Luminescence properties of LaBr$_3$-Ce microcrystals embedded in NaBr matrix

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The LaBr$_3$:Ce$^{3+}$ single crystals are extensively studied in the last years due to their high scintillation light yield and energy resolution [1]. However, the hygroscopicity of LaBr$_3$ crystal reduces their potential. The embedding of La-based microcrystals into halide matrices is one of the possible solutions for this problem. The possibility to obtain the LaCl$_3$:Ce microcrystals dispersed in NaCl matrix was demonstrated earlier [2]. In this work the luminescence-kinetic properties of LaBr$_3$:Ce$^{3+}$ microcrystals embedded in NaBr matrix prepared using same procedure are reported.

The morphology of NaBr-LaBr$_3$-Ce crystalline system was studied using the scanning electronic microscopy. Embedded microcrystals of 5 – 20 µm size were revealed on the microphotos. The electron beam analysis has shown the microcrystalline inclusions that contain La and Br elements in mass ratio corresponding LaBr$_3$ compound. Time-resolved luminescent spectroscopy studies were performed at $T$=9-300 K using the facility of SUPERLUMI station at HASYLAB.

Emission spectrum of NaBr-LaBr$_3$(1 mol.%)-CeBr$_3$(0.05 mol.%) at 9 K upon the excitation in the range of cerium intracenter absorption consists of two bands peaked at 356 and 386 nm (Fig. 1a) that arise from 5d-4f electronic transitions of Ce$^{3+}$ ions. The spectral position of these bands coincides with that in the bulk LaBr$_3$-Ce crystal [3]. This fact additionally denotes the creation of LaBr$_3$:Ce microcrystals in NaBr matrix.

Upon the excitation in the excitonic absorption range of LaBr$_3$ microcrystals except the cerium emission bands the band ascribed to STE emission of LaBr$_3$ matrix [3] is observed (Fig. 1b). The light quanta with energy $E > 6.1$ eV falling into fundamental absorption range of NaBr matrix effectively excites cerium emission of NaBr-LaBr$_3$:Ce crystal (Fig. 1c) at 9 K. Also upon the excitation in this range the STE emission band of NaBr crystal is observed at 4.57 eV [4].

![Figure 1: Emission spectra of the NaBr-LaBr$_3$(1 %)-CeBr$_3$(0.05 %) at the excitation by the quanta with 3.75 (a, curve 1), 5.4 (b) and 10.5 eV (c) at the 9 K.](image)
In the 5.0 – 6.1 energy range the luminescence excitation bands with maxima at 5.5 and 6.0 eV are observed at 9 K (Fig. 2b). Similar luminescence excitation bands were revealed for bulk LaBr$_3$-Ce crystal at 5.4 and 5.9 eV. The 5.4 eV band is ascribed to exciton absorption and band at 5.9 eV corresponds to onset of band-to-band absorption of LaBr$_3$ crystal [3]. Small difference in spectral positions of these bands in bulk LaBr$_3$ crystal and LaBr$_3$ microcrystals can be caused by the pressure of NaBr matrix on microcrystals.

The cerium emission is excited by high energy quanta (E > 6.1 eV) falling into fundamental absorption range of NaBr matrix only at low temperatures (Fig. 2b, curve 1). At ambient temperature the cerium emission is not excited in the range of fundamental absorption of NaBr matrix (Fig. 2b, curve 1). The structure of luminescence excitation spectrum for cerium emission is similar to that for emission band of STE in NaBr crystal (Fig. 2a). Such peculiarities of luminescence excitation spectra of cerium emission NaBr-LaBr$_3$-Ce crystal can be explained under assumption that the excitations created in NaBr matrix don’t transfer the excitation energy to embedded LaBr$_3$-Ce microcrystals. In this case the cerium emission at the excitation with light quanta with energy E>6.1 eV appears at low temperatures exceptionally due to the reabsorption of NaBr STE emission band (4.59 eV) that overlaps the intracenter absorption band of Ce$^{3+}$ ions (3.7 – 5.0 eV).

The luminescence decay kinetic of cerium emission upon the intracenter excitation possesses a single exponential character. The decay time constant is estimated to be 14 ns and 15.6 ns at 9 and 300 K, respectively. Similar decay time constants are found for bulk LaBr$_3$-Ce crystal.

Figure 2: a) Luminescence excitation spectrum of the NaBr-LaBr$_3$(1 %)-CeBr$_3$(0.05 %) crystal for 270 nm emission (curve 1) at 9 K and reflection spectrum of NaBr (curve 2); b) luminescence excitation spectrum of cerium emission at 9 and 300 K (curves 1 and 2, respectively).

References