The Lu for La substitution effects on the single crystal growth and luminescence properties in $Lu_{3-x}La_xGa_3Al_2O_{12}:Ce^{3+}$ scintillators

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The Ce^{3+} activated $Lu_3Al_5O_{12}$ (LuAG:Ce) single crystal is a promising scintillator for γ-rays and high energy particles detection, due to high density (6.7 g/cm^3), good radiation stability, fest scintillation response and light yield of about 12-18 kph/MeV [1]. However, high-temperature crystal growth process creates many shallow trapping centers which significantly diminish light yield and timing performances [2]. Such shallow trap centers arise due to the displacement of some part of Lu atoms to Al sites and forms so-called Lu_{Al} antisite defects [3]. The negative effect of the antisite defects can be greatly reduced by substitution Al for Ga. Such improvement can be reached by burying antisite defects in the conduction band, whose edge moves towards lower energies upon Ga admixture. Consequently, light yield value increased and slow component of the scintillation decay time was accelerated [4].

The motivation for this work comes from the positive impact of the "band gap engineering" and "Ce^{3+} energy-level positioning" in the aluminum garnet single crystal scintillators [5]. We study the effect of substitution Lu for La and Al for Ga in LuAG:Ce on the crystal growth process and scintillation and luminescence performances. Those characteristics are strongly dependent on the La/Lu and Al/Ga content ratio. The LuAG:Ce single crystals with various La and fixed Ga content were grown from the melt by the micro-pulling-down method. Single crystals were characterized by optical absorption, photoluminescence excitation, and emission and radioluminescence spectra and photoluminescence decay kinetic measurements. Scintillation properties of the crystals were studied by means of light yield value and scintillation decay time analysis. The garnet phase is confirmed by powder X-ray diffraction.

[1] M. Nikl et al. Prog. Cryst. Growth Charact. Mater. 59 (2013) 47-72
[2] M. Nikl et al. Phys. Rev. B 76 (2007) 195121
[3] L.G. Volzhenskaya et al., Opt. Spectrosc. 63 (1987) 790
[4] H. Ogino et al., J. Cryst. Growth 311 (2009) 908-911
[5] K. Kamada et al., Cryst. Growth Des., 11 (2011) 4484-4490