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The luminescence thermometry based on analysing of $^3P_0$-$^3H_5$ emission band of Pr^{3+} ions in Pr^{3+}:$LiYF_4$ nanoparticles and microparticles

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Abstract. The study is devoted to the possibility of using and Pr^{3+}:$LiYF_4$ microparticles and nanoparticles as luminescent thermometers in the temperature range of 80-320 K. The ratio of luminescence peaks corresponding to the transitions from the $^3P_0$ state to two Stark sublevels of the $^3H_5$ state of Pr^{3+} ions is considered as a temperature-dependent parameter. This system demonstrates an absolute temperature sensitivity of 0.0009 K^{-1} at a temperature of 185 K.

The Pr^{3+}:$LiYF_4$ nanoparticles were synthesized via the hydrothermal synthesis method [1]. Microparticles of Pr^{3+}:$LiYF_4$ were synthesized by mechanical grinding of a Pr^{3+}:$LiYF_4$ crystal grown by the Bridgman method. The ground particles were sieved through a sieve with a mesh diameter of 0.45 mm The morphology of nanoparticles was studied by transmission electron microscopy using a Hitachi HT7700. The samples were optically excited by a JV LOTIS TII pulsed laser (420–1200 nm) at λ= 442 nm, which corresponds to the $^3H_5 \rightarrow {}^3P_2$ transition of Pr^{3+} ions. The luminescence spectra were recorded using a Stellarnet spectrometer (200-1100 nm). The TEM data of Pr^{3+}:$LiYF_4$ nanoparticles are presented in Figure 1 a. The average nanoparticle diameter was 38 ± 3 nm. According to X-ray diffraction analysis, nanoparticles and microparticles are crystalline particles of tetragonal syngony corresponding to the $LiYF_4$ matrix. The normalized luminescence spectrum of Pr^{3+}:$LiYF_4$ nanoparticles, corresponding to the $^3P_0$-$^3H_5$ emission band as a function of temperature, is shown in Figure 1b. As a temperature-dependent parameter, we consider the ratio of the integrated and peak intensities of the bands at wavelengths of 547 and 550 nm. The ratio of intensities as a function of temperature is shown in Figure 2a. It can be seen from the figure that the ratio of peak intensities decreases monotonically with decreasing temperature. This dependence was approximated by the function $y=A+B*\exp(\Delta E/kT)$, where A and B are the constants, the Boltzmann k-constant, T is the absolute temperature, and ΔE is the activation. The ratio of integral intensities apparently shows a similar dependence, however, a wide spread of points does not allow a full approximation.

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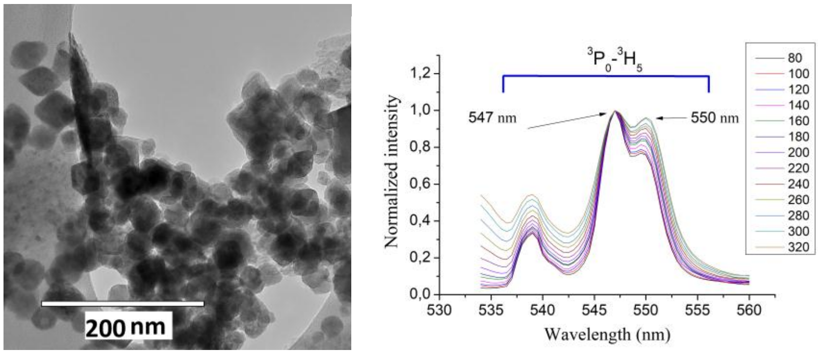

Fig. 1. TEM data of Pr^{3+}:$LiYF_4$ nanoparticles (a), normalized luminescence spectrum of Pr^{3+}:$LiYF_4$ nanoparticles, corresponding to the arrival of $^3P_0$-$^3H_5$ as a function of temperature (b)

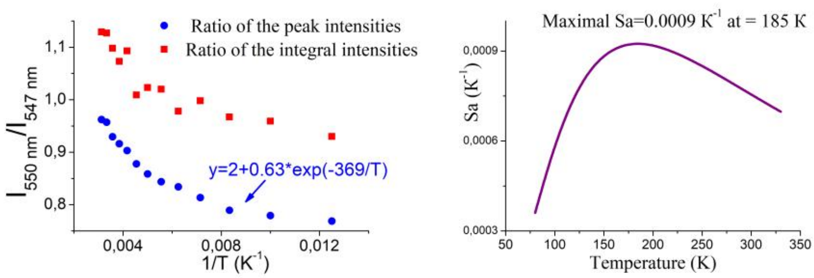

Fig.2. The luminescence intensity ratio for Pr^{3+}:$LiYF_4$ nanoparticles (a), absolute temperature sensitivity as function of temperature(b)

This may be due to the high degree of overlap of the studied bands. To determine the absolute temperature dependence calculated by the formulas described in the source [2], the ratio of peak intensities was used. The dependence of the absolute temperature sensitivity on temperature is shown in Figure 2 (b).

This system demonstrates the absolute temperature sensitivity of 0.0009 K^{-1} at a temperature of 185 K, which indicates the possibility of using the studied particles as luminescent thermometers in the cryogenic temperature range. Microparticles of Pr^{3+}:$LiYF_4$ show similar dependencies.

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