Scintillation Properties of $TlGd_2Cl_7$ (Ce^{3+}) Single Crystal

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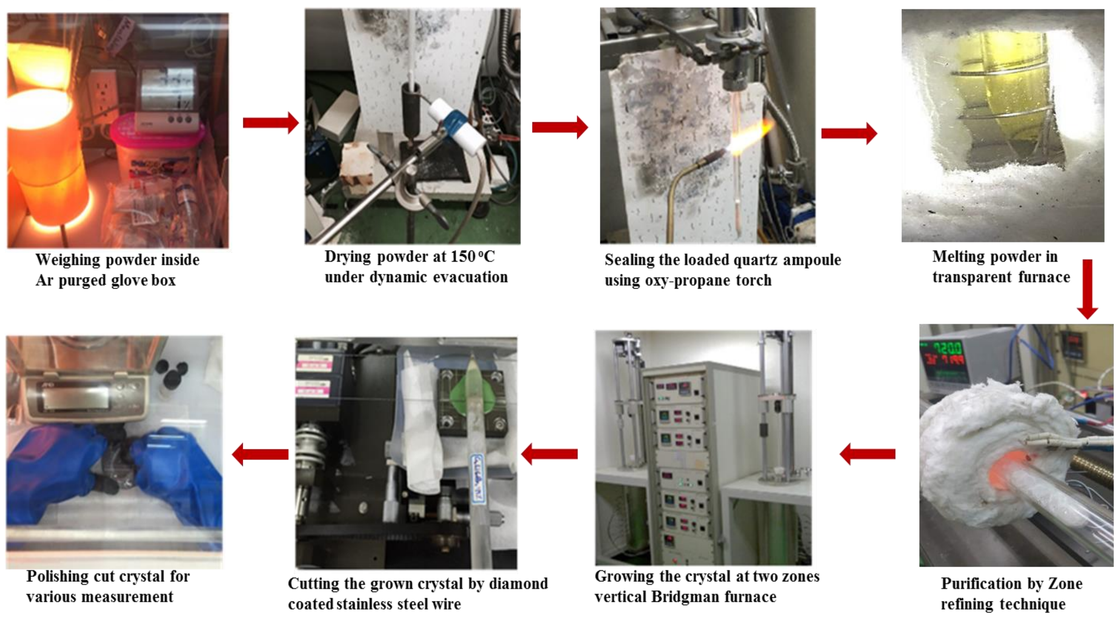
Abstract

Scintillation properties of new $TlGd_2Cl_7$ single crystal is presented. Different Ce-doped (0, 0.5, 1 and 5 mol %) single crystals of $TlGd_2Cl_7$ are grown by vertical Bridgman technique. All doped samples show typical Ce^{3+} emission under X-ray excitation between 350 nm and 500 nm. The emission peak positions slightly changed with the increase of Ce-concentration in the host matrix. Excellent light yield and good energy resolution is obtained under γ-ray excitation at room temperature. Three exponential decay components are obtained for all Ce-doped samples at room temperature. Decay components changes with Ce-concentrations i.e. get faster with higher Ce-concentration. Effective Z-number is found to be 66 and therefore X- and γ-ray detection will be detected efficiently with this scintillator. High light yield, high Z-number with moderate energy resolution and fast scintillation response suggest that this scintillator could be used in the medical imaging techniques. Further investigations are under way for the improvement of its scintillation properties with higher Ce-concentrations.

