Accepted Manuscript

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PII: S1002-0721(18)30337-5

DOI: 10.1016/j.jre.2018.02.011

Reference: JRE 174

To appear in: *Journal of Rare Earths*

Received Date: 1 December 2017

Revised Date: 8 February 2018

Accepted Date: 9 February 2018

Please cite this article as: Daniel DJ, Panday IR, Kim HJ, Kim S, Fawad U, Luminescence and low temperature trap centers in mixed rare earth borate crystal, *Journal of Rare Earths* (2018), doi: 10.1016/j.jre.2018.02.011.

Luminescence and low temperature trap centers in mixed rare earth borate crystal

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Abstract:
The single crystal of this compound has been grown from melt by using a conventional Czochralski technique. The temperature dependent luminescence spectra were measured using a 265 nm laser as an exciting source in the range of 10 – 300 K. The scintillation decay time profile was measured and found to have three components. The influence of the trap centers on the luminescence properties was studied by means of thermoluminescence (TL) glow peak analysis. Low temperature TL glow peaks were measuredin the temperature range of 10 -300 K at the heating rate of 0.1 K/s for X-ray irradiated sample. The TL glow peak consists of two dominant peaks at 88 and 109K. Several glow peaks with a complex nature causes the decrease in the light yield at temperatures below 250 K, and along with long scintillation decay components were observed. The trap parameters such as activation energy (*E*), frequency factor (*s*) and order of kinetics (*b*) were calculated using various standard methods such as peak shape (PS), variable heating rate (VHR), initial rise (IR) and computerized glow curve deconvolution (CGCD).
Keywords: Rare earth; Decay time; Thermoluminescence; Kinetic parameters

Foundation item: Project supported by Ministry of Science and Technology, South Korea (MEST) (2015R1A2A1A13001843).
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1. Introduction

Although extensive research has been done with borate crystals owing to their wide range of applications such as luminescence, nonlinear optical and radiation detectors[1-4], still investigations are being vigorously pursued on their synthesis, crystal growth and characterizations. Certainly, rare earth based lithium (Li) borates are having great interest not only for studying basic physical properties but also for practical applications of these optical materials. Several research works have been putlished to investigate the fundamental properties of rare earth based Li borate crystals. The combinations of high neutron capture cross-sections isotopes such as ^{6}Li and^{10}B with Gd^{3+}ion form $Li_6Gd(BO_3)_3$ crystal would produce a potential candidate for heat-scintillation application with high light yields over a wide neutron energy range. A number of rare earth based ^{6}Li materials, such as $Li_6Y(BO_3)_3$, $Li_6Gd(BO_3)_3$, Ce:$Li_6Lu(BO_3)_3$ have been reported for optical applications [5-7].

One of the issues affecting the scintillation properties of the crystals is the existence of lattice defects and trap centers [8].The shallow traps of intermediate localized charge carriers may cause the long decay time (slow components). The deep traps may play an important role in the suppression of light yield because the thermal vibration is not sufficient for the release of the trapped charge carriers. As with all scintillation detectors, it is essential to study point defects, both intrinsic (interstitials, vacancies, and antisites) and extrinsic (intentional or unintentional impurities), which may affect the device performance [9]. Thermoluminescence (TL) is one of the most sensitive tool to characterize and study trap centers and lattice imperfections in wide-bandgap compounds.

In this present study, we focus on the low temperature TL trap centers of $Li_6Lu_{0.5}Gd_{0.5}(BO_3)_3:Ce^{3+}$ single crystal hereafter referred to as LLGBO. The temperature dependent light yield and decay time measurements were studied in the temperature range of 10 – 300 K. Trap centers were analyzed by using low temperature TL measurements and the kinetic parameters were calculated using various standard methods.

2. Experimental

The single crystals of these compounds were grownby the conventional Czochralski method using platinum crucible. Synthesized powder was taken into a platinum crucible and placed inside the chamber of the Czochralski furnace and melted. The seed crystal of LLGBO was attached with the platinum seed holder and dipped inside of the