Single Crystal Growth of Mg and Ce co-doped $Y_3(Ga,Al)_5O_{12}$ with various Mg concentration and their scintillation properties

Hisato Suezumi[1,2], Kei Kamada[3,4], Masao Yoshino[2,3], Kyoung Jin Kim[3], Rikito Murakami[2,3], Satoshi Ishizawa[2,3], Akihiro Yamaji[2,4], Shunsuke Kurosawa[4], Yuui Yokota[2,4], Hiroki Sato[2,4], Takashi Hanada[2], and Akira Yoshikawa[2,3,4]

[1]*Graduation school of Engineering, Tohoku University, Japan*
[2]*Institute for Materials Research (IMR), Tohoku University, Japan*
[3]*C&A corporation, Japan*
[4] *New Industry Creation Hatchery Center (NICHe), Japan*

[Introduction] Ce:$Gd_3(Ga,Al)_5O_{12}$ (GAGG) single crystal has been attracted as scintillator in X-ray photon-counting detectors (PCDs) for Photon Counting Computed Tomography (PCCT) in the medical field.[1] However, the K-absorption edge of Gd is at around 50 keV which is in the range of the X-ray inspection energy region, can affect to the degrade of imaging quality due to the difficulty in energy discrimination. On the other hand, Ce:$Y_3(Ga,Al)_5O_{12}$ (YAGG) single crystal has been focused on as a candidate material for PCDs scintillator since the K-edge of Y is at around 17 keV which is out of the X-ray energy region, therefore, it is possible to discriminate the energy well. On the other hands, the micro-pulling down (μ-PD) method[2] based material explorations have been conducted in YAGG.[3] Among them, Mg co-doped Ce:$Y_3Ga_xAl_{5-x}O_{12}$ (x=2,3) showed the higher light yield of 36,000-38,800 photons/MeV and shorter decay time of below 20 ns. This enhancement of light yield and decay time shortening are expected to be the effect of Mg^{2+} to the increase in conduction band minimum by changing the Ce charge from Ce^{3+} to Ce^{4+} states.[4] However, the detailed luminescent properties related to co-doping with Mg and the presence of Ce^{4+} remain unresolved.

[Results and Discussion] In this research, Mg and Ce co-doped $Y_3Ga_xAl_{5-x}O_{12}$ single crystals were grown by the μ-PD method with various Mg concentrations. The scintillation properties and the effect of Mg^{2+} to the defects were measured. Single crystals of Mg,Ce:$Y_3Ga_xAl_{5-x}O_{12}$(x=2,3) were grown with a radio frequency heating system. Yellow like colored single crystals with 3 mm diameter and 70 mm length were grown. Mg,Ce:$Y_3Ga_2Al_3O_{12}$ showed a light yield of 44,000 photons/MeV and decay time of 50 ns. For further investigation of the understanding of Mg co-doping effect on YAGG, optical absorption measurement and positron annihilation measurement were conducted. As the increase in Mg^{2+} concentration, Ce^{3+}(4f-5d$_1$) absorption sharply decreased to 0, and the absorption intensity around 200-350 nm highly increased from the optical absorption spectra, and the previous defect engineering study in the Mg^{2+} co-doped $Lu_3Al_5O_{12}$ showed the same absorption phenomenon.[4]Moreover, positron annihilation measurement revealed defects sharply decreases as the increase in Mg^{2+} concentration from the positron annihilation measurement. Therefore, the absorption enhancement of the charge transfer suggested an increase in Ce^{4+} is expected to be due to the charge compensation of Mg^{2+} which compensates for defects.

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