Low-afterglow CsI:Tl microcolumnar films for small animal high-speed microCT

PSD8
8th International Conference on Position Sensitive Detectors
Glasgow, Scotland
September 1-5, 2008

S.C. Thacker[1], B. Singh[1], V. Gaysinskiy[1], E.E. Ovechkina[1], S.R. Miller[1], C. Brecher[2], and V.V. Nagarkar[1]

[1]RMD Inc., 44 Hunt Street, Watertown, MA 02472
[2]ALEM Associates, 44 Hunt Street, Watertown, MA 02472

ABSTRACT

Dedicated high-speed microCT systems are being developed for the noninvasive screening of small animals. Such systems require scintillators with high spatial resolution, high light yield, and minimal persistence to ensure ghost-free imaging.

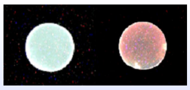
Unfortunately, the afterglow associated with conventional CsI:Tl *microcolumnar films* used in current high speed systems introduces image lag, leading to substantial artifacts in reconstructed images, especially when the detector is operated at hundreds of frames per second. At RMD, we have discovered that the addition of a second dopant, Eu^{2+}, to CsI:Tl *crystals* suppresses afterglow by as much as a factor of 40 at 2 ms after a short excitation pulse of 20 ns, and by as much as a factor of 18 at 2 ms after a long excitation pulse of 100 ms. Our observations, supported by theoretical modeling, indicate that Eu^{2+} ions introduce deep electron traps that alter the decay kinetics of the material, making it suitable for many high-speed imaging applications. Here we report on the fabrication and characterization of CsI:Tl,Eu *microcolumnar films* to determine if the remarkable afterglow properties of CsI:Tl,Eu *crystals* are preserved in CsI:Tl,Eu *microcolumnar films*. Preliminary results indicate that the co-doped microcolumnar films show a factor of 3.5 improvement in afterglow compared to the standard CsI:Tl films.

Crystal Growth

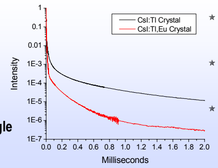
- The vertical Bridgman technique was used to grow crystals of CsI:Tl,Eu:
  - The raw material was melted in evacuated quartz ampoules, which were then passed through a temperature gradient structured for optimal nucleation and growth of CsI single crystals.
  - The concentration of the Eu^{2+} codopant varied from 0.05 to 0.5 mole percent, within an order of magnitude of that of the primary Tl^{+} activator.
- The resulting cylindrical boules were 10 mm in diameter and 35 mm long, from which disks were cut and polished to optical transparency, with a finished thickness of 2.5 mm.

A representative photograph of CsI:Tl and CsI:Tl:Eu single crystals grown at RMD.

Scintillation Decay of Codoped CsI:Tl Crystals After Short Pulse Excitation

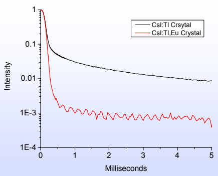


A representative photograph of tablets of CsI:Tl and CsI:Tl,Eu single crystals grown at RMD.



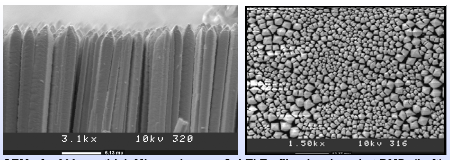
- Conventional semi-log plot of the scintillation decay of CsI:Tl and CsI:Tl,Eu.
- Exposure was stopped and light measurement started at Time = 0 ms.
- Addition of a second dopant, Eu^{2+}, to the CsI:Tl crystals suppresses afterglow by a factor of up to 40 at 2 ms after a short excitation pulse of 20 ns.

Scintillation Decay of Codoped CsI:Tl Crystals After Long Pulse Excitation



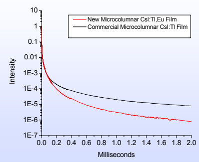
- A semi-log plot of the scintillation decay of CsI:Tl after long pulse excitation, with and without the decay-modifying additive Eu^{2+}.
- The codopant provides a substantial afterglow–suppressing affect, even when subjected to a long excitation pulse of 100 ms, lowering the afterglow level in the millisecond range by more than an order of magnitude relative to standard CsI:Tl.

