Radiation Damage of BGO Scintillator Irradiated by ^{60}Co Gamma-ray

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1. Introduction

The major advantages of $Bi_4Ge_3O_{12}$(BGO) are its high density(7.13 g/cm^3) and the large atomic number(83) of the bismuth component. Because of easiness to handle and use, BGO is commonly available as crystals of reasonable size[1]. When exposed to radiation of high energy particles or other sources such as gamma-rays and X-rays, BGO crystal will emit a green fluorescent light with a peak wavelength of 480 nm. Also BGO crystal has high stopping power, high scintillation efficiency and non-hygroscopicity[2]. Small volume BGO crystals are widely used in nuclear medicine diagnostic systems, particularly Positron Emission tomographs(PET) and Computed Tomography Scanners (CTS). In gamma-ray spectroscopy, NaI(Tl) crystals was used as the most suitable scintillation detectors of gamma-rays. After BGO was invented in the late 1970s, it gradually took the place of NaI(Tl) as the scintillation detector in most PET and CTS systems because of its high stopping power, light yield and decay time, as well. Light yield dependence on irradiation dose seems to be one of the most decisive parameter for practical using of these scintillators in various applications[3].

The main goal of our investigation is to compare the scintillation properties of BGO before and after gamma-ray irradiation with a crystal of 10x10x10 mm^3 size. In this work, we measured and compared the radiation damage of BGO crystal at accumulated doses of 1 kGy and 10 kGy using ^{60}Co gamma-rays.

2. Experiments

The absorption and emission spectra of the BGO crystal were measured with fluorescence and UV-visible spectrometer. Pulse height spectra of BGO crystal before and after irradiation were measured and compared with ^{109}Cd and ^{137}Cs radiation sources. The spectra were measured with Hamamatsu R6094 PMT which has sensitive range from 300 nm to 650 nm, and the wavelength of maximum response is 420 nm. The BGO crystal was coupled onto PMT with optical silicon grease, and the crystal was wrapped with several layers of white Teflon tape as reflector. The used amplifier and preamplifier models were ORTEC 113 and 572A, respectively.

The crystal was irradiated by ^{60}Co gamma-ray source in two times. The irradiation was performed at the irradiation facility of Cheju National University, and the source was ^{60}Co with an activity of 6435 Ci. The BGO crystal was placed at 6 cm distance from source center. The irradiation of 1 kGy and 10 kGy were done for 622 and 6217 seconds, respectively. The irradiation condition and times were calculated with MCNP code.

3. Results and discussion

3.1. Scintillation property measurements

The scintillation properties of BGO crystal before and after gamma-ray irradiation were measured. The BGO crystal emits a fluorescent light with a peak wavelength of 480 nm when the excitation wavelength is 300 ~ 320 nm in crystal. The radiation damages were examined by the measurement of absorption and emission spectra before and after 1 kGy and 10 kGy irradiations. These results are shown in Fig 1. The emission spectra were measured with CARY Eclipse of Varian, and the excitation wavelength was 300 nm. The absorption and emission spectra were measured from 300 nm to 600 nm. The emission spectra were low changed when the crystal was irradiated.

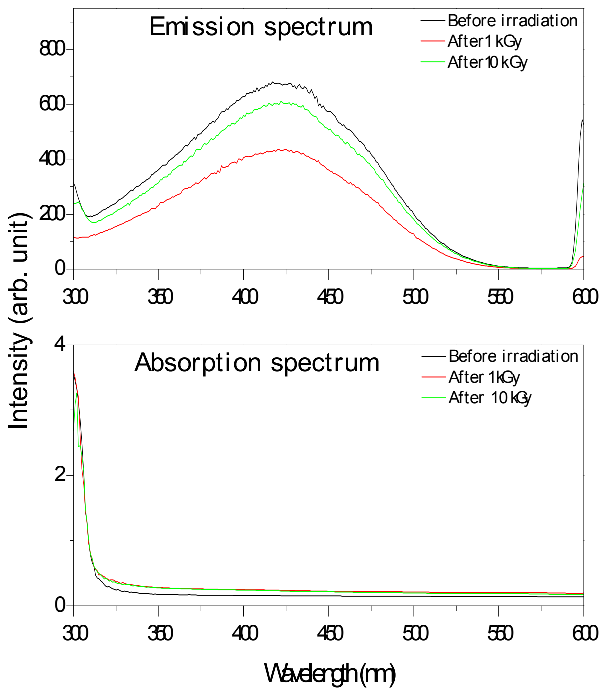

Fig. 1. Emission and absorption spectra of BGO before and after gamma-ray irradiations.

