Crystal growth and optical characterization of Ce-doped mixed rare-earth sesquioxide single crystals for scintillator applications

Takahiko Horiai[1,2], Yuui Yokota[1,2], Masao Yoshino[1,2], and Akira Yoshikawa[1,2]

[1]*New Industry Creation Hatchery Center, Tohoku University, 6-6-10 Aoba, Sendai, Japan*
[2]*Institute for Materials Research, Tohoku University, 2-1-1 Katahira, Sendai, Japan*

Scintillation materials, which can convert a high energy photon such as gamma-rays and X-rays into low-energy photons such as UV and visible light, are widely used as radiation detectors when combined with photodetectors. Focusing on oxide scintillators, which are relatively high density and chemically stable, single crystals have been grown from melts using the Czochralski technique and/or the micro-pulling-down (μ-PD) method with metal crucible [1]. For the development of novel oxide scintillator materials, we focused on mixed rare-earth sesquioxide with melting points between 2,100 and 2,230°C, which is near the softening point of the iridium used as a crucible material [2]. Thus, in this study, we investigated the crystal growth method combining the μ-PD method and a tungsten crucible for growing Ce-doped $YScO_3$ single crystals and evaluated their optical properties.

As starting materials, commercial oxide powders (Y_2O_3, CeO_2) with purities of over 99.99% and Sc_2O_3 powder with purity of over 99.9% were used. After weighing according to (Ce_x Y_{1-x})ScO_3 (0.2 $\leq$ x $\leq$ 3.0), the powders were formed into pellets by a hydraulic press. The pellets were sintered at 1700°C for 24 hours under air atmosphere. After the sintered compact was crushed into powder, the powder was filled into a tungsten crucible and crystals were grown at a pulling-down rate of 0.03 mm/min. To prevent oxidation of the tungsten crucible during crystal growth, deoxygenated stabilized zirconia was used for insulation [3].

As a result of crystal growth, we succeeded in growing transparent Ce-doped $YScO_3$ crystals. The grown crystals showed orange coloration, thus we measured the transmittance and found broad absorption in the wavelength range of 400-600 nm. Since this absorption was considered to be caused by oxygen vacancies generated during crystal growth, we annealed the grown crystals at 1200°C for 12 hours under an atmospheric atmosphere and obtained transparent crystals. From the results of the powder X-ray diffraction analysis, the crystalline system and the space group were identified cubic and Ia-3, respectively. However, the crystals with Ce concentration of 1% or more contained small diffraction peaks around 2 ϑ of 31° and 32°, which originated from different phases.

This work was supported by Japan Society for the Promotion of Science (JSPS) KAKENHI, the Grant-in-Aid for Scientific Research [K22K144690]

[1] A. Yoshikawa, et al., Opt. Mater. 30 (2007) 6.
[2] R. Uecker, et al., J. Cryst. Growth, 310 (2008) 2649.
[3] T. Suda, T. Horiai, A. Yoshikawa, et al., J. Cryst. Growth, 575 (2021) 126357.