Optical Materials 59 (2016) 145–149

Contents lists available at ScienceDirect

Optical Materials

journal homepage: www.elsevier.com/locate/optmat

Radioluminescence as a function of temperature and low temperature thermoluminescence of BaY_2F_8:Ce and BaY_2F_8:Nd crystals

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ARTICLE INFO

Article history:
Received 30 October 2015
Received in revised form 12 December 2015
Accepted 30 December 2015
Available online 15 January 2016

Keywords:
Scintillator
Fluoride
Cerium
Neodymium
Radioluminescence
Thermoluminescence

ABSTRACT

Radioluminescence spectra at temperatures ranging from 10 to 320 K and low temperature thermoluminescence glow curves of BaY_2F_8:Ce and BaY_2F_8:Nd scintillator crystals have been investigated. In both materials the intensities of the excitonic and the activator ion's emission at X-ray excitation vary with temperature, anticorrelating with each other, which provides valuable information on the host-to-ion energy transfer. Detailed thermoluminescence studies, in turn, prove the existence of charge traps, which introduce quasi-continuous distributions of energy levels into the bandgap.

1. Introduction

The crystals of BaY_2F_8:Ce (BYF:Ce) and BaY_2F_8:Nd (BYF:Nd) were already examined for their scintillating properties with research dating in the 20th century [1,2]. The interconfigurational *d–f* emissions of Ce^{3+} and Nd^{3+} ions had been supposed to produce fast and efficient scintillation, strengthening the potential of the BaY_2F_8 host already displaying the extremely fast still not efficient core-to-valence luminescence. Such expectations were not met, as the scintillation yield of BaY_2F_8:Ce and BaY_2F_8:Nd turned out to be very low. This result was related to the tenuous host-to-ion energy transfer, probably limited to the radiative mode from self-trapped excitons (STE), as well as to the STE emission quenching increasing with temperature [3]. Regardless of their rather weak scintillation properties, BYF:Ce and BYF:Nd provide very interesting subject for studies of energy transfer processes.

In this work we present the results of our research on radioluminescence (RL) as a function of temperature and low temperature thermoluminescence (TL) of the above mentioned crystals. The acquired data are discussed and compared with those available in relevant literature in order to enrich the knowledge on the energy transfer from the Ce^{3+} and Nd^{3+} ions to the BaY_2F_8 host, as well as on the charge trapping processes in this material.

2. Materials and experiment

Single crystals used in this study were grown by two different methods: BYF:Ce by the vertical Bridgeman technique, while BYF:Nd by the Chochralski method. Thin samples were cut from the boules and polished on both sides. BaY_2F_8 has a density of 4.97 g/cm^3 and an effective atomic number of 44. The crystal structure of BaY_2F_8 is monoclinic, equal to that of monoclinic $BaLu_2F_8$ [4].

Room temperature pulse height spectra necessary for light output determination were collected at 662 keV gamma excitation delivered by a ^{137}Cs source. The output signal from a photomultiplier tube (Hamamatsu R2059) was processed by an integrating preamplifier (Canberra 2005), a spectroscopy amplifier (Canberra 2022), and a multichannel analyzer (Tukan 8 k USB). Numbers of photons emitted by the studied materials were estimated by comparing their spectra with a spectrum of a reference $Y_3Al_5O_{12}$:Pr (YAG:Pr) sample cut from a Czochralski-grown boule obtained at the Institute of Electronic Materials Technology (ITME) in Warsaw [5]. This sample was thin (1 mm) to avoid errors due to different loss coefficients [6] and had a known scintillation yield of 26,000 ph/MeV.

A standard set-up consisting of an X-ray generator (Inel XRG3D) with a Cu-anode tube, a monochromator (Acton Research SP-150), a photomultiplier (Hamamatsu R928), and a helium cooler (APD Cryogenics) with a temperature controller (Lake Shore 330), was

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http://dx.doi.org/10.1016/j.optmat.2015.12.047
0925-3467/

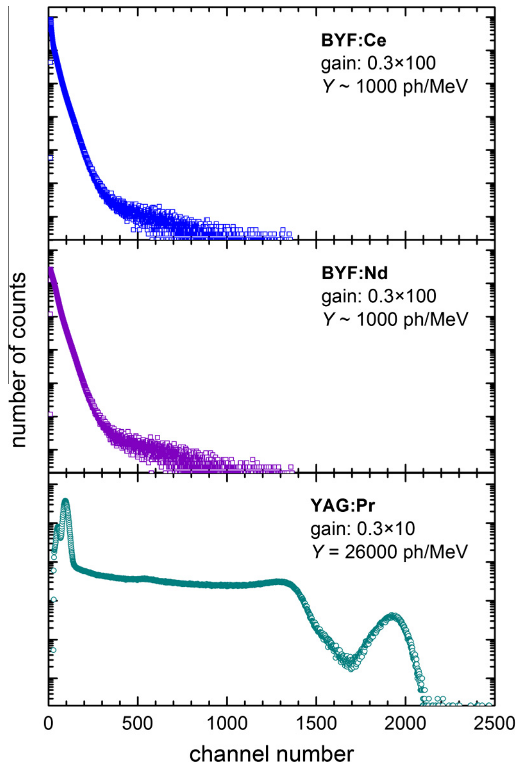

Fig. 1. 662 keV pulse height spectra of BYF:Ce, BYF:Nd and reference YAG:Pr.

used to register RL spectra and TL glow curves. The RL measurements as a function of temperature were started at 325 K and terminated at 10 K to avoid a possible contribution from any thermally activated processes. The glow curves were taken between 10 and 320 K at a heating rate of 0.14 K/s, following a 10 min X-ray irradiation. Details of the additional T_m–T_{stop} experiment were already reported by Brylew et al. [7].

