Spectrally resolved thermoluminescence of BaF_2 doped with Ce^{3+}, Pr^{3+}, and Tb^{3+} ions

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Thermoluminescence (TL) is a valuable experimental technique providing important information on traps that are likely to interfere with the process of luminescence production in wide bandgap materials. At HASYLAB the SUPERLUMI station at the beam I of the DORIS storage ring makes it possible not only to record wavelength integrated TL glow curves ranging from 10 to 350 K, but also to resolve the TL signal due to the light released at different temperatures into separate wavelengths. Such measurements provide information not only on traps, but also on recombination centers that take part in luminescence, thus providing more complete and detailed information than the simple TL experiment.

Studies on energy transfer and charge trapping processes are necessary to establish scintillation mechanism in any scintillator material. Barium fluoride, the fastest known inorganic scintillator, is a particularly interesting case. First measurements of spectrally resolved TL of pure BaF_2 at HASYLAB have been performed by Shi *et al.* [1]. In this note we report our initial results on BaF_2 doped with Ce^{3+}, Pr^{3+}, and Tb^{3+}.

The glow curve of BaF_2:Ce irradiated at 10 K with synchrotron radiation (0th-order) for 30 minutes, taken at the heating rate of ~0.04 K/s, is shown in Fig. 1a. There are five peaks at about 106, 127, 156, 224, and 348 K, positions of which are, taking into account differing heating rates, in a good agreement with previous experiments on the same crystals [2,3]. The photoluminescence spectrum excited at 120 nm (Fig. 1b) consists of both excitonic (STE) and Ce^{3+} *d-f* luminescence. At 200 nm excitation (Fig. 1c) we observe the latter emission with no contribution from the former one. We note that the Ce^{3+} *d-f* emission band is present in all TL spectra (Figs. 1b,c), while the STE band occurs only in the 85-115 K range and above 290 K.

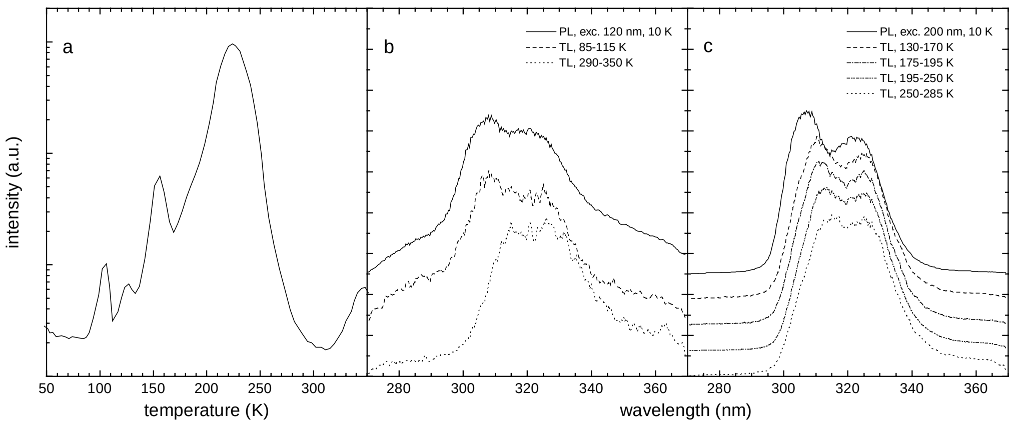

Figure 1: glow curve (a), photoluminescence spectra and thermoluminescence spectra (b,c) of BaF_2:Ce

The ~100 K peak in the glow curve of BaF_2:Ce, observed earlier in pure BaF_2 [4,1], is due to thermal activation of the self-trapped hole (V_K center) motion. As established recently by Glodo *et al.* [2], this peak can be well represented by a 0.26 eV trap. The room temperature lifetime of this trap at 62 ns is responsible for the slower than radiative decay of the major component in the scintillation time profile of BaF_2:Ce, thus confirming that direct and trap mediated recombination at cerium ions is the dominant scintillation mechanism in this material. Deeper traps uncovered by TL introduce even slower components. The TL spectra, dominated by the Ce^{3+} *d-f* luminescence, support these conclusions.

