Improvement in PSD Ability of CsI(Tl) Scintillator

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Introduction

Inorganic scintillators are the most promising material for the radiation detection and have several applications in high energy physics, isotope identification and study of shapes of rotating nuclei [1]. Pulse shape discrimination of a scintillator is the ability to distinguish between two different charged particles on the basis of its decay constant. PSD have many applications like in discrimination of gamma background in neutron counting experiment, phoswich detectors for hard X-rays detection [2] etc. In PSD method, discrimination is achieved by the integration of collected charge in two different time intervals, called gates. In recent years, there have been many efforts to develop new scintillation materials that have efficient PSD ability and pulse shape has been employed in various scintillation single crystals like NaI(Tl), CsI(Tl), BaF_2, ZnS:Ag, $LaBr_3$, GGAG:Ce and LuAg:Ce [3]. GGAG:Ce,B is more capable in pulse shape discrimination as compared to CsI(Tl) [3], however, garnet scintillators are relatively expensive and not very much friendly for the machining point of view. So one possible approach is to tailor the CsI(Tl) properties via band gap engineering approach and make its PSD ability comparable to garnet scintillators. In this research work we have tailored the properties of CsI(Tl) by co-doping to enhance the PSD performance. In this, we have used Na as dopant in CsI and co-dopant in CsI(Tl) for the absolute study of the effect of Na in CsI matrix and grown the single crystals for the study. The grown crystals have been characterized to investigate the effect of Na on the gamma and alpha decay of CsI, CsI(Tl) and mathematically analyzed the pulse shape ability of CsI(Na), CsI(Tl) and CsI(Tl+Na).

Experimental

Single crystals of CsI(Na), CsI(Tl) and CsI(Na+Tl) were grown by the vertical Bridgman technique using a furnace having four separately controlled zones. Anhydrous NaI, TlI were used as the dopant and co-dopant in the CsI matrix. All materials used have 99.999% purity level and APL make. The apparent concentration of NaI, TlI in CsI melt was 0.15 % and NaI in CsI(Tl) melt was 0.04 %. The materials were loaded into the quartz crucibles inside a glove box (MB 200B mBarun) under Argon environment (O_2 and H_2O level < 0.1 ppm) to avoid any moisture contamination. The grown crystals were crack free and highly transparent and inclusion free. For further characterization, the crystals were cut using diamond impregnated copper wheel in the presence of silicon oil and lapped, polished with emery paper and different grading alumina powder to optical finish. Scintillation decay were measured at room temperature by coupling the crystal to a PMT (Hamamatsu R 6095) with optical grease. A high voltage power supply Hamamatsu C9727 was used to bias the PMT. All mounting conditions were same in all experiments for the precise compression between samples. The scintillation decay time was measured for pulse shape analysis using Tektronics MDO3102 oscilloscope with ^{60}Co for gamma and ^{241}Am-^{239}Pu source for alpha.

Results and discussion

The combined scintillation decay for gamma and alpha of all samples have shown in Figure 1. Typically, alpha has fast decay compare to gamma in CsI(Tl), because of the non-radiative quenching of the emission. Alpha particles introduces the higher ionization density which interacts with excited Tl^+ states that leads to non-radiative quenching of the emission.

There is small difference observed in Gamma and alpha decay time in CsI(Na) which we can see in Figure 1(b). Similar to CsI(Tl) there is significant difference in pulse shape for the gamma and alpha radiation of CsI(Tl+Na) as shown in Figure 1(c).

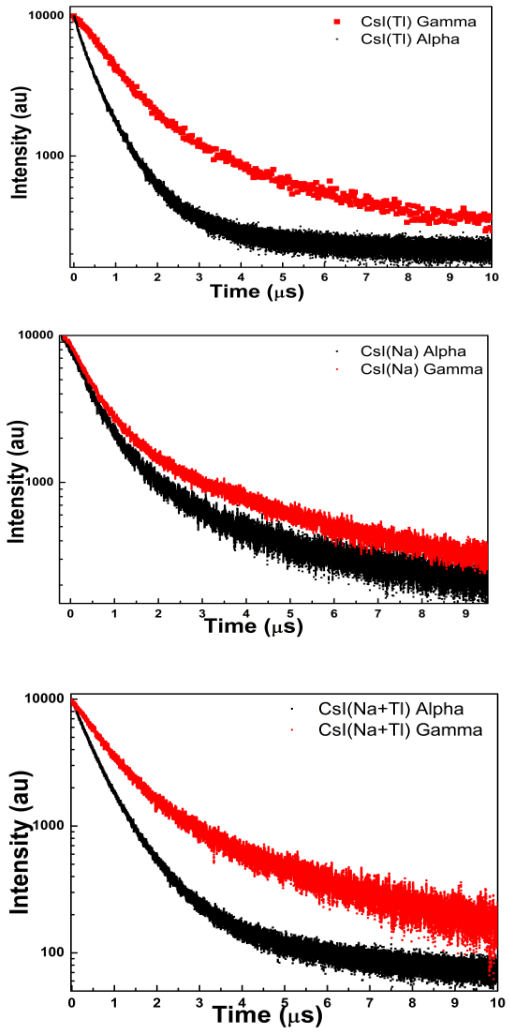

Figure 1. Combined Scintillation Decay of (a) CsI(Tl) (b) CsI(Na) and (c) CsI(Tl+Na).

To quantitatively analyze the pulse shape ability, we have mathematically computed the PSD of the decay pulse. Integrated charge for long gate or short gate is given by

$$dQ_{L,S} = \int S(t)\, dt$$

Here S(t) is the fitted waveform. We have calculated the difference in PSD for gamma and alpha (Figure 2.) for CsI(Na), CsI(Tl) and CsI(Tl+Na) keeping long gate at 10 μs and varying the short gate. It is observed that CsI(Tl+Na) has larger difference in PSD parameter for alpha and gamma radiation as compared to CsI(Tl) for all value of short gate. This improvement may be ascribed to the presence of Na-Tl complex centers in Na co-doped CsI:Tl that is affecting the ratio of short and long scintillation decay components in a favorable manner to increase the PSD ability of the material for differently charged particles.

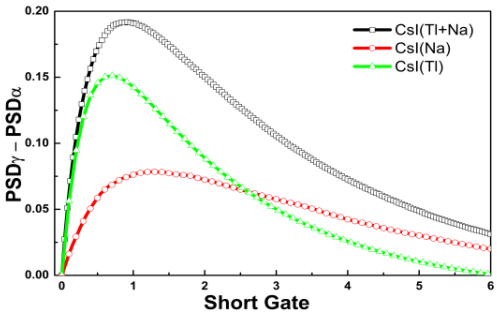

Figure 2. Pulse Shape of ability of all grown samples at Long Gate 10 μs.

Conclusion

In summary we have altered the decay scheme of CsI(Tl) by using Na as a co-dopant. Mathematical analysis for PSD shows that Na co-doping significantly improves the PSD ability of CsI(Tl).

References

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