3. Results and discussion

3.1. Light output

Pulse height spectra of the BaY_2F_8:Ce and BaY_2F_8:Nd samples are compared to the spectrum of the YAG:Pr sample in Fig. 1. Contrary to the reference spectrum, the examined spectra do not have any distinct structure. Since no clear photopeak is marked, it is only possible to estimate the light outputs very roughly. We assume that the photopeak for both BYF:Ce and BYF:Nd is located somewhere between the channels No. 500 and 1000. If 750 was taken as the photopeak position for BYF:Ce and BYF:Nd at a gain of 30, and 1950 for YAG:Pr at a gain of 3, we could get a very approximate scintillation yield of the studied crystals as:

$$(750/1950) \times (3/30) \times 26,000 \text{ ph/MeV} = 1000 \text{ ph/MeV}$$

Taking into account the data available in literature [1,3] our value can still be overestimated. Anyway, it confirms that concerning the light output both BaY_2F_8:Ce and BaY_2F_8:Nd are simply very poor scintillators.

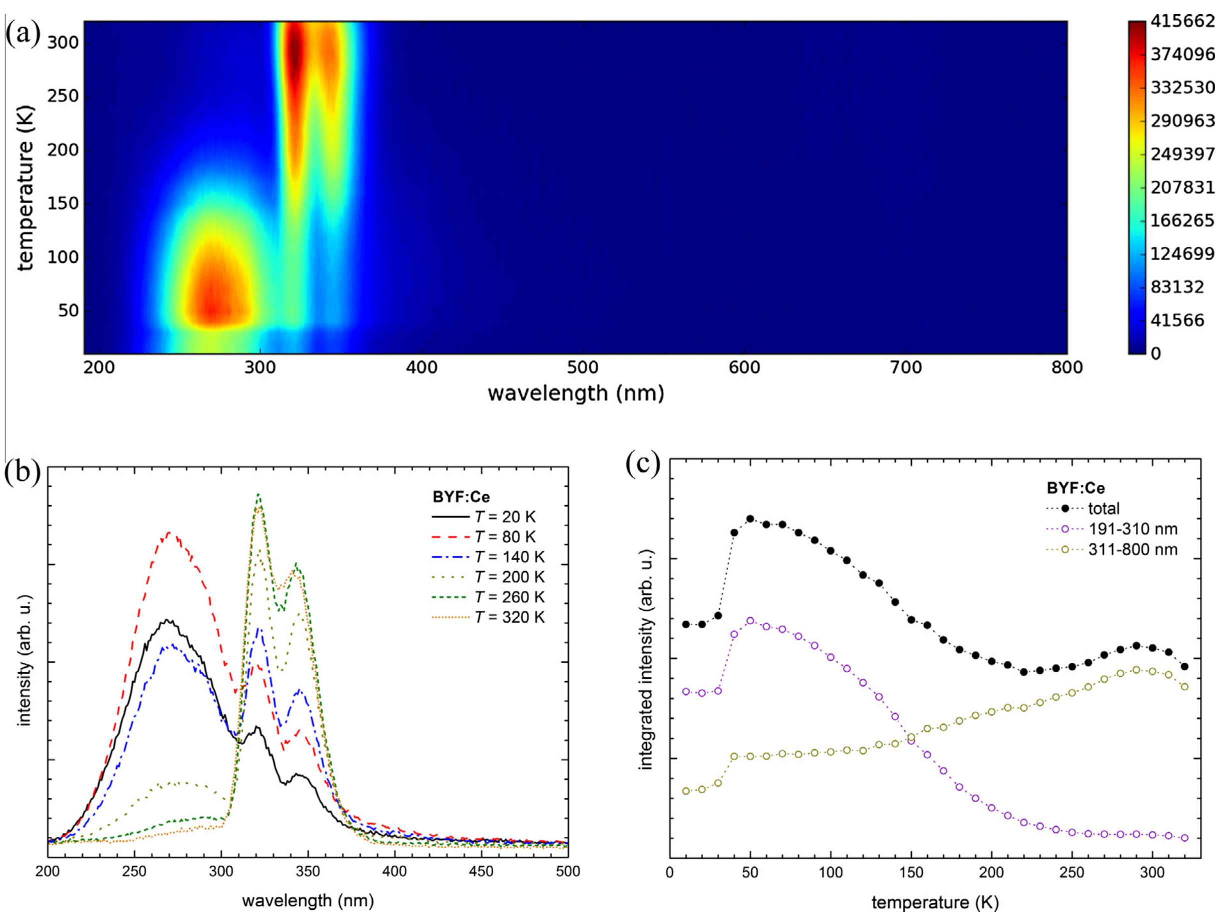

Fig. 2. Radioluminescence of BYF:Ce.