annealed in H_2	32.3
CsI:Tl film annealed in Ar	38.7
CsI:Tl film annealed in vacuum	----
CsI:Tl crystal	21.5

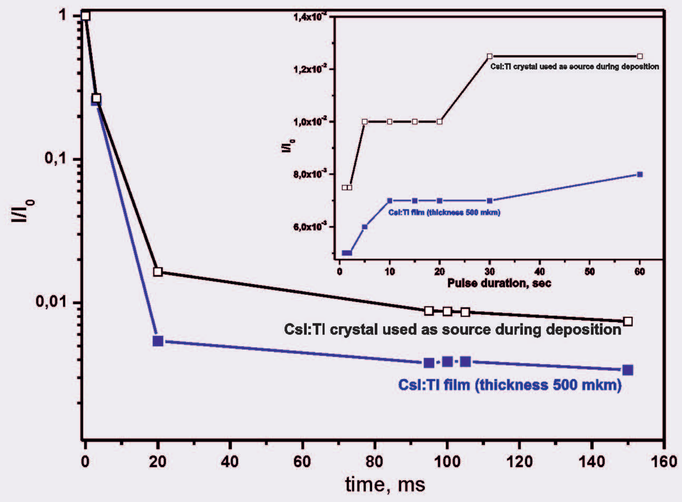
Resume The film annealing totally disposes of the disbalance between light collection (channeling) and scattering

Comments:

- *the slight improvement of CsI:Tl films energy resolution is caused by decrease in defects concentration in the columns due to increasing of crystalline structure perfection during annealing;*
- *the light output reducing is a result of columnar morphology demolishing and dopant (Tl) depletion. As an example, hydrogen annealing at 723K during 8 hours results in thallium concentration change from $6.8\cdot10^{-2}$ to $5.8\cdot10^{-2}$ wt.%., while vacuum treatment leads to decreasing of Tl concentration from $6.8\cdot10^{-2}$ to $1.2\cdot10^{-2}$ wt.%;*

Afterglow

Afterglow in the millisecond range . Insert: afterglow level versus pulse duration

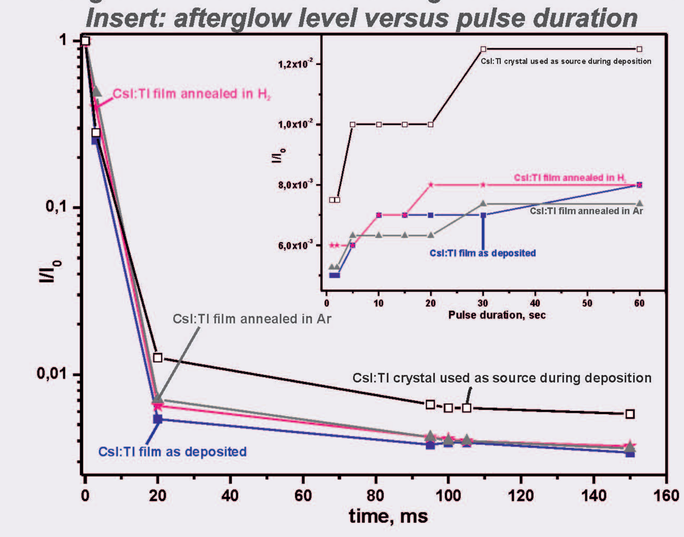


Resume Vacuum deposited CsI:Tl films demonstrate low afterglow signal in comparison with the bulk crystal

Comments:

- *difference in afterglow between film and CsI:Tl crystal, probably, caused by purification of raw material from harmful impurities during deposition process;*
- *afterglow level depends on excitation pulse time;*

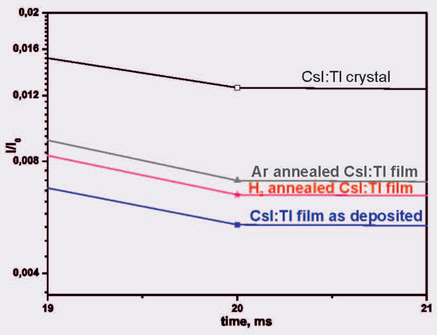
Afterglow in the millisecond range of annealed films. Insert: afterglow level versus pulse duration



Resume Annealing can change afterglow level of films

Comments:

- *Tl concentration decrease in film is accompanied by afterglow level increasing;*
- *the number of charge carrier traps in annealed films depends on annealing terms and atmosphere. For instance (see picture below) ;*



Conclusions

Thick CsI:Tl films could be transformed to the thin bulk crystal without change of luminescence spectra.

- *CsI:Tl columnar films with low afterglow can be obtained by sublimation of bulk CsI:Tl crystal.*
- *The film thickness increasing above 200 mkm results in significant decrease in transmittance.*
- *Decreasing of film light output under low γ-energy is a result of the channeling effect decrease.*
- *Annealing in different atmospheres allows to modify the film properties.*