Growth and scintillation properties of Tl doped LiI single crystal: A fast thermal neutron scintillator

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Introduction

Thermal neutron detector using single crystal scintillators has attracted a lot of attention recently due to its high efficiency, radiation hardness and compactness. Of all the known scintillators for simultaneous detection of neutrons and gammas, CLYC (Cs_2LiYCl_6:Ce) is the most widely used elpasolite scintillator because of the presence of ^{6}Li nuclei which offers a high capture cross section for neutrons [1]. But the atomic ratio of ^{6}Li in CLYC is of ~1:10, which is quite low when compared to a suitably doped LiI where ~1:2 ratio makes it a more promising candidate for thermal neutron detection having higher stopping efficiency in smaller size. Recently a lot of research is going on the improvement of scintillating performance of doped LiI single crystals [2]. It has been grown with different activators and characterized for the scintillation properties. Single crystals of LiI(Eu) area being the mostly used scintillators for the detection of thermal neutrons using pulse height discrimination for gamma background. LiI(Eu) has a slow decay time of 1.2 µs which makes it a not the most preferred scintillator for the fast counting applications [3]. Therefore, it is required to introduce a more appropriate activator in LiI which can make the decay time of crystal faster and also able to discriminate neutrons and gammas.

In this paper we report the crystal growth and decay time measurements of Tl doped LiI and assess its ability to do pulse shape discrimination of neutron and gamma.

Experimental details

A very first attempt was made to grow LiI single crystal doped with 0.5% thallium (Tl) using the Bridgeman technique. LiI and TlI powder with 4N and 5N purity respectively were loaded into a quartz ampoule having diameter of ~ 15 mm. The weighing and loading of the material was performed inside a glove box in controlled atmosphere. The crystals growth rate was kept 0.5 mm/h. The grown crystal was then cut into three disks of ~ 1mm thickness and having diameter of 6 mm, 4 mm and 2 mm respectively. Lapping and polishing of the crystal was also carried inside the glove box due to its hygroscopic nature. The processed samples were coupled to a 1" Hamamatsu PMT and sealed hermitically for avoiding the degradation due to moisture. The scintillation characterizations were performed by connecting the output of PMT with a signal processing chain. Pulse shape discrimination (PSD) of alpha (^{241}Am) and gamma (^{137}Cs) excitations was carried out employing charge integration method in a CAEN DT5790M dual digital pulse analyzer. Decay time measurements of LiI(Tl) for ^{137}Cs gamma were done using a fast Tektronics oscilloscope.

Figure 1. LiI(Tl) single crystal grown via Bridgeman technique.

Results and Discussion

Figure 1 shows the grown LiI(Tl) single crystal. A transparent single crystal was formed upto 37 mm length while the rest portion was found to be polycrystalline due to a sudden power failure during the growth. Figure 2 shows the scintillation decay curve of LiI(Tl) and LiI(Eu) measured at 662 keV. The scintillation kinetics of LiI(Tl) single crystals was observed to be faster than that of measured for LiI(Eu) scintillators. Figure 3 shows the PSD measured with alpha and gamma excitations for three different sized cut and polished crystals of LiI(Tl). The difference in PSD properties from a single crystal may be assigned due to the segregation of Tl in the grown crystal which lead to the three disks differ from each other in terms of thallium concentration. The optimized short gate and long gate settings for all the three crystals for PSD measurements are 120 ns and 1100 ns respectively. The PSD was observed to be improved in the sample cut closer to the conical tip of the crystal. The reason for the improvement in PSD of alpha gamma in LiI(Tl) can be attributed to the segregation of thallium concentration inside the single crystal as we go down axially in the crystal. Therefore the PSD ability of LiI(Tl) crystals may be further improved with the optimization of dopant concentration. The neutron and gamma discrimination with the optimized thallium concentration has been planned to be carried out in the future.

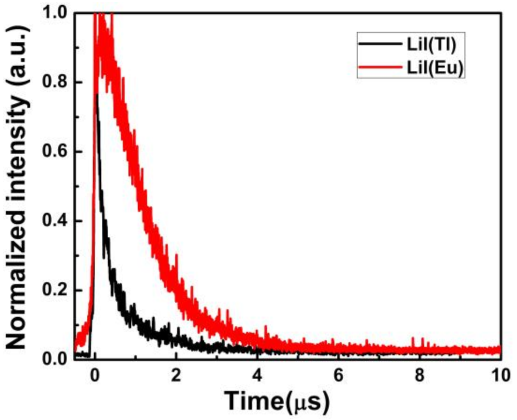

Figure 2. Decay curves of 662 keV gamma excitations in LiI(Tl) and LiI(Eu) single crystals.

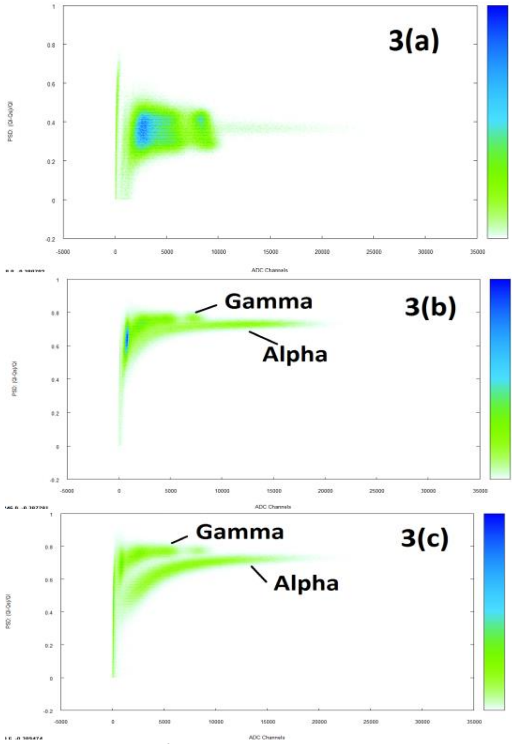

Figure 3. PSD of alpha and gamma excitations using 3 LiI(Tl) disk scintillators having dimensions of **(a)** 6 mm × 1 mm, **(b)** 4 mm × 1 mm and **(c)** 2 mm × 1 mm.

Summary

The higher atomic ratio and density of ^{6}Li in LiI(Tl) makes it promising crystal for thermal neutron detection due to the high atomic capture cross-section of ^{6}Li for neutrons. LiI(Tl) has shown faster scintillation kinetics in comparison with the LiI(Eu). The pulse shape discrimination ability was found to be dependent on Tl concentration. The optimization of dopant concentration may make LiI(Tl) a better candidate for carrying out PSD for neutrons and gammas.

References

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