Luminescent and Structural Studies of $Y_3Al_5O_{12}$ Nanopowders Doped with Different Concentrations of Yb^{3+} Ions

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Yttrium aluminum garnet $Y_3Al_5O_{12}$ (YAG) doped with rare-earth ions is an important laser material and phosphor with excellent chemical and thermal stability, as well as good optical-luminescent properties. As a rare-earth ion with the simplest energy-level construction, Yb^{3+} has some important advantages, in particular, a long radiative lifetime of the upper laser level and no excited-state absorption or upconversion loss compared with other rare-earth ions [1]. On the other hand, significant changes in the optical-luminescent properties are observed in nanomaterials and are due to surface-related defects.

The studied YAG nanopowders doped with Yb^{3+} ions have been synthesized by citrate sol-gel method, as described in [2]. In this method following substances were used: yttrium nitrate hexahydrate $Y(NO_3)_3{\cdot}6H_2O$ and aluminum nitrate nonahydrate $Al(NO_3)_3{\cdot}9H_2O$, ytterbium oxide Yb_2O_3, nitric acid HNO_3, citric acid $C_6H_8O_7$ and distilled water H_2O. The temperature of calcinations was 1000 °C. Activator concentration was equal 5, 10, 15, 20 and 30 at.%. The phase formation of YAG: Yb was characterized by X-ray powder diffraction (XRD) techniques. The average size of particles was estimated from the line broadening by using of well-known Scherrer's formula, as well as by Williamson-Hall analysis [3] and was in the range 60...200 nm. Anomalous increase of nanopowder lattice parameter with increasing of Yb concentration was observed, despite that the Yb^{3+} ionic radius is smaller than that of Y^{3+}. This anomalous concentration dependence, apparently, connected with presence of ytterbium ions in aluminum positions of crystal lattice.

The luminescence spectra and decay kinetics of YAG:Yb with various doping levels were measured at room temperature. All emission and excitation spectra are typical of ytterbium ions and correspond to f-f transitions of Yb^{3+}. Two main excitation peaks are centered at 1016 nm and 1039 nm, as well as main emission peak, is at about 1030 nm. The Yb^{3+} luminescence intensity has the maximum for 5% of ytterbium and decreases with increasing concentration to 30 % more than one order. Activator concentration has no effect on the positions of the peaks in the luminescence spectra. Doping levels increasing also leads to shortening of Yb^{3+} lifetimes from 600 to 20 μs at the Yb^{3+} concentration changing from 5 to 30 %, respectively. The decays are related to $^2F_{5/2} \rightarrow {}^2F_{7/2}$ transition in Yb^{3+} ions. The observed decreasing of the luminescence intensities and shortening of the lifetimes are caused most probably by concentration quenching and energy transfer from Yb^{3+} to host or surface-related defects.

The effects of various Yb^{3+} concentrations and thermal treatment on structural distortion and luminescent properties of YAG nanopowders are discussed.

[1] X. Xu, Z. Zhao, P. Song et al., *Journal of the Optical Society of America B* **21**(3) (2004) 543-547.
[2] Ya. Zhydachevskii, I.I. Syvorotka, L. Vasylechko, D. Sugak, I.D. Borshchyshyn, A.P. Luchechko, Ya.I. Vakhula, S.B. Ubizskii, M.M. Vakiv, A. Suchocki, *Optical Materials* **34** (2012) 1984–1989.
[3] G.K. Williamson, W.H. Hall, X-ray line broadening from filed aluminium and wolfram, *Acta Metall*. **1** (1953) 22–31.