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New Tl_2LaBr_5: Ce^{3+} crystal scintillator for γ-rays detection

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ABSTRACT

In this study we present our preliminary report on the scintillation properties of new Ce-doped Tl_2LaBr_5 single crystal. Two zones vertical Bridgman technique is used for the growth of this compound. Pure and Ce-doped samples showed maximum emission peaks at 435 nm and 415 nm, respectively. Best light yield of 43,000 ± 4300 ph/MeV with 6.3% (FWHM) energy resolution is obtained for 5% Ce-doped sample under γ-ray excitation. Single exponential decay time constant of 25 ns is observed for 5% Ce doped sample. Effective Z-number is found to be 67, therefore efficient detection of X- and γ-ray will be possible. Preliminary results revealed that this compound will be an ideal candidate for the medical imaging techniques. Further investigations are under way for the determination of optimized conditions of this compound.

1. Introduction

For the efficient detection of ionizing radiations, radiation detector based on inorganic scintillation compounds are used in many applications [1]. Different scintillators are discovered and employed in various application since the discovery of NaI: Tl [2,3]. Most of the research and development for the discovery of new scintillation compounds is devoted to achieve a superior scintillation compound which can be used in all applications. Unfortunately, such an ideal scintillator could not be discovered so far. Usually a scintillation compound should possess high light output, good energy resolution, fast scintillation response, high density and high effective Z-number [4]. Inorganic halide scintillators are considered to be the best among the discovered scintillators. Specially, Ce-doped inorganic halide scintillators are extensively studied and their scintillation properties are found excellent among the discovered scintillators [5,6].

Recently, we discovered new class of inorganic halide scintillators which contained Thallium (Tl) ion and activated with Ce^{3+}-ions. Due to high density and high Z-number of Tl (ρ=11.8 g/cm^3, Z =81) ion, these scintillators showed excellent scintillation performance [7–11]. These scintillators showed excellent performance and could be used in different applications such as medical imaging techniques, high energy and nuclear physics research, homeland security and basic research in condense matter physics.

In this study, we report on new Tl_2LaBr_5: xCe^{3+} where x=0 and 5 mol% (TLB). For the growth, two zones vertical Bridgman technique is used. Luminescence and scintillation properties are measured under X-ray and γ-ray source at room temperature. Luminescence properties include X-ray induced emission spectra. Scintillation properties of TLB crystal include energy resolution, light output and decay time.

2. Experimental section

2.1. Crystal growth

Pure and 5%Ce doped single crystals of TLB has been grown by two zone vertical Bridgman technique. Stoichiometric amounts of TlBr (99.999%, Alfa-Aesar), $LaBr_3$ (99.999%, Sigma-Aldrich) and $CeBr_3$ (99.999%, Sigma-Aldrich) powders were weighing and loaded in quartz ampoule inside argon purged glovebox. Powder loaded ampoules were sealed under high vacuum and were grown by two zone vertical Bridgman technique. Grown crystals were transparent, homogenous and cracks free. The grown ingots were cut into slices of Ø8×2 mm^3 dimensions with diamond cutting wire followed by polishing with polishing cloth. Fig. 1 shows the as grown and polished sample of TLB single crystal. Grown samples were kept in mineral oil to avoid the surface degradation. Density and effective Z-number of TLB is found to be 5.90 g/cm^3 and 67, respectively.

2.2. Experimental setup

In order to study the phase transition and melting point of TLB single crystal, Differential Scanning Calorimetry (DSC) and Thermogravimetric analysis (TGA) were performed. 28 mg sample of

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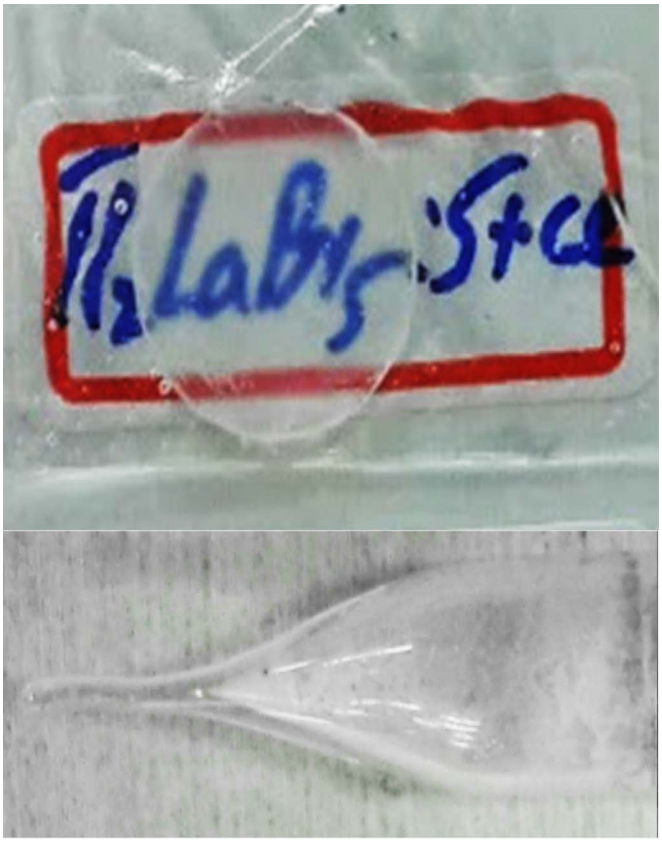

Fig. 1. Photograph of the as grown and polished Ø8×2 mm^3 TLB single crystal.