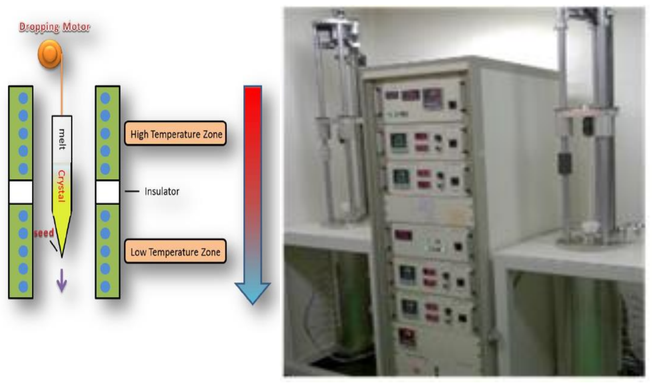
Experimental

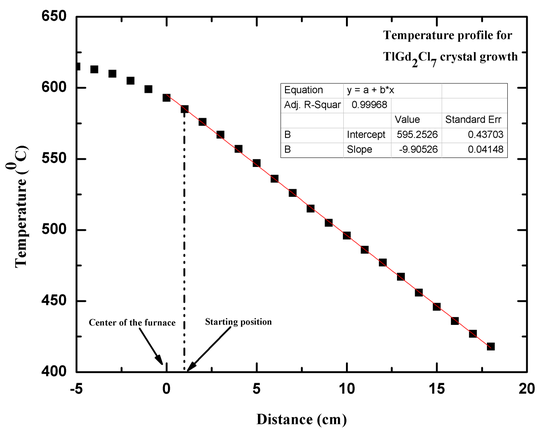
Crystal growth process



Photographic representation of the procedure followed for the growth of $TlGd_2Cl_7$ Crystal.

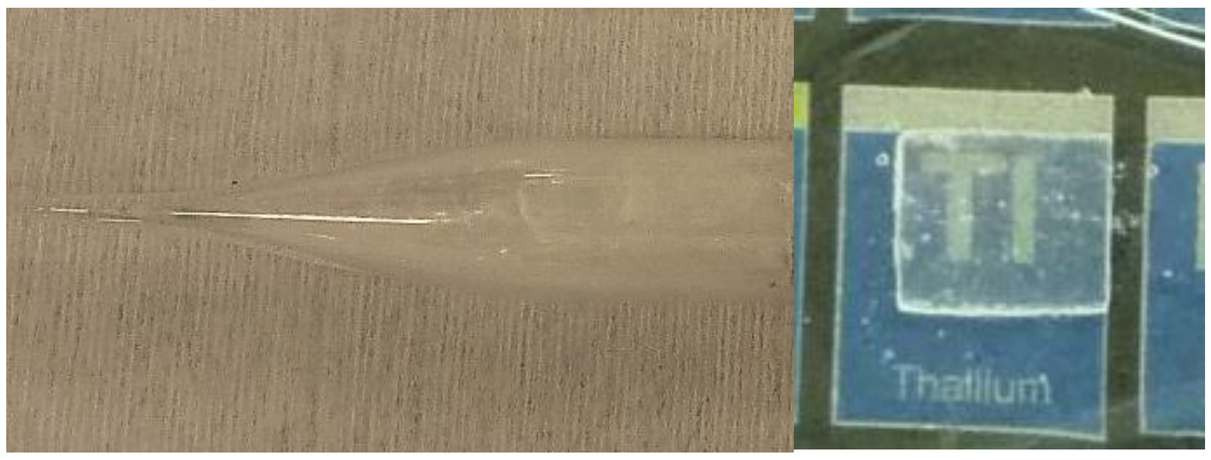
Bridgman technique





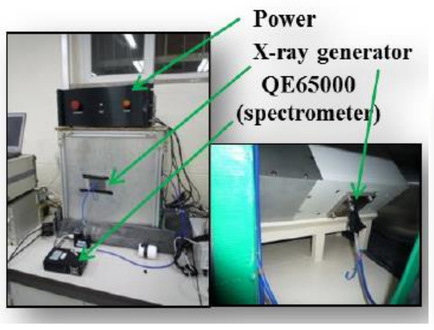
Schematic representation and photographic view of Bridgman furnace

Grown $TlGd_2Cl_7$ crystals

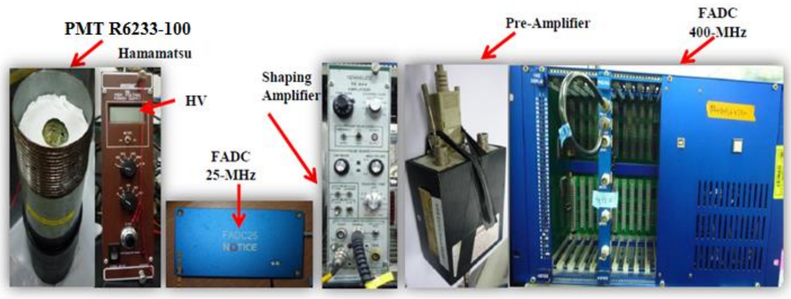


Photograph of the as grown $TlGd_2Cl_7$ crystal.

