A Time-Resolved Luminescence Spectroscopy Study of Scintillation Crystals $SrI_2:Eu^{2+}$

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We report experimental results on luminescent properties of modern scintillation material $SrI_2:Eu^{2+}$. The study was carried out by the means of the low-temperature luminescence VUV spectroscopy. Photoluminescence (PL) spectra in the energy range from 1.2 eV to 6.2 eV, PL excitation (PLE) spectra in the energy range from 3.7 eV to 40 eV (0.32 nm resolution) were measured at 9 and 295 K for these crystals at the SUPERLUMI experimental station of HASYLAB using synchrotron radiation. All the examined crystals were grown at the Institute of Geology and Mineralogy SB RAS (Novosibirsk) by the vertical Bridgman method (see more details in Ref. [1]).

Photoexcitation of $SrI_2:Eu^{2+}$ at photon energies E_{ex}=5-30 eV at T =295 K produces broad-band PL emission with a maximum at 2.85 eV and a shoulder at 2.4 eV, Fig. 1. The observed PL spectrum is consistent with published data [2,3]. Cooling down to 9 K leads to a narrowing of the PL emission band width and to an increase in the luminescence yield by 4-5 times. In addition, a new band in the region at 3.4 eV appears in the PL spectrum, Fig. 1.

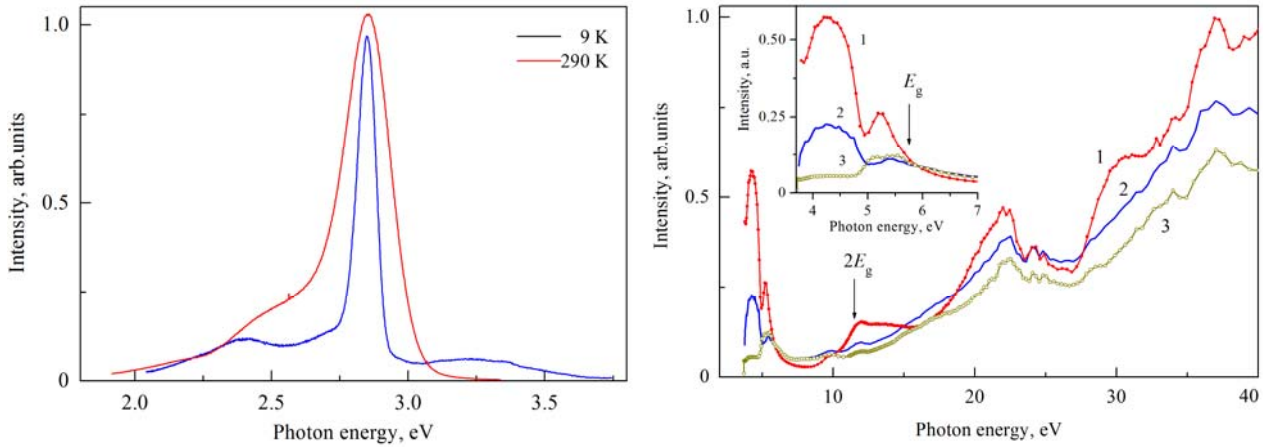

Figure 1: Left panel - PL emission spectra of $SrI_2:Eu^{2+}$ measured at E_{ex}=14 eV. Right panel - PL excitation spectra of $SrI_2:Eu^{2+}$ measured at E_m=2.85 - (1, 2) and 2.40 eV - (3), T = 295 - (1) and 9 K - (2, 3). The inset displays a zoom of the low-energy part of the spectra.

Figure 1 presents the PLE spectra of $SrI_2:Eu^{2+}$ measured at 9 and 295 K for monitored bands E_m=2.4 and 2.85 eV. In the low-energy region of the PL excitation spectrum there are two pronounced peaks at 5.26 eV (E_m=2.4 and 2.85 eV) and 4.26 eV (E_m=2.85 eV). In the energy range of exciting photons more than 10 eV ($E_{ex} > 2E_g$) there is a sharp increase in the PL yield which is associated with the manifestation of the multiplication of electronic excitations and it characterizes the generational stage of the scintillation pulse formation. The effect is pronounced, and it is a necessary attribute of an effective scintillator.

