Available online at www.sciencedirect.com

ScienceDirect

Nuclear Instruments and Methods in Physics Research A 579 (2007) 11–14

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH
Section A

www.elsevier.com/locate/nima

Growth, thermo-stability and radiation damage of cerium-doped lanthanum chloride ($LaCl_3$:Ce) scintillation crystal

Guohao Ren*, Yu Pei, Xiaofeng Chen, Dongmin Yao, Laishun Qin, Zhongbo Li

Shanghai Institute of Ceramics, Chinese Academy of Sciences, No.215 Chengbei Road, Jiading District, Shanghai 201800, PR China

Available online 20 April 2007

Abstract

$LaCl_3$:5%Ce crystals with diameter of 25 mm were grown by modified non-vacuum Bridgman method. Their photo-luminescence at temperature from 80 to 500 K in steps of 50 K were measured by the single-photon counting method with FLS920 spectrofluorimeter. It was found that the total emission intensity above room temperature is little stronger than that below room temperature. And the decay times also show slight increase with temperature. Irradiation with γ-ray from ^{60}Co source will induce some optical absorption within 320–500 nm in the crystals, cause decrease of light yield and change the relative intensity ratio of the two emissions from $5d \rightarrow {}^2F_{5/2}$ and $5d \rightarrow {}^2F_{7/2}$, but have no influence on the luminescence mechanism.

PACS: 81.10.Fq; 78.55.Hx; 61.80.Ed

Keywords: Lanthanum chloride; Growth; Thermo-stability; Radiation damage

1. Introduction

$LaCl_3$:Ce is a promising scintillator because of its high light yield (46,000 ph/MeV), fast response and excellent energy and time resolution (3.3%) [1]. The unique scintillating properties make it a competitive material in the application of medical imaging, nuclear physics and security inspection, etc. However, it is difficult to grow a high-quality, crack free and large size $LaCl_3$ crystal because of its hygroscopic nature [2]. In 2003, Shah et al. reported a small $LaCl_3$ sample with a volume of 2.5 cm^3 produced by the Bridgman method [3]. Another reason for the difficulty to produce high-quality $LaCl_3$ crystals is the oxygen contamination during the crystal growth process. Recently, a $LaCl_3$:Ce crystal with a dimension of $\varphi 25 \times 25$ mm was successfully grown in our lab. Its scintillation properties, radiation damage and thermo-stability are presented in this paper.

2. Crystal growth

The raw materials used for growing $LaCl_3$ crystal were proven by XRD to be $LaCl_3 \cdot nH_2O$ ($n = 3,7$). The crystallized water molecules in the raw material are harmful for crystal growth and, therefore, must be removed. A DTA curve of $LaCl_3 \cdot nH_2O$ shows that five endothermal peaks 100.4, 156.0, 181.0, 210.6 and 840 °C can be identified (Fig. 1 (left)). Apart from 840 °C, which is the melting point of $LaCl_3$, the other four endothermal peaks originate from the dehydration effect of adsorbed and crystallized water. The dehydrated materials, $CeCl_3$ activator and oxygen scavenger were mixed and then charged into a platinum crucible and the crystal was grown by the vertical Bridgman method. The crucible was lowered at a velocity of 0.4–1.0 mm/h. A colorless and transparent cylinder $LaCl_3$:5%Ce crystal with the dimension of $\Phi 25 \times 20$ mm^3 was obtained (Fig. 1 (right)). Due to hygroscopicity, the cutting and polishing must be carried out under the protection of kerosene. Cubic samples with dimensions of $10 \times 10 \times 10$ mm^3 were obtained and used for the measurement of luminescence properties and radiation effects (Fig. 2).

*Corresponding author. Tel.: 86 21 69987740; fax: 86 21 59927184.
E-mail address: rgh@mail.sic.ac.cn (G. Ren).

0168-9002/$ - see front matter
doi:10.1016/j.nima.2007.04.003

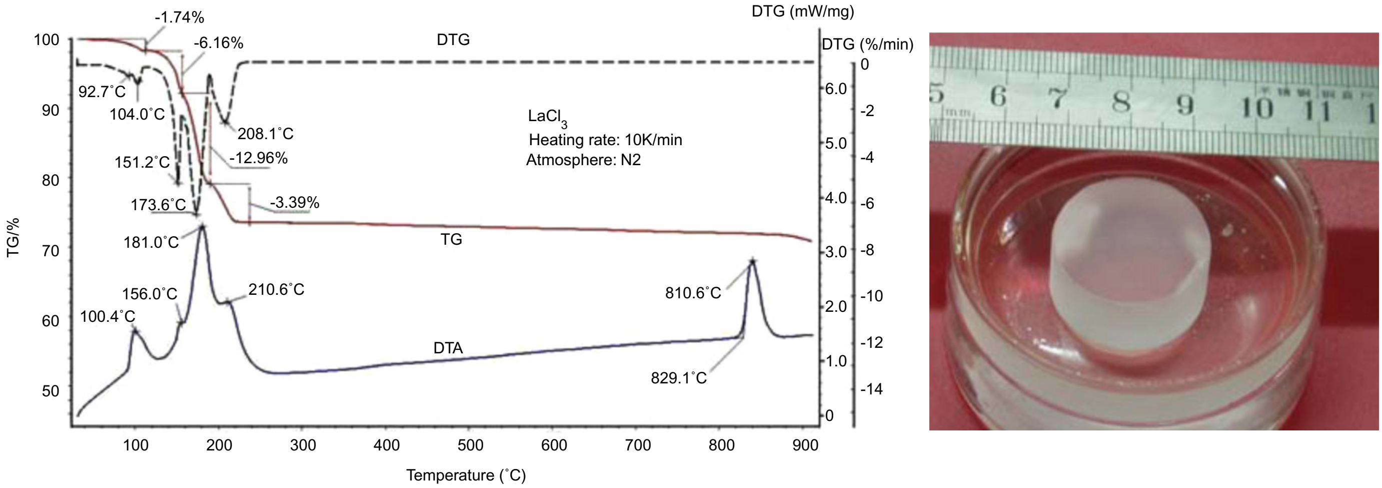

Fig. 1. DTA, TG and DTG curves (left)of $LaCl_3$ raw materials and $LaCl_3$:5%Ce crystal (right) grown with Bridgman method.

