Relationship of Single Crystal Growth and Luminescence Properties of Garnet-type Single Crystals for Radiation Dose-Rate Monitoring Systems

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For the decommissioning of Fukushima Daiichi Nuclear Plants, the real-time dose-rate monitor under the high dose-rate situation is required to remove debris left inside the plants. As a monitoring system, we have proposed a dose monitor consisting of a scintillator, optical fiber, and CCD spectrometer (Fig. 1), and scintillation photons are read with the CCD spectrometer under the lower dose condition such as outside of the plants [1]. Since the scintillator is coupled with an over 100-m long optical fiber, photon loss through the fiber should be suppressed. Also, the noise derived from the optical fiber (under 550 nm of emission wavelength) such as luminescence and Cherenkov photons must be separated from the scintillation signal [2], [3]. Therefore, longer emission wavelength (longer than 650 nm) and high light output are required for the scintillator.

In this study, we focused on Cr-doped $Gd_3Ga_5O_{12}$ (Cr:GGG) crystals with an emission wavelength of approximately 700 nm of emission wavelength originating from Cr^{3+} d-d transition. Here, we assumed that light output is expected to increase by Ce co-doping owing to overwrapping some trap sites, so that Ce-coded Cr:GGG (Ce/Cr:GGG) crystals were also grown. Since the segregation of Ce and Cr can affect luminescence properties, we investigated the relationship between Ce and Cr segregation and luminescence properties in Ce/Cr:GGG single crystals.

$(Gd_{1-x}\ Ce_x)_3(Ga_{0.995}\ Cr_{0.005})_5O_{12}$ (x=0.01, 0.05%) single crystals were grown by the micro-pulling down method [4] as shown in Fig. 2. Ce and Cr concentrations were measured with Electron Probe Micro Analyzer (EPMA) along the pulling-down direction and radial direction. Cr concentration in the center part of the radial direction was around 3 times thicker than the nominal concentration had.

Radioluminescence properties were also measured for the part of single crystals with Cr-concentration of 0.22-0.94%. The results showed emission intensity became larger as the actual Cr concentration was lower. GGG doped with around 0.2% Cr was found to be suitable for the monitoring system due to higher light output. We also demonstrated monitoring system with such samples.

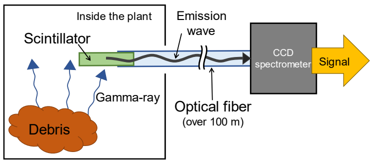

Fig. 1 Schematic view of the radiation dose monitoring system

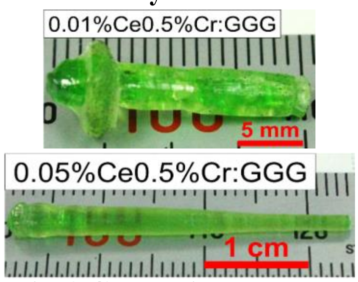

Fig. 2 Grown single crystals

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