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Optical and scintillation properties of $Sr_3BGa_3Si_2O_{14}$ ($B =$ Nb, Ta) single crystals

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HIGHLIGHTS

- We investigated optical and scintillation properties of the $Sr_3NbGa_3Si_2O_{14}$ [SNGS] and $Sr_3TaGa_3Si_2O_{14}$ [STGS] single crystals.
- In the transmittance spectra, absorption peaks around 380 and 505 nm originated from the excess oxygen were observed.
- There was an emission peak around 420 nm in the X-ray radioluminescence spectra of the SNGS.
- There was an emission peak around 335 nm in the X-ray radioluminescence spectra of the STGS.

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ABSTRACT

Optical and scintillation properties of $Sr_3NbGa_3Si_2O_{14}$ [SNGS] and $Sr_3TaGa_3Si_2O_{14}$ [STGS] single crystals with the langasite-type crystal structure were investigated as a novel scintillator materials. In the transmittance spectra of the SNGS and STGS polished specimens, absorption peaks around 380 and 505 nm were observed and the absorptions are considered to be attributable to the excess oxygen in the crystals. An emission peak around 420 nm was observed in the X-ray radioluminescence spectrum of the SNGS crystal. On the other hand, there was an emission peak around 335 nm in the X-ray radioluminescence spectrum of the STGS crystal.

1. Introduction

Langasite-type materials with the $A_3BC_3D_2O_{14}$ chemical composition (A = La^{3+}, Ca^{2+}, Sr^{2+}, Ba^{2+}, $B = Nb^{5+}$, Ta^{5+}, Ga^{3+}, $C = Al^{3+}$, Ga^{3+}, Fe^{3+}, In^{3+}, and D = Ga^{3+}, Si^{4+}) have been investigated as a material for laser devices and a piezoelectric crystal for sensor devices which can be used at high temperature and oscillators (Takeda et al., 2005; Bohm et al., 1999; Shimamura et al., 1996). The langasite-type materials have several advantages as a functional element for some applications. The single crystal can be grown with relative ease by various conventional melt-growth methods as represented by the Czochralski (Cz) method (Kawanaka et al., 1998), Vertical Bridgmann (VB) method (Taishi et al., 2007) and micro-pulling-down (μ-PD) method (Yokota et al., 2011, 2012, 2013), and their large bulk single crystals with several inches diameter have been already developed for mass production (Uda et al., 2005). In addition, the langasite-type single crystals have strong chemical, impact and temperature resistant properties, and the elements can be used under various conditions.

In our previous reports, we clarified the optical and scintillation properties of the $Ca_3NbGa_3Si_2O_{14}$ [CNGS] and $Ca_3TaGa_3Si_2O_{14}$ [CTGS] which were one of the langasite-type materials with the ordered structure (Kurosawa et al., 2014; Futami et al., 2012). The CNGS and CTGS crystals indicated emission around 300–500 nm under UV, α-ray and X-ray excitation. On the other hand, there are other langasite-type materials which are composed of A = Sr,

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$B=Nb$ or Ta, $C=Ga$ and D = Si, $Sr_3NbGa_3Si_2O_{14}$ [SNGS] and $Sr_3TaGa_3Si_2O_{14}$ [STGS], and their single crystals have been grown by the Cz methods as a piezoelectric material (Jung et al., 2001; Wang et al., 2004). Their crystal growths by a micro-pulling-down (μ-PD) method, phase identifications, crystallinities, and piezoelectric properties have been investigated in our previous reports (Yokota et al., 2011, 2012). The density and effective atomic number are larger than that of the CNGS and CTGS due to the difference of the A site ion (Ca^{2+} and Sr^{2+}). However, there is no report about the investigations about the SNGS and STGS as a scintillator material. The our report (Kurosawa et al., 2014) revealed that the Ta-containing scintillator single crystals as the CTGS could demonstrate well-measurable scintillation response. Therefore, it is worthwhile to develop novel Ta-containing crystals with a larger effective atomic number.

On these backgrounds, in this study, the SNGS and STGS single crystals were grown by the μ-PD method, and their optical and scintillation properties were measured to evaluate them as a novel scintillator materials with larger density and effective atomic number than the CNGS and CTGS.

2. Experimental

$Sr_3NbGa_3Si_2O_{14}$ and $Sr_3TaGa_3Si_2O_{14}$ single crystals were grown by the μ-PD method in air. The detail of the crystal growth was described in the previous report (Yokota et al., 2011, 2012). As-grown SNGS and STGS single crystals with approximately ϕ2 mm diameter and several centimeters length were obtained by the crystal growth. The as-grown crystals were cut and polished for the measurements of optical and scintillation properties.

