Investigations on pulse shape discrimination performance in CsI doped with different Tl concentrations

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Introduction

Commercially available CsI:Tl scintillator has very fascinating properties such as light output of 64,800 photons/MeV, density of 4.51 g/cm^3,emission wavelength peaking at 550 nm [1]. These attractive properties lead to wide areas of applications using this scintillator such as security, space exploration, industrial, medical etc [2-3]. CsI:Tl scintillator is also used for particle discrimination in mixed radiation environment. The effect of dopant concentration to optimize the light yield and energy resolution has been explored in details [4]. However, studies of the Tl concentration effect on scintillation kinetics and pulse shape discrimination ability for simultaneous measurements of alpha and gamma radiations are limited.

In this paper we report the crystal growth, scintillation and pulse shape discrimination performance of CsI doped with different concentrations of Tl.

Experimental details

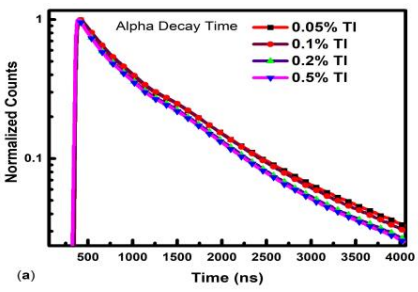
In the present work, CsI single crystals doped with Tl (0.05%, 0.1%, 0.2%, 0.5%) were grown using Bridgman technique. The CsI with 4N purity and TlI with 5N purity weighted powder was loaded into the crucibles and then dehydrated. The crucibles were sealed using glass-blowing technique. All of four crucibles were hanged altogether inside the four-zone Bridgman furnace. The grown crystals were cut in a dimension of 10 mm × 7 mm (dia. × thick.) and polished. All samples were cut from the same position from all of the four crystals to avoid any segregation effect on concentration. The crystals were coupled to PMT to measure decay times. A CAEN digitizer (DT-5790) was used to study PSD measurements. Radio-luminescence and Thermo-luminescence studies were also done to explore defect structures.

Results and discussion

Fig. 1 shows the Four CsI:Tl grown crystals using Bridgman furnace. Grown crystals were transparent and crack free.

Fig1. Grown CsI:Tl (0.05%, 0.1%, 0.2%, 0.5%) crystal.

Fig. 2 shows the scintillation decay time of CsI doped with different concentrations of Tl activator. Decay time is calculated by fitting the curve using double exponential function.



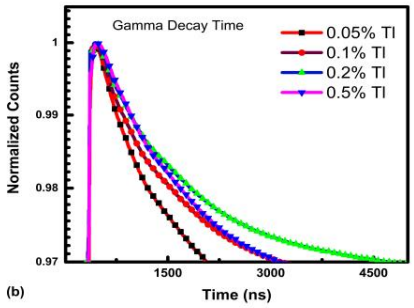


Fig 2. Scintillation decay curves of (a) Alpha excitation (b) 662 KeV gamma excitations in CsI(Tl).

The scintillation decay time increases with increasing Tl concentration on irradiation with gamma. On the other hand, alpha scintillation decay time was decreasing with increasing Tl concentration. Table 1 summarizes the alpha and gamma average scintillation decay time values. The average decay time was calculated as follows

$$\tau = \frac{A_1\tau_1 + A_2\tau_2}{A_1 + A_2}$$

Where, τ_1 and τ_2 denotes the fast and slow decay time components, respectively and, A_1 and A_2 denotes their relative contributions in the total pulse intensity. The difference in decay time of CsI:Tl under gamma and alpha radiation introduces the possibility of PSD in these crystals.

Table1. Average decay time by the irradiation of alpha and gamma sources

Crystal	τ_{avg} **(Alpha) (ns)**	τ_{avg} **(Gamma) (ns)**	$\tau_{avg,\gamma}/\ \tau_{avg,\alpha}$
CsI_05%Tl	1033	1450	1.40
CsI_0.1%Tl	975	1833	1.88
CsI_0.2%Tl	945	2225	2.35
CsI_0.5%Tl	940	1875	1.99

Fig. 3 shows the 2D spectra of CsI doped with different concentrations of Tl irradiated with Cs-137 gamma and Am-241 alpha source. The energy deposited in the crystal was plotted in X-axis. The Y-axis represents the PSD ratio calculated as $1 - \frac{Q_S}{Q_L}$, where Q_S and Q_L were the charges collected in short and long gates, respectively. Lower band in Y-axis represents the alpha band. The energy straggling of alpha was observed as measurements were done in air. On increasing the Tl concentration in CsI, PSD was slightly improving. This can be attributed to more difference between scintillation decay time of gamma and alpha for CsI:0.2%Tl sample than other doped samples. The best FoM (2.85) was obtained for CsI:0.2%Tl.

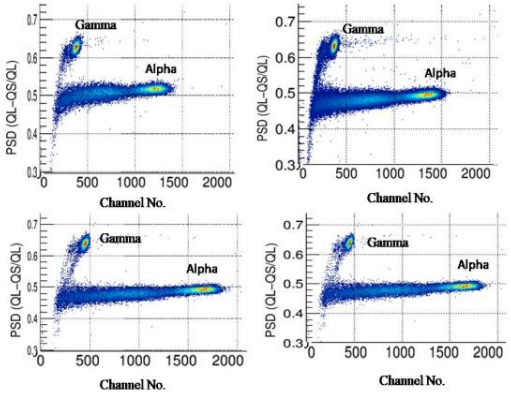


Fig 3. 2D plot obtained by irradiation of alpha and gamma in CsI:Tl.

Summary

Crack free and transparent crystal of CsI:Tl (0.05%, 0.1%, 0.2%, 0.5%) were grown using Bridgman technique. Radio-luminescence, Thermo-luminescence and PSD properties were studied at room temperature. No change in RL was observed with Tl concentration. However, a slight improvement in PSD for alpha and gamma with Tl concentration was observed. Growth of more crystals with co-doping for better PSD is our future work.

References

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