Vapor-Deposition of Codoped Microcolumnar CsI:Tl Films



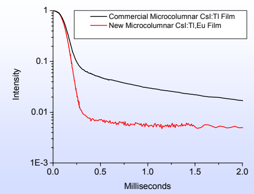
SEM of a 200 µm thick Microcolumnar CsI:Tl,Eu film developed at RMD. (Left) Well-separated columns of the film. (Right) The corresponding top view.

Scintillation Decay of Codoped CsI:Tl Films After Short Pulse Excitation



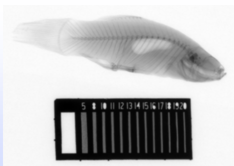
- Standard semilog plot of the scintillation decay of microcolumnar CsI:Tl after short pulse (20 ns) excitation, with and without Eu^{2+} ions.
- At 2 ms after the pulse, Eu^{2+} suppresses the afterglow by as much as an order of magnitude.

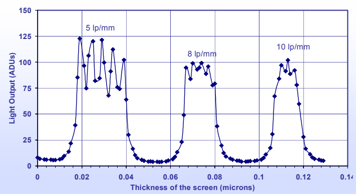
Scintillation Decay of Codoped CsI:Tl Films After Long Pulse Excitation



- Standard semilog plot of the scintillation decay of microcolumnar CsI:Tl after long pulse (100 ms) excitation, with and without Eu^{2+} ions.
- At 2 ms after the pulse, Eu^{2+} suppresses the afterglow by as much as a factor of 3.5.

Radiographic Imaging Using Codoped Microcolumnar CsI:Tl Films





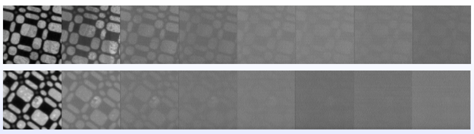
- Radiographic imaging of a fish and a mammography line pair phantom using a 200 µm microcolumnar CsI:Tl,Eu film coupled to a CCD with Nyquist limiting resolution of 11 lp/mm.
- Very fine, <100 µm features of the fish are well resolved, which is consistent with the measured spatial resolution of the film.
- The 200 µm thick CsI:Tl,Eu film shows good spatial resolution and contrast.

EMCCD Camera for Dynamic Imaging

For dynamic imaging:

- Films integrated into a special back-thinned electron-multiplying CCD (EMCCD) camera.
- 512×512 array, 16µm × 16µm pixels.
- Camera operated at 30 fps.
- 300 kVp pulsed X-ray source (20 ns).
- Object exposed to X-rays during only the first integration period, with subsequent frames acquiring the residual image as an exclusive result of scintillator afterglow.

Dynamic Imaging Using CsI:Tl Films With and Without Eu^{2+}



- Dynamic imaging of a tungsten coded aperture mask after 20 ns excitation using microcolumnar CsI:Tl films without and with Eu^{2+} to suppress afterglow.
- Each frame lasts 30 ms and is separated from the next by 1 ms.
- The X-ray pulse occurs during the first frame only, but the image in CsI:Tl persists even after 8 frames.
- The corresponding data for CsI:Tl,Eu shows virtually no residual image after 3 frames, demonstrating the practical utility of this new material.

CONCLUSIONS

- The addition of Eu^{2+} ions can substantially suppress the afterglow exhibited by CsI:Tl crystals.
- This afterglow suppressive effect also occurs in microcolumnar CsI:Tl films, making them useful for high speed radiography such as small animal high-speed microCT and radionuclide imaging.

Contact: Vivek Nagarkar, Ph.D., email: vnagarkar@rmdinc.com

Acknowledgements

We thank the Public Health Service (NIH), DHHS for Grant No. 2R44CA001871-02A2, and the Medical Sciences Div., DOE, for Grant No. DE-FG02-04ER84054, for providing support for parts of this work.

Radiation Monitoring Devices, Inc.
44 Hunt Street
Watertown, MA 02472-4699, U.S.A.

http://www.rmdinc.com
Phone: (617) 668-6800
Fax: (617) 926-9980