Experimental setup



(a)



(b)

Photographic view of the (a) X- and (b) γ-ray spectroscopy measurement apparatus.

Measurement conditions

Pulse height spectra

- **25 MHz FADC**
- **^{137}Cs 662 keV γ-ray source**
- **High voltage = -500 V (-600 V for Pure)**
- **Gain = 50 (200 for Pure)**
- **Shapping Time = 10 μs (1.5 μs for pure)**

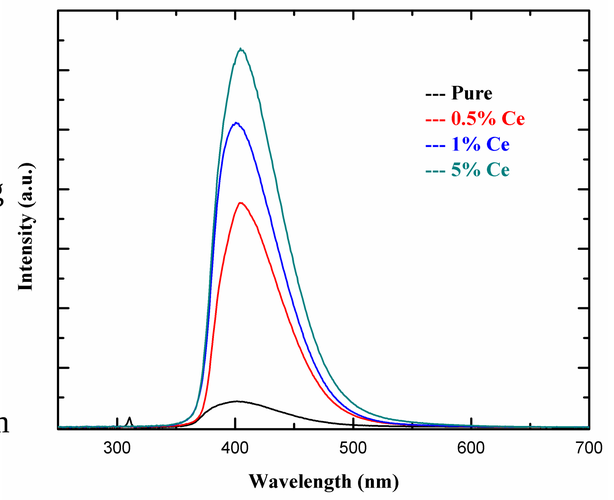
Decay time

- **400 MHz FADC**
- **^{137}Cs 662 keV γ-ray source**
- **High voltage = -1000 V**
- **Threshold = 12**

Results

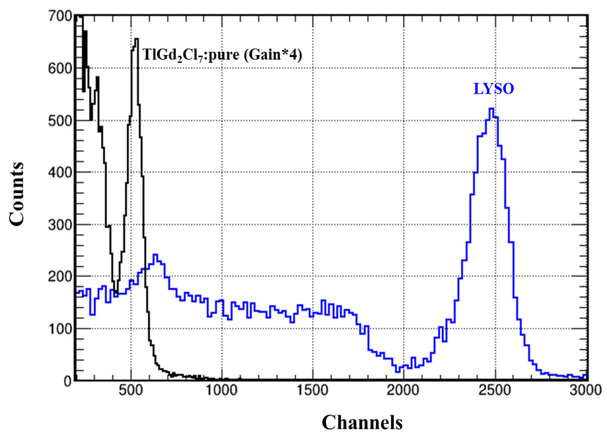
X-ray induced luminescence spectra

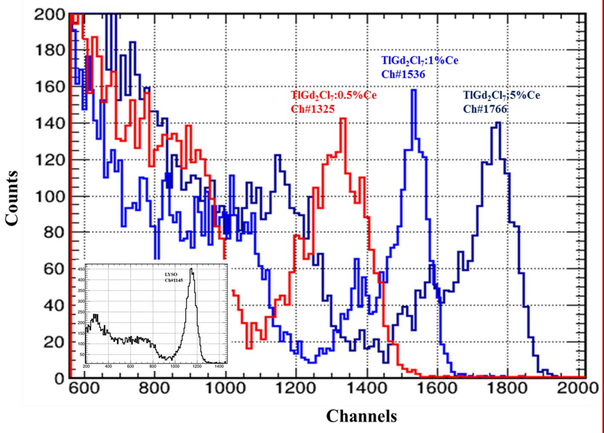
- Pure $TlGd_2Cl_7$ crystal shows Gd^{3+} *4f-4f* transition at 310 nm along with broad band emission in the range of 350-600 nm peaking at 402 nm.
- Doping $TlGd_2Cl_7$ with Ce^{3+} ion, the peak at 310 nm disappear while similar emission bands between 375-550 nm having maximum emission at 405 are observed.



