Development of Translucent Ceramics for X-ray Imaging Applications

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ABSTRACT

A 0.5% Eu-doped BaFBr translucent ceramic was synthesized, and the potential for X-ray imaging applications was evaluated. The sensitivity of the translucent ceramic was higher than that of a commercial IP (HR-BD). In addition, we have successfully obtained an X-ray image of the electronic component using the translucent ceramic.

1 Introduction

X-ray imaging applications have been used for various fields such as medical diagnosis [1], security [2], industrial inspection [3]. Imaging plates (IP) made of optically stimulated luminescence (OSL) phosphors are one of the common X-ray imaging applications [4]. OSL phosphors have a function to store and readout the information of the incident ionizing radiation [5]. The required properties of OSL phosphors for IPs are a high OSL intensity, wide dynamic range, a large effective atomic number, a low fading [6].

To date, the IPs were mainly used in the form of powders and films [7], [8]. In recent years, the translucent ceramics synthesized by a spark plasma sintering (SPS) method showed better OSL properties in comparison with opaque ceramics [9], [10]. As one of the reasons, SPS process was done in a highly reductive environment, and the trapping centers would be efficiently generated. In addition, the OSL signals were obtained from not only the surface but also inside of the ceramics. However, there are only a few reports available on OSL properties of translucent ceramics for IPs [11], [12].

In this study, we have focus on the Eu-doped BaFBr translucent ceramics to evaluate the potential of translucent ceramics for X-ray imaging applications. Since Eu-doped BaFBr have a good OSL properties, Eu-doped BaFBr powders have been used in IPs made by Fujifilm [13]. However, there are no reports on the OSL properties of Eu-doped BaFBr translucent ceramics. Therefore, we have synthesized Eu-doped BaFBr translucent ceramics by the SPS method and investigated the optical and OSL properties.

2 Experiment

A 0.5% Eu-doped BaFBr translucent ceramic was synthesized by the SPS method. As the raw powders, BaF_2 (99.9%, Kojundo Chemical Laboratory), $BaBr_2$ (99.9, Furuuchi Chemical), and EuF_3 (99.99%, Stella Chemifa) were used. The detailed procedure of synthesis was written in our past report [14]. Here, the sintering temperature, sintering time and pressure were fixed to 800°C, 1 h and 6 MPa, respectively. The surfaces of the obtained sample were mechanically polished using various sandpapers.

As the optical properties, the diffuse transmittance spectrum was measured by a spectrometer (Shimadzu, SolidSpec-3700). Regarding OSL properties, the OSL spectrum, stimulation spectrum and dose response function were observed by a spectrofluorometer (JASCO, FP-8600). As the radiation source, an X-ray generator (Spellman, XRB80P &N200×4550) was used. To evaluate the potential for X-ray imaging applications, the X-ray imaging of electronic component was obtained using the original setup [15].

3 Results and Discussion

Fig. 1 shows diffuse transmittance spectra of a 0.5% Eu-doped BaFBr translucent ceramic. When the thickness of sample was fixed to 0.5 mm, the transmittance was 30% in the spectral range of 400–850 nm. The absorption peak around 350 nm was observed. In the previous reports, the Eu-doped BaFBr ceramics showed the absorption peak around 350 nm [16], [17]. Thus, the origin would be the 4f-5d transitions of Eu^{2+}.

OSL and stimulation spectra of a 0.5% Eu-doped BaFBr translucent ceramic are illustrated in Fig. 2. After X-ray irradiation (1 Gy), the samples showed OSL peak around 390 nm under stimulation wavelength of 550 nm. Since the spectral shape was similar to that of Eu-doped BaFBr opaque ceramics, the emission origin would be the 5d-4f transitions of Eu^{2+} [18]. In addition, the stimulation spectrum monitored at 390 nm showed two broad bands around 530 and 600 nm. Those peaks were consistent with that of absorption peaks due to two types of F-centers formed by F^- and Br^- ion vacancies [19]. Thus, the F-centers (F^- and Br^-) would be acted as the trapping centers.

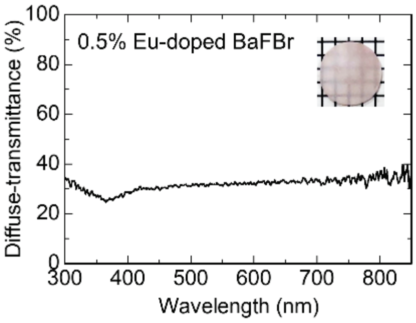

Fig. 1 Diffuse-transmittance spectra of a 0.5% Eu-doped BaFBr translucent ceramic.

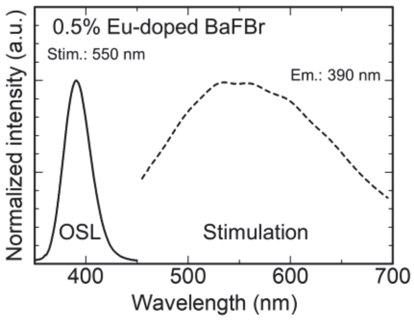

Fig. 2 OSL and stimulation spectra of a 0.5% Eu-doped BaFBr translucent ceramic.

Dose response functions of OSL signals by a 0.5% Eu-doped BaFBr translucent ceramic and a commercial Eu-doped BaFBr IP (Fujifilm, HR-BD) are plotted in Fig. 3. The 0.5% Eu-doped BaFBr translucent ceramic showed a good proportionality in the range of 10 μGy to 1 Gy. The dynamic range of the 0.5% Eu-doped BaFBr translucent ceramic was wider than that of a commercial IP.

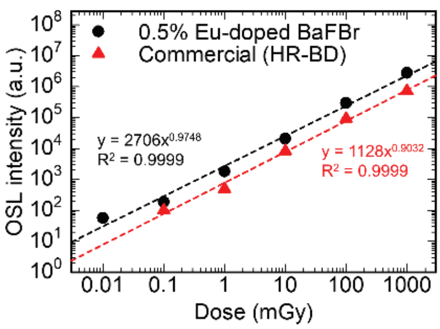

Fig. 3 Dose response functions of OSL signals by a 0.5% Eu-doped BaFBr translucent ceramic and a commercial Eu-doped BaFBr IP (Fujifilm, HR-BD).

Fig. 4 illustrates an X-ray image of the electronic component taken by OSL signal of a 0.5% Eu-doped BaFBr translucent ceramic. The image of the inside electronic component was confirmed through the epoxy encapsulations. The spatial resolution was better than 1.0 mm because the legs of electronic component with a width of 10 mm were clearly separated. Therefore, we consider that translucent ceramics have promising potential for use as X-ray imaging applications.

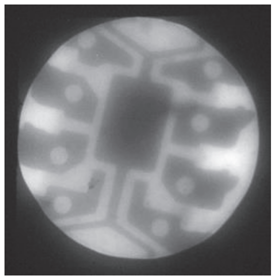

Fig. 4 X-ray image of the electronic component taken by OSL signal of a 0.5% Eu-doped BaFBr translucent ceramic.

4 Conclusions

We have synthesized a 0.5% Eu-doped BaFBr translucent ceramic by the SPS method, and their optical and OSL properties were investigated. In the 0.5% Eu-doped BaFBr, the transmittance was 30% in the spectral range of 400–850 nm. Regarding the OSL properties, the sample showed the OSL peak around 390 nm originated from the 5d-4f transitions of Eu^{2+} under stimulation of 550 nm. The dose sensitivity of a 0.5% Eu-doped BaFBr translucent ceramic was higher than that of a commercial IP. Finally, we have successfully obtained an X-ray image of the electronic component using the translucent ceramic.

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