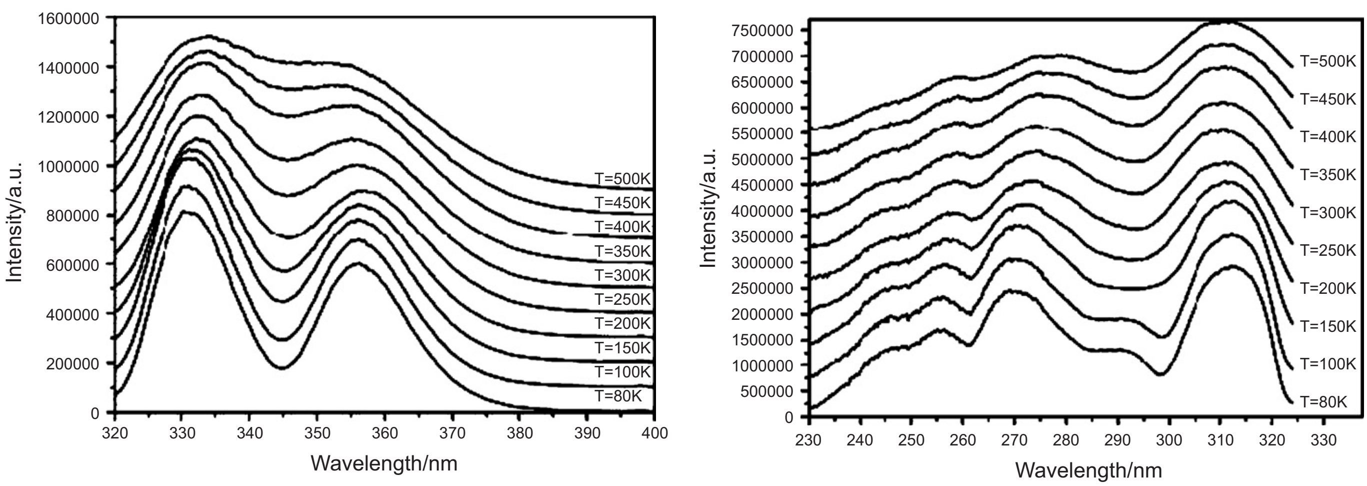

Fig. 2. Emission (left) and excitation (right) spectra of $LaCl_3$:5%Ce crystals measured at temperature from 80 K to 500 K.

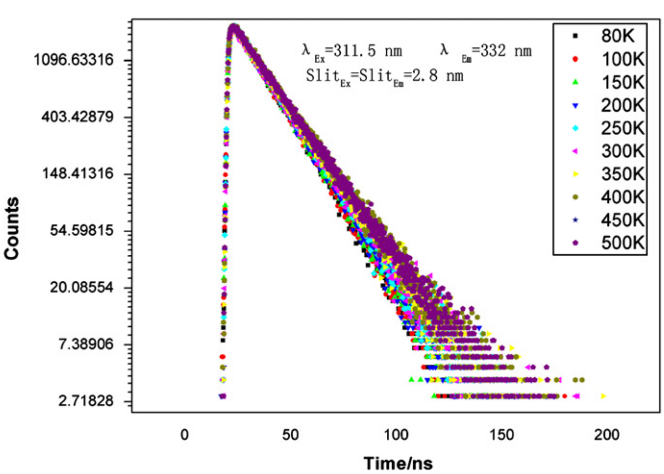

Fig. 3. Decay curves of $LaCl_3$:5%Ce crystals at different temperatures.

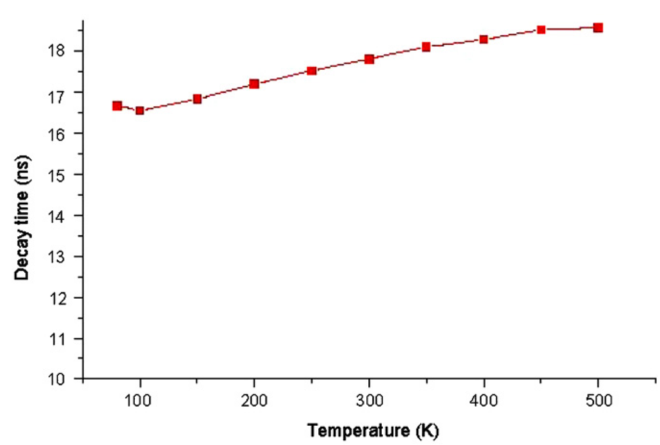

Fig. 4. Variation of decay time of $LaCl_3$:5%Ce crystal with the temperature.

3. Thermo-stability of photoluminescence (PL)

PL spectra of $LaCl_3$:5%Ce measured from 80 to 500 K in steps of 50 K are shown in Fig. 2. The measurement was carried out by the single photon counting method with a FLS920 spectrofluorimeter. The spectral shapes are corrected for the grating efficiency and PMT quantum efficiency. The integral over all