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Total luminescence yield of some scintillators in the photon energy region from 300 eV to 1.3 keV

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Total luminescence yield (TLY) spectra of scintillators were measured to identify which scintillator exhibited high luminosity in the SX region from 300 eV to 1.3 keV. The obtained TLY intensities were Tl:CsI, Eu:GGG, Ce:LYSO, Tb:LSO, Eu:YAP, and Ce:YAP in descending order of spectral intensity, which differs from the known intensities in the hard X-ray region.

1 Introduction

In recent years, some scintillators exhibited stimulated emission suppression (STED) phenomenon, and the application of STED phenomenon to the 2D detector is expected to further reduce pixel size in the detector plane [1]. A point for selecting luminescence materials on applying the STED phenomenon is high intensity of the luminescence because detection efficiency will increase as the increase of the luminescence intensity. In a photon energy region from 300 eV to 1.3 keV, the component atoms show many absorption edges in scintillators; therefore, the luminosities of the scintillators in the SX region differ from those in the HX region because of the absorption of the scintillators. For example, the luminosity of Ce:LYSO, 33.8 photons/keV, is less than that of Tl:CsI, 61 photons/keV in the HX region [2], but the measured luminosity of Ce:LYSO was comparable to that of Tl:CsI in the extreme ultraviolet region [3]. In this study, the TLYs of scintillators were measured and compared in the SX photon energy region.

2 Experimental

In the measurement, a small vacuum chamber was placed at around the focus point of SX beam from the beamline, BL11D. A SX photodiode was installed in the vacuum chamber to measure the intensity of the incident SX beam as shown in Fig. 1. The detector plane of the SX photodiode was large enough to cover the beam size of the incident SX beam. A sample holder made from a Cu block was placed at the focus point of the incident SX beam. Samples were adhered on the sample holder using a black carbon tape to reduce the stray light and a 3-mm diameter hole was made on the sample holder to prevent the light reflection from the sample holder. The luminescence from the sample was emitted through an optical window (Kovar Glass), and the extracted light was focused to a VI photodiode for TLY measurements. Both the SX and the VI photodiode currents were measured with a pico-ammeter.

The wavelength resolutions at the measurement were $\lambda/\delta\lambda$ = 1000 and 500 in the SX and VI regions. The beam size of the monochromatized SX beam can be changed using the four-dimensional (4D) slit installed on the downstream side of the exit slit of the monochromator. The 4D slit was adjusted so that a diameter of the focus point was 1 mm or less. The measurements were made at both room temperature (RT) and the liquid nitrogen temperature (LNT) (< 85 K). For the TLY spectroscopic measurements, the photon energy of the incident SX light was changed from 300 eV to 1.3 keV every 5 eV, and the exposure time per step was 3 s. After the energy distribution curves of TLY were normalized by both of that of the incident SX intensity and exposure time, the TLY spectra of the scintillators were obtained.

3 Results & Discussion

The measurement results of the TLY spectra at the LNT are shown in Fig. 2. In the figure, six spectral shapes were selected and drawn from the measured scintillators because

the TLY intensity of the other three scintillators (i.e., Ce:YAG, Ce:LuAG, and Eu:CaF_2) were weak in the present energy region. The reflectance at the sample surface was calculated and the values were 1.0×10^{-8} or less in the measured SX region [4]; therefore, they are negligibly small. The TLY spectra were also measured at the downstream side of the sample through the hall back of the sample using the SX photodiode because it showed sensitivity in the VI region. The results were consistent with the results of Fig. 2, where the backside reflection from the samples was considered to be small enough. As for the relative luminosities of the measured scintillators to that of Ce:LYSO, Tl:CsI was about 200%, Eu:GGG was about 140%, Tb:LSO was about 75%, Eu:YAP was about 50%, and Ce:YAP was about 35% in descending order of strength.

As can be seen in Fig. 2, the measured TLY intensities increase as the excited photon energy increases. The absorption coefficients of the base materials of the present scintillators show that the values of absorption coefficients decrease as the incident photon energy increases; therefore, the increase of the measured TLY intensities can be interpreted as the increase of the product of an excitation probability of excitons associated with both SX excitation processes and the succeeding relaxation processes of the excitation, and a luminescence probability associated with the relaxation processes of the excitons.

4 Summary

The luminosities of some scintillators were investigated in a photon energy region from 300 eV to 1.3 keV. TLY spectra of scintillators showing high luminosity in HX region were measured and compared. The luminosities obtained from the TLY intensities were different from those known in the HX region. The difference can be explained by either or both the excitons excited by the incident X-rays and the accompanying the exciton relaxations.

Acknowledgments

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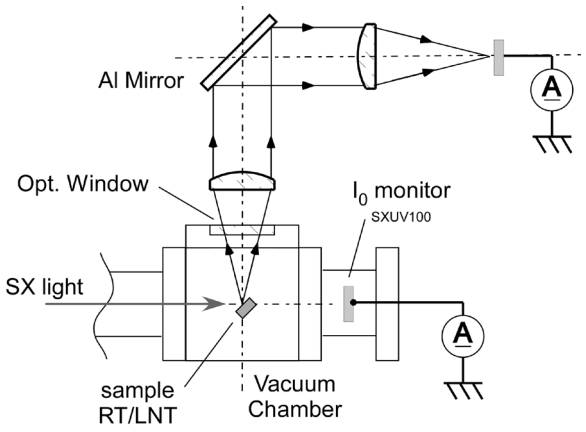

Fig. 1 : Layout of TLY measurements.

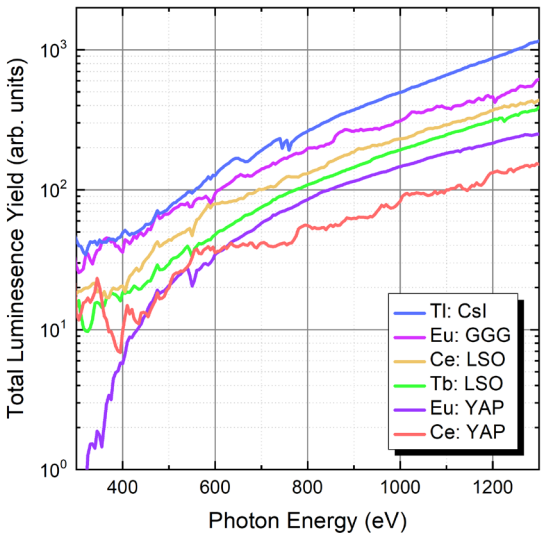

Fig. 2 : TLY spectra of scintillators.