Transmittance spectra of the SNGS and STGS polished specimens were measured in the wavelength range from 200 to 800 nm using a spectrophotometer (JASCO V530). X-ray radioluminescence spectra of the polished specimen under X-ray irradiation from an X-ray tube (40 kV, 40 mA) were measured by the spectrofluorometer (EDINBURGH INSTRUMENTS FLS920) and the charge coupled device [CCD] with the optical cable, respectively. Pulse-height spectra under γ-ray or α-ray irradiation were investigated using the polished specimens exposed to a ^{137}Cs or ^{241}Am radiation source with a photomultiplier [PMT] (HAMAMATSU R7600U-200). Specimens were covered by Teflon tape except for one plane and the plane was attached to the light entrance window of the PMT with optical grease. Signals from the PMT were converted to digital signals by a multi-channel analyzer (AMPTEK CO. Pocket MCA 8000A). In the pulse-height spectrum measurement, $Bi_4Ge_3O_{12}$ [BGO] single crystal with 8000 ph/MeV light yield was used as a standard scintillator.

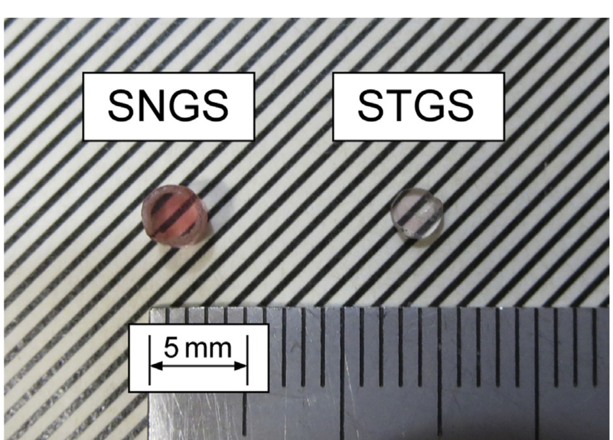

Fig. 1. SNGS and STGS polished single crystals grown by the μ-PD method.

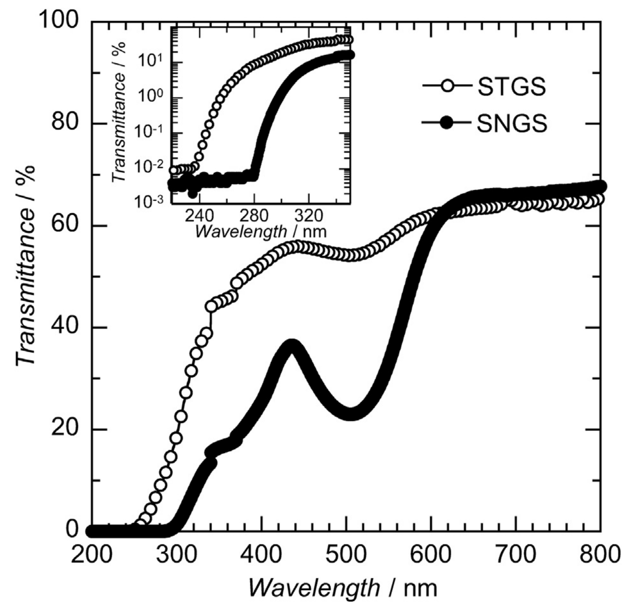

Fig. 2. Transmittance spectra of the SNGS and STGS polished specimens.

3. Results and discussions

The as-grown SNGS and STGS single crystals were cut perpendicular to the growth direction and cutting planes were polished. The SNGS and STGS polished specimens were shown in Fig. 1. The SNGS polished specimen indicated deep pink color while the color depth of the STGS polished specimen was weaker. Both polished specimens indicated high transparency and there were no visible cracks and inclusions in the crystals.

The transmittance spectra of the SNGS and STGS polished specimens were measured as it is illustrated in Fig. 2. In the

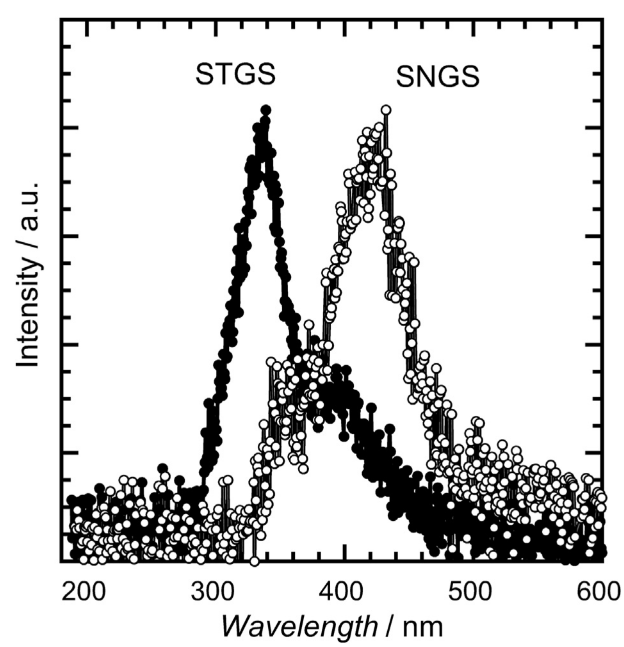

Fig. 3. X-ray radioluminescence spectra of the SNGS and STGS polished specimens.