Physical Properties of the $(Ga_{70}La_{30})_2S_{300}$, $(Ga_{69,75}La_{29,75}Er_{0,5})_2S_{300}$ Single Crystals

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The single crystals of the $(Ga_{70}La_{30})_2S_{300}$, $(Ga_{69,75}La_{29,75}Er_{0,5})_2S_{300}$ compositions were grown by solution-melt method from their primary crystallization range. The compositions and the growth conditions were selected using the Ga_2S_3 – La_2S_3 phase diagram [1]. The supercooling of the solid solution was 70 K as determined from the cooling thermograms of the samples. The synthesis of the starting alloy at maximum temperature 1200 K and the crystal growth was performed in the same evacuated quartz container with a conical bottom. The growth process was performed in a vertical two-zone furnace. The temperature gradient at the solid-melt interface was 20 K/cm. After melting the batch, the ampoule was lowered at a rate of 5 mm/day. Immediately after the crystallization of 10 mm along the ampoule, we followed by remelting 6.0-8.0 mm of the crystallized portion. Then the ampoule was annealed for 100 hours. After that, the crystal growth was performed at a rate of lowering of 5 mm/day. At the end of the process, both furnaces were cooled to 820 K at a rate of 50-70 K/day, and then cooled to room temperature with the furnaces switched off. The grey-yellow single crystals with a diameter of 15 mm and a length of 24 mm were obtained. Both samples were indexed in the monoclinic structure, S.G. $P2_1/c$, a=1,5168(4) nm, b=1,0555(4) nm, c=1,283(3) nm, β=137,60° for $(Ga_{70}La_{30})_2S_{300}$, with good agreement with [2] and a=1,5175(3) nm, b=1,0564(2) nm, c=1,289(2) nm, β=137,70° for $(Ga_{69,75}La_{29,75}Er_{0,5})_2S_{300}$.

Photoluminescent properties of the single crystal $(Ga_{69.75}La_{29.75}Er_{0.5})_2S_{300}$ were investigated. The excitation by 400 mW laser at 810 nm wavelength led to photoluminescence (PL) in the spectral range 510–560 nm. PL spectrum consists of two peaks at 525 and 545 nm, with the ratio of the intensity at their maxima being $I_{545/I525}$=4.2. Characteristic narrow maxima and PL absence in the $(Ga_{70}La_{30})_2S_{300}$ crystal means that the emission in the $(Ga_{69.75}La_{29.75}Er_{0.5})_2S_{300}$ single crystal is caused by the intra-center transitions in Er^{3+} ions, namely $^2H_{11/2} \rightarrow {}^4I_{15/2}$ and $^4S_{3/2} \rightarrow {}^4I_{15/2}$ for 525 and 545 nm, respectively. The absorption of IR quanta (810 nm) yields green luminescence, with higher energy quanta. Such a phenomenon (so called up-conversion photoluminescence) is especially common in erbium-doped chalcogenide glasses [3]. This can occur by sequential absorption of two photons with 810 nm wavelength; or when one erbium ion is in excited $^4I_{9/2}$ state, energy is transferred to another $^4I_{9/2}$-excited ion nearby: $^4I_{15/2} + h\nu_{810} \rightarrow {}^4I_{9/2} + h\nu_{810} \rightarrow {}^2H_{9/2}$ $^4I_{9/2} + {}^4I_{9/2} \rightarrow {}^4I_{15/2} + {}^2H_{9/2}$. The next step is non-radiative relaxation of erbium ions to the lower energy states or cross-relaxation involving $^2H_{11/2}$ and $^4S_{3/2}$ states. Thus, a high concentration of erbium ions in the $^2H_{11/2}$ та $^4S_{3/2}$ states is obtained through which PL radiation is emitted. This type of radiation is particularly promising for the manufacture of up-converters from infrared to visible light.

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