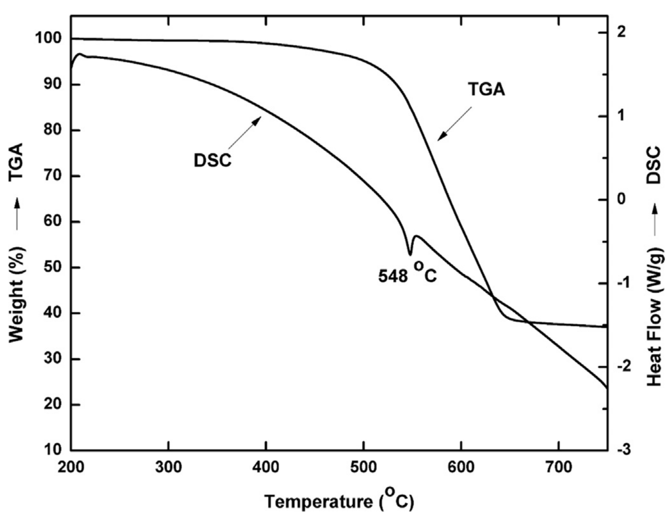

Fig. 2. TGA/DSC curves of TLB single crystal.

TLB was analyzed in protected nitrogen gas environment using TA instruments model SDT Q600 and heated at a rate of 5 °C/min.

X-ray induced luminescence spectra of TLB: Ce^{3+} crystals was measured with an X-ray tube having W anode from a DRGEM. Co at room temperature. Power setting of the X-ray generator was set as 100 kV and 1 mA. A QE65000 fiber optic spectrometer made by Ocean Optics was used to measure the X-ray induced emission spectra of the crystals. For the evaluation of pulse height spectra, TLB: Ce^{3+} crystals were wrapped in several layers of Teflon tape with one face left uncovered. The uncovered face of the crystal was directly coupled with the entrance window of the photomultiplier tube (PMT) (R6233, Hamamatsu) using index matching optical grease. After irradiated with 662 keV γ-rays from a ^{137}Cs source, the signal of the detector were

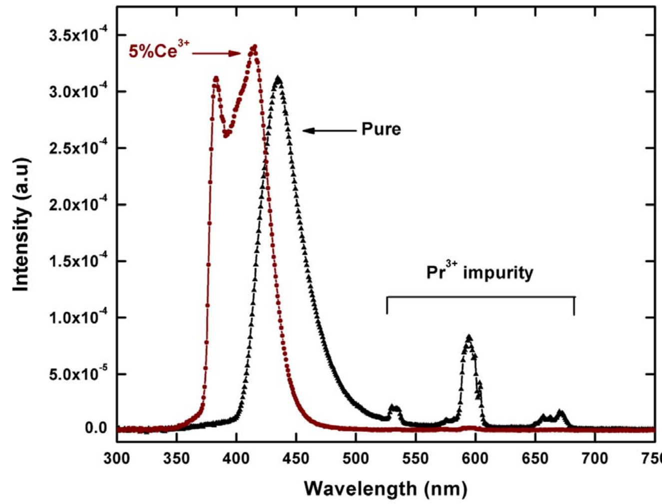

Fig. 3. X-rays induced luminescence spectra of pure and 5%Ce doped TLB single crystals at room temperature.

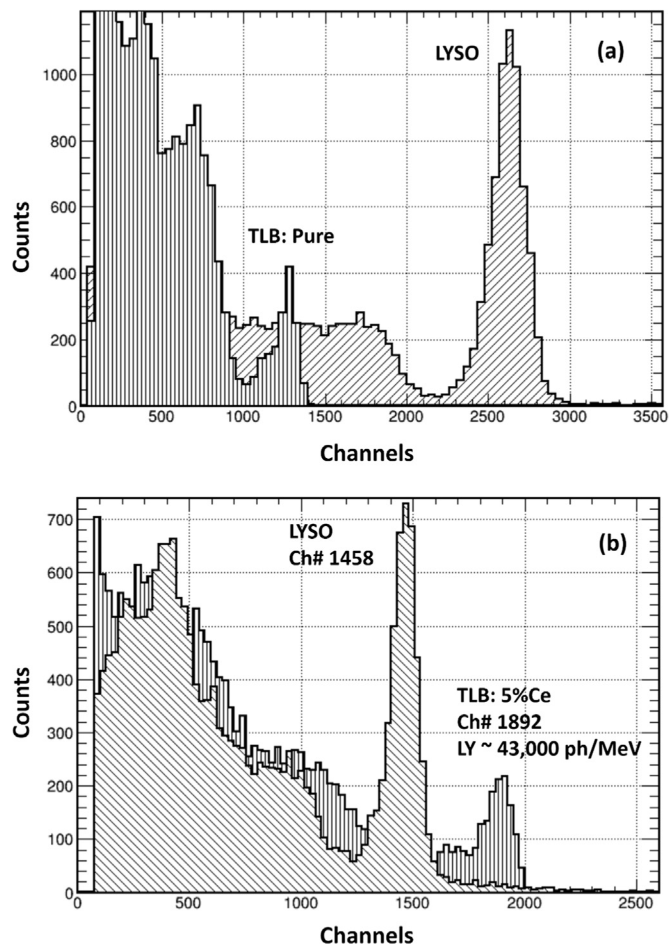

Fig. 4. Pulse height spectra of LYSO: Ce^{3+} and TLB (a) pure (b) 5%Ce-doped crystals excited with ^{137}Cs-γ-rays. The photopeak channel numbers are proportional to the light yield.

shaped with a Tennelec TC 245 spectroscopy amplifier and then fed into a 25-MHz flash analog-to-digital converter (FADC) [12]. A software threshold was set to trigger an event by using a self-trigger algorithm on the field programmable gate array (FPGA) chip of the FADC board. The FADC output was recorded into a personal computer by using a USB2 connection, and the recorded data were analyzed with a C++ data analysis program [13].