INFLUENCE OF {Ce^{3+} – Mg^{2+}} PAIRS ON LUMINESCENCE OF $Gd_3(Ga,Al)_5O_{12}$:Ce, Mg SINGLE CRYSTALS

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Single crystals of Ce^{3+}-doped $Gd_3(Ga,Al)_5O_{12}$ multicomponent garnets, owing to their extremely high light yield, fast scintillation response, good energy resolution, relatively high density, high radiation hardness, and the absence of the intrinsic radioactivity, are intensively investigated as promising scintillation materials for their applications in medical imaging devices and high-energy physics experiments. Co-doping with Mg^{2+} ions, leading to the $Ce^{3+} \rightarrow Ce^{4+}$ transformation, results in a noticeable improvement of timing characteristics and strong suppression of the afterglow and thermally stimulated luminescence. However, Mg^{2+}-induced acceleration of the luminescence decay kinetics is accompanied with undesirable reduction of its light yield. The aim of this work is to understand the mechanisms of these processes and their dependence on the composition of the $Gd_3(Ga,Al)_5O_{12}$ garnets and concentration of impurity Ce^{3+} and Mg^{2+} ions.

The $Gd_3Ga_xAl_{5-x}O_{12}$:Ce, Mg (x = 2.46 - 2.95) single crystals with different true concentrations of Ce (0.016 - 0.188 at.%) and Mg (0 - 0.083 at.%) ions have been investigated by the X-ray diffraction, steady-state and time-resolved photoluminescence, and thermoluminescence methods. The Mg^{2+}-induced reduction of the light yield and acceleration of the decay kinetics of the Ce^{3+} luminescence are found to be connected with the formation of {Ce^{3+} – Mg^{2+}_{Ga}} pairs. The perturbation of Ce^{3+} energy levels by the closest Mg^{2+}_{Ga} ions in these pairs is suggested to result in the appearance of the luminescence optical quenching and decrease of the energy barrier E_q for the crossover processes in the $5d_1$ excited state of Ce^{3+}. All the Mg^{2+}-induced processes, such as $Ce^{3+} \rightarrow Ce^{4+}$ transformation, luminescence optical quenching, decrease of the E_q value, as well as the appearance of the fast decay component and increase of its relative contribution into the luminescence decay kinetics, are found to be most effective at relatively small Mg^{2+} concentrations, reaching the saturation with the increasing Mg^{2+} content. This effect is explained by limited concentration of the closest {Ce^{3+} – Mg^{2+}_{Ga}} pairs due to limited number of Ga^{3+} ions in the tetrahedral crystal lattice sites. It is found that in order to obtain the best positive effect from the Mg^{2+} co-doping, the concentration of Mg^{2+} should be about 0.035 at.%. The optimum Ga^{3+} content should not exceed x = 2.65.