Structure and scintillation yield in Ce-doped Al-Ga substituted yttrium garnet

O.Sidletskiy[1], K. Lebbou[2], V. Kononets[1,2], A. Belsky[2], S. Neicheva[1], O. Voloshina[1], V. Bondar[1], N. Starzhinsky[1], V. Baumer[3], A. Gektin[1], B. Grinyov[1]

a - Institute for Scintillation Material NAS of Ukraine, 60 Lenin Ave., 61001 Kharkiv, Ukraine;
b - LPCML, CNRS, Universite de Lyon 1, 69622 Villeurbanne cedex, France;
c - SSI "Institute for Single Crystals" NAS of Ukraine, 60 Lenin Ave., 61001 Kharkiv, Ukraine.

Motivation

Improvement of trustworthy and acquisition speed of medical diagnostics devices, border control and security systems is a driving force for search of new scintillators with improved properties High scintillation yield, fast decay, and low cost are the basic criteria of materials choice for these applications.

Aim of the study

The present work is pointed at growth and characterization of $Y_3(Al_{1-x}Ga_x)_5O_{12}$:Ce crystals in all the concentration range from YAG to YGG.

Growth conditions

$Y_3(Al_{1-x}Ga_x)_5O_{12}$:Ce (YAGG) system demonstrate a continuous series of solid solutions (Fig. 2). YAGG crystals with of 30-35 mm diameter and 100 mm length with the Ga fraction 15.4, 36.6, and 66.2 % were grown by Czochralski method from melts with Ga fraction 20, 40, 60 %, correspondingly. crystals were grown by the Czochralski method (Fig. 1). Corresponding mix of Y2O3, Al2O3, Ga2O3 and Ce2O3 powders with 99.99 % purity were used as the raw materials. CeO_2 concentration in melt was 1 mol.%. Some of crystals contain significant number of cracks. Detailed description of growth conditions and crystals structure is presented in [1].

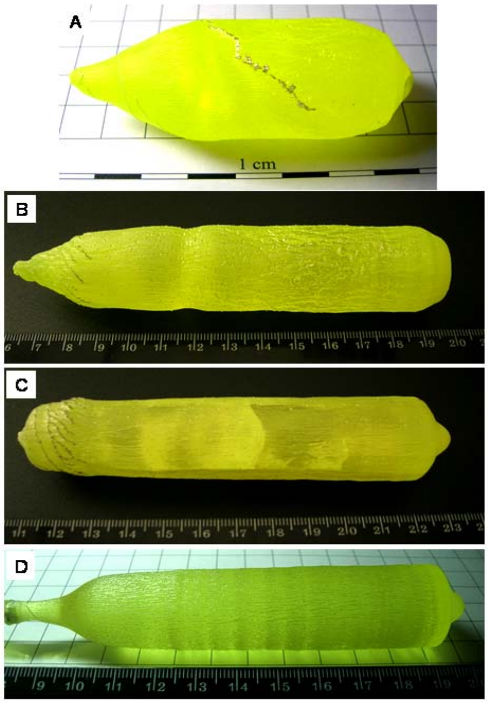

Fig. 1. As-grown YAG:Ce (A), YAGG:Ce (B,C), YGG:Ce (D) crystals.

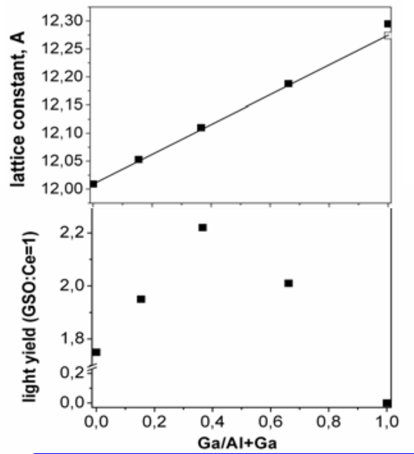

Fig. 2. Lattice constant (filled symbols correspond to experimental values) and light yield in YAGG:Ce vs. Ga fraction

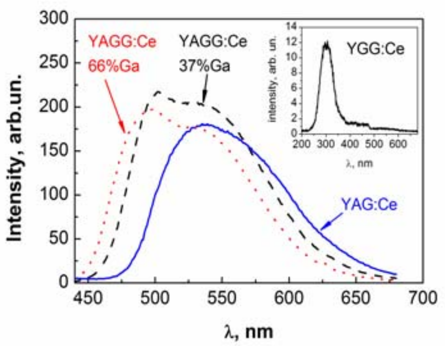

Fig. 3. X-ray luminescence spectra curves are obtained in the same conditions, and one may compare relative intensities of the peaks. Luminescence band shifts by ~50 nm at addition of 66 % of Ga into YAG:Ce is in agreement with. At the same time, only host weak luminescence is observed in YGG:Ce.

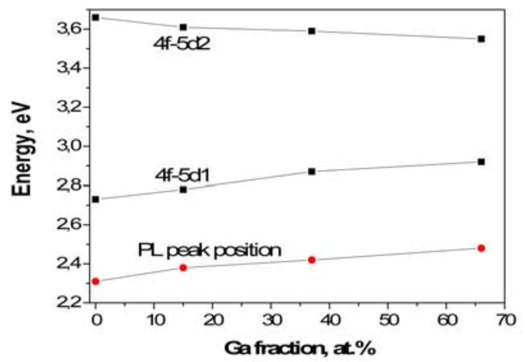

Fig. 4. Stokes shift equals to 0.42 ± 0.03 eV in all the range of Al/Ga substitution. Simultaneously the splitting of Ce^{3+} 5d levels decreases due to the weakening of crystal field.

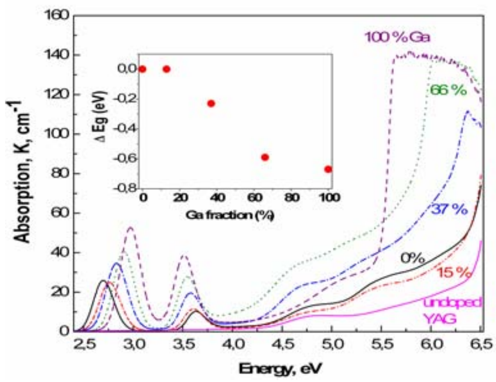

Fig. 5. The shift of fundamental absorption edge indicates the bandgap decrease ~0.7 eV, from YAG to YGG.

Conclusions

❖ The gap between 5d1 level of Ce3+ and conduction band edge in YAGG diminishes with Ga addition due to the bandgap decrease by ~0.7 eV and the increase by ~0.2 eV of the energy gap between 4f and 5d1 levels of Ce^{3+}.

❖ Addition of ~40 % Ga in YAGG leads to elimination of shallow carrier traps and stimulation of carrier transport to the activator. As the result, light output increases and reaches 130 % compared to YAG:Ce.

❖ Further Ga addition leads to decrease of the light output, evidently, due to thermal ionization of 5d levels in Ce^{3+}. In YGG:Ce, the 5d levels of Ce^{3+} are completely buried inside the conductance band, and Ce^{3+} luminescence is not observed. The similar phenomena have been observed recently on $(LuGd)_3(AlGa)_5O_{12}$:Ce crystals [2, 3].

❖ Further work should be devoted to optimization of host composition and activator content.

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