Similar measurements have been performed on BaF_2:Pr (Fig. 2) and BaF_2:Tb (Fig. 3), with results that are close to those obtained for BaF_2:Ce. In all cases the excitonic emission is efficiently excited at 120 nm, while the 200 nm excitation leads to characteristic *d-f* (Ce^{3+}, Pr^{3+}) or *f-f* (Tb^{3+}) luminescence of rare earth (RE) ions. The three glow curves peak at ~105 and ~125 K, and the STE band occurs in the wavelength resolved TL spectra of the first peak. From 130 to 290 K these spectra consist almost entirely of the RE ion emission, just like in the case of BaF_2:Ce. Nevertheless we note that, unlike for Ce^{3+}, there is no Pr^{3+} *d-f* luminescence below 110 K and there is also some contribution of the excitonic band above 250 K. The more detailed description of scintillation and radioluminescence processes in BaF_2:Pr and BaF_2:Tb must await later publication.

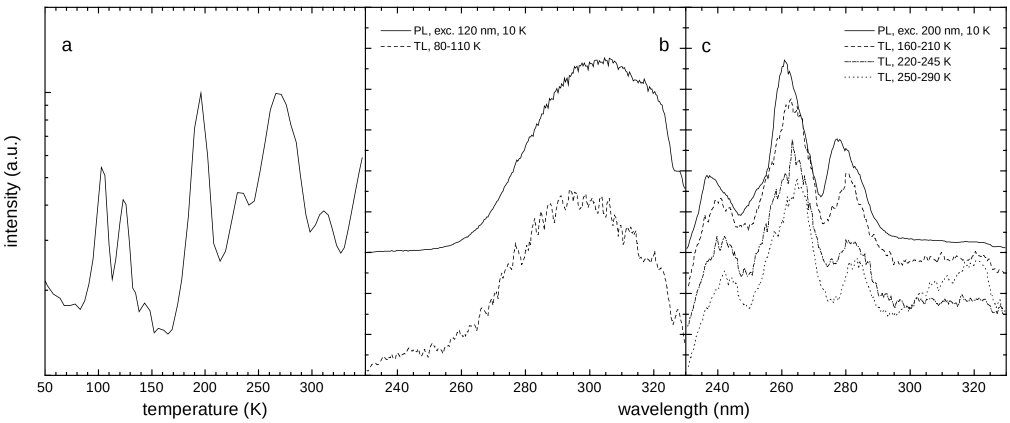

Figure 2: glow curve (a), photoluminescence spectra and thermoluminescence spectra (b,c) of BaF_2:Pr

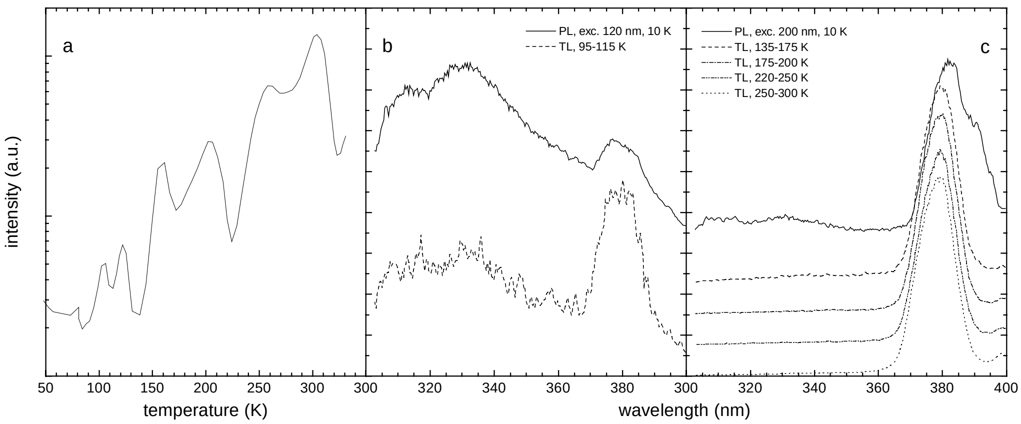

Figure 3: glow curve (a), photoluminescence spectra and thermoluminescence spectra (b,c) of BaF_2:Tb

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