2.2. Pulse height spectrum measurements

The pulse height spectra were measured with R6094 PMT at 1000 V vias, the energy resolutions of BGO crystal were measured with ^{109}Cd and ^{137}Cs radiation sources. The distance of the crystal from the radiation source was 3 cm. The spectra of 1 kGy and 10 kGy irradiated crystal were measured after 10 hours and 12 hours, respectively. The resulting spectra of 88.04 keV gamma-rays from a ^{109}Cd source are shown in Fig 2. The energy resolutions of 1 kGy and 10 kGy irradiated BGO crystal were measured as 42.18 % and 53.42 %. 90 hours later, the BGO crystal was annealed at 350 ℃ for 1 hour, and the energy resolution of annealed crystal was 49.27 %. The energy resolution before irradiation was 37.8 %, but after irradiation the results was changed to 42.8 % and 53.42 %.

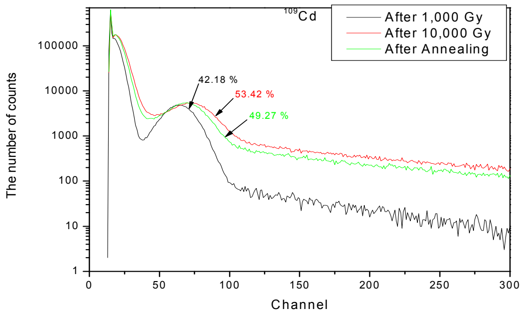

Fig. 2. The pulse height spectra of ^{109}Cd (the black and red lines are irradiated 1 kGy and 10 kGy, respectively. The green line is obtained after annealing for 1 hour at 350℃).

Fig 3 shows the result when the 661.6 keV gamma-rays from a ^{137}Cs source were measured. The energy resolutions of irradiated BGO crystal were 17.32 % and 16.91 %, and energy resolution of annealed BGO crystal was 16.9 %. The positions of the peaks before and after irradiation were different, but the energy resolutions were similar to each other.

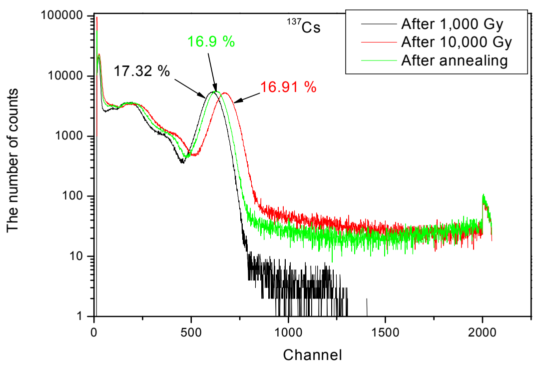

Fig. 3. The pulse height spectra of ^{137}Cs(the black and red lines are irradiated 1 kGy and 10 kGy, respectively. The green line is obtained after annealing for 1 hour at 350℃).

4. Conclusion

Scintillation properties of irradiated 10×10×10 mm^3 BGO crystal at ^{60}Co gamma-rays were changed badly. In the present work, absorption intensities of BGO crystal before and after irradiation were 0.18, 0.28 and 0.32 at 348 nm, respectively.

The pulse height spectra of the small BGO crystal at 1 kGy and 10 kGy were measured with R6094 PMT. In case of ^{109}Cd which emit 88.4 keV low gamma-ray, the pulse height spectrum indicated the variation of the energy resolution whose result was 42.18 % with 1 kGy irradiation and 53.42 % with 10 kGy irradiation, respectively. In case of ^{137}Cs, the positions of the peaks were moved, but the energy resolution was scarcely varied contrary to our expectation. We will perform an additional research on this part.

Acknowledgements

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