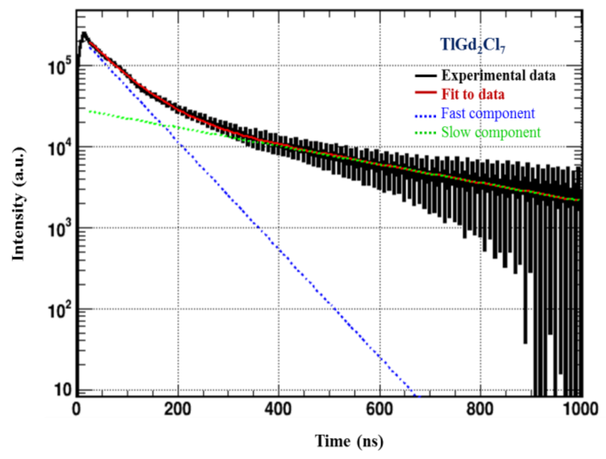
X-ray induced emission spectra of $TlGd_2Cl_7$ crystals. The intensities are in arbitrary scale.

Pulse height spectra

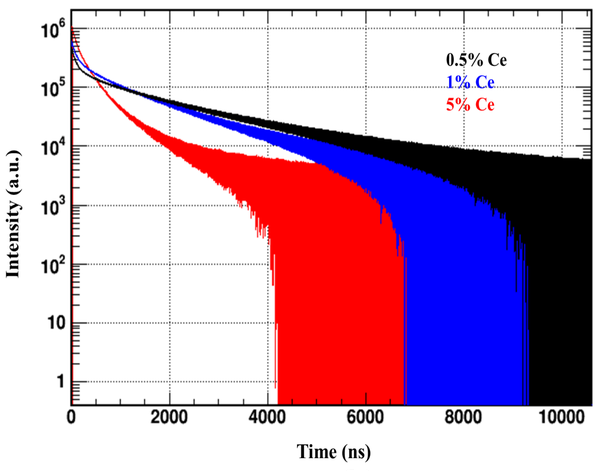




Scintillation decay time



(a)



(b)

Decay time curves of (a) Pure and (b) Ce^{3+} doped $TlGd_2Cl_7$ crystals.

$TlGd_2Cl_7$	Energy resolution (%)	Light yield Ph/MeV	Decay Time
Pure	20	1780±178	τ_1= 65.57±0.09 ns (52 %), τ_2= 382.11±0.73 ns (48 %)
0.5% Ce	14	38000±3800	τ_1= 82.75±0.14 ns (6 %), τ_2= 807.75± 1.30 ns (22 %), τ_3= 2.76±0.01 μs (72 %)
1% Ce	7	44000±4400	τ_1= 84.17±0.14 ns (8 %), τ_2= 654.02±1.28 ns (30 %), τ_3= 1.93±0.01 μs (62 %)
5% Ce	6	51000±5100	τ_1= 89.28±0.08 ns (20 %), τ_2= 357.90±0.25 ns (21 %), τ_3= 1.78±0.02 μs (58 %)

Summary

- Pure $TlGd_2Cl_7$ has low light yield and bad energy resolution, however doping Ce^{3+} ion in this material improves its scintillation performance.
- Light yield of 51000 ph/MeV with energy resolution of 6% (FWHM) was obtained for 5%Ce^{3+} doped $TlGd_2Cl_7$ crystal under 662 keV γ-rays excitation. At the obtained light yield one can expect better energy resolution, which can be achieved by improvement in crystal quality.
- The relative contribution of fast decay component increased and other decay components become faster with increase in Ce^{3+} concentration.
- Further investigation on the optimization of Ce^{3+} doping, crystal growth conditions and raw materials purification is underway.