The PL decay kinetics measured at T =295 K is monoexponential in shape for both the intracenter (E_{ex} =4.26 eV) and interband (E_{ex} =13 eV) excitations. According to our data the PL decay kinetics, measured at E_m = 2.4 and 2.85 eV, exhibit no appreciable differences. The measured time constant of the PL decay kinetics was always equal to τ =0.36 ms. This value is noticeably different from the time-constants obtained with other types of excitations: τ = 1.2 ms for single pulse of YAG:Nd laser with E_{ex} =4.66 eV [3] and τ =1.1 ms for ^{137}Cs-gamma radiation [2]. It happens because of radiation trapping, at which the scintillation light is multiple time absorbed and consequently

emitted by the dopant. The further ‘shortening’ of the decay time-constant occurs due to the high repetition frequency (5.21 MHz) of excitation pulses used in our measurements.

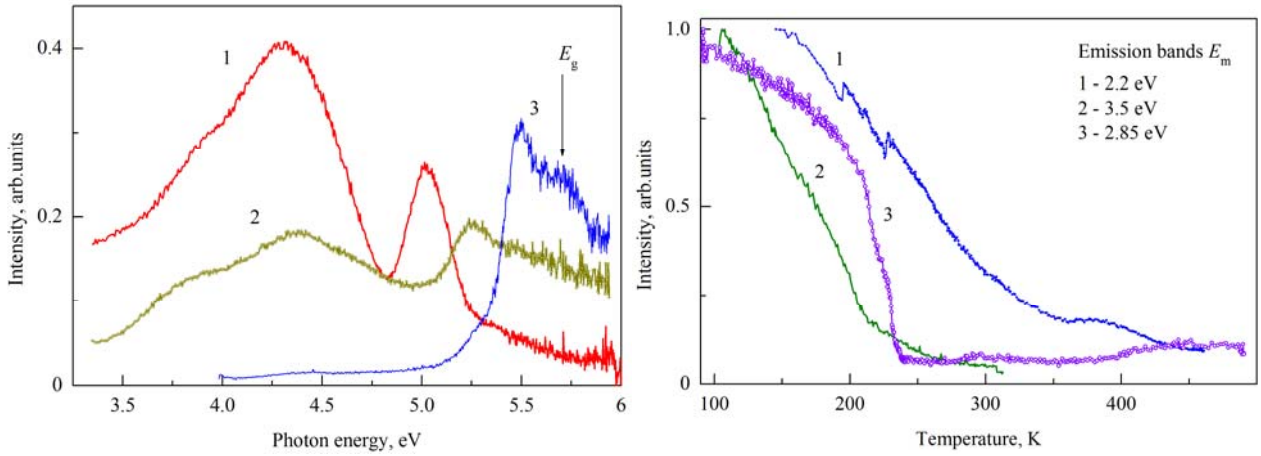

Figure 2: Left panel - PL excitation spectra of $SrI_2:Eu^{2+}$ measured for E_m = 2.85 - (1, 2), 3.5 - (3) at 295 - (1) and 90 K - (2, 3). Right panel - Temperature dependence of the luminescence intensity measured under excitation with E_{ex} = 4.34 - (1), 5.5 eV - (2) and X-rays - (3).

Fig. 2 shows the PLE spectra for E_m =2.85 and 3.4 eV. The cooling to 90 K causes the 0.22 eV blue shift of the high-energy peak of the PL excitation spectrum measured for E_m =2.85 eV. The similar shift can be observed in the PLE spectra presented on Fig. 1. At the same time, the 3.4 eV emission band can not be excited at $E_{ex} < 5.2$ eV, whereas at $E_{ex} > 5.2$ eV the PL excitation spectrum of this band demonstrates a sharp increase in intensity with a maximum near 5.5 eV.

The low-temperature emission band at 3.4 eV can be excited only in the fundamental absorption region of a crystal and its decay kinetics is characterized by the micro- and millisecond time-constant. In this connection the 3.4 eV band can be assigned to the intrinsic emission due to radiative annihilation of triplet self-trapped excitons. The PLE spectrum of the 3.4 eV emission allows us to refine an estimate of the bandgap value for the $SrI_2:Eu^{2+}$ crystal. We derived from the PL excitation spectra (curve 3 on Fig. 2) the value of E_g =5.7-5.8 eV. From the PLE spectra (curve 3 on Fig. 2) it follows that the cutoff energy at 90 K should be located in the energy range of 5.0-5.2 eV.

Figure 2 shows the temperature dependence of the PL intensity, measured for the 2.2 and 3.5 eV emission bands, as well as the temperature dependence of the XRL intensity, measured for the 2.85 eV emission band. According to the Mott law, we estimated roughly the activation energies for appropriate processes of temperature quenching: E_a = 0.14, 0.10 and 0.27 eV for curves 1, 2 and 3, respectively, Fig. 2.

References

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