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Comparative studies of CsI(Tl), LYSO and BGO scintillators

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Abstract. Inorganic scintillators of CsI(Tl), LYSO and BGO crystals were characterized using photomultiplier tube R1306 PMT readout for gamma ray detection. The photoelectron yield, light yield and photofraction were measured at gamma energies in range 356 keV to 1332 keV. It is found that the photoelectron yield of LYSO is much better than that of CsI(Tl) and BGO crystals. CsI(Tl) crystal showed the high light yield of 63855.25 ph/MeV in this energy range, which is better than that of LYSO and BGO crystals. The photofraction for all crystals was determined and compared with the cross-section ratio for the photoelectric effect to the total counts of the spectrum calculated by WinXCom program.

Introduction

The search for the new scintillators, driven to a major degree by the expeditiously growing needs of old and new applications, has become increasingly successful in recent years. The main challenge of the scintillator research is to find a scintillator material that has the correct combination of properties to match the need of a given application rather than to find a scintillator with a single outstanding characteristic. Therefore the research and the development of inorganic scintillators are of interest. The first important requirement for a scintillator to be used in many applications such as high effective atomic number, high density and proportional response. However, the performances of a scintillator to the specific requirements of difference end users [1-2]. In 2002 Tumpa et al. reported on the studies on comparative studies of YAG(Ce) and CsI(Tl) scintillators [3], Martin Nikl studies on scintillation detector for X-ray [4] and Thomas Kimble et al. studies on scintillation properties of LYSO crystals [5]. One of the main goals of the scintillator research is to reveal the exact way a scintillator converts radiation into light. If this were perfectly understood, it would not be any problem to predict which materials would be perfect scintillators [2].

The objectives of this experiment, we will start investigation and comparison of photoelectron yield, light yield and photofraction of BGO, LYSO and CsI(Tl) crystals measured with different gamma energies.

Experimental

The bismuth germinate (BGO), lutetium yttrium oxyorthosilicate (LYSO) and thallium activated cesium iodide CsI(Tl) inorganic crystals used in the present work have been delivered by Nuclear System Co., Ltd, were studied. Sample with a good spectrometric quality form the dimension $10\times10\times10$ mm^3 of LYSO and CsI(Tl) crystals coupling with Hamamatsu R1306 PMT were first wrapped with white Teflon tape then wrapped with black tape and covered with aluminum housing in order to minimize light leakage. The cylindrical of BGO crystal with dimension 10×10 mm^2 has been similarly wrapped and covered [3]. These experiments were using standard nuclear instrument modules (NIM) electronics. After photon absorption the visible light arises in scintillator conversion, which is focused by the optical relay element onto the photodetector at the output of which an electrical signal is available for further processing [4]. The electronics signal from the R1306 PMT through transfer a Canberra 2007B preamplifier and then transport to Canberra 2022 amplifier. The differential coarse gain were measured at ×30 of LYSO and CsI(Tl) crystals but BGO crystal using at ×100. The amplitude of the output pulse were change to digital signal by analog to digital converter (ADC), then the spectra were recorded using Gamma Acquisition & Analysis software of Canberra in a multichannel analyzer [6].

In the present study, the photoelectron yield, light yield and photofraction were measured at gamma energies in range 356 keV to 1332 keV by Bertolaccini method [7]. Measurement were made using radioactive sources ^{133}Ba, ^{137}Cs, ^{22}Na and ^{60}Co. The photofraction for all crystals in the pulse height spectra at 662 keV were compared versus the cross section ratio by WinXCom program.

Result and Discussion

The gamma ray excite of the energy spectra from a ^{137}Cs source at 662 keV measured with CsI(Tl), LYSO and BGO crystals see in Fig 1, The results show a very good energy resolution of 7.13% for CsI(Tl) crystal gives superior than 10.31% of LYSO and 16.59% of BGO crystals. From the number of counts values, LYSO crystal show very high counts than CsI(Tl) and BGO crystals.

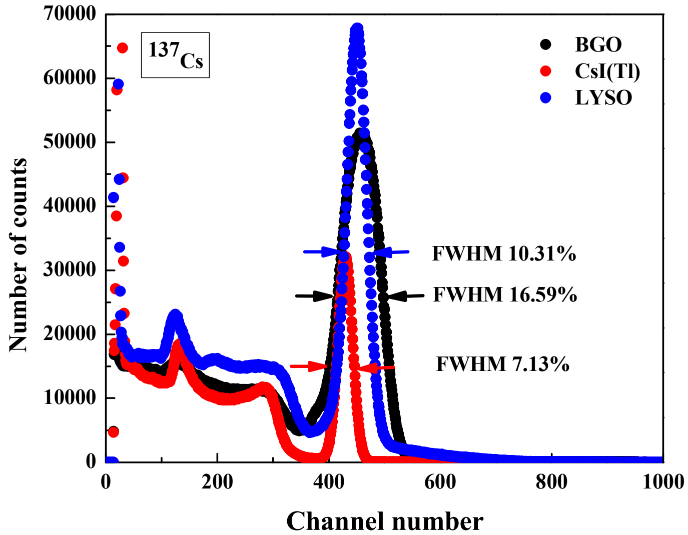

Fig. 1. Energy spectra of BGO, LYSO and CsI(Tl) crystals excited with 662 keV gamma rays from a ^{137}Cs source.

In the case of photoelectron yield and light yield measurement the pulsed gamma radiation from radioactive source are used to excite the sample varying from 356 keV to 1332 keV by the Bertolaccini method for the verified crystals [7]. At the 662 keV, the photoelectron yield of CsI(Tl) crystal shows values 7662.63 phe/MeV tally with the very high light yield of 63855.25 ph/MeV. The photoelectron yield of BGO crystal shows values 2211.27 phe/MeV tally with the light yield of 8504.88 ph/MeV and LYSO crystal shows a high values 8676.58 phe/MeV tally with the light yield of 30987.80 ph/MeV. The light output of CsI(Tl) crystal is much better than with LYSO and BGO crystals. Although the photoelectron yield of LYSO is clearly superior to CsI(Tl) crystal but there is a little progress in energy resolution for LYSO crystal. In Fig. 2 shows the linear trend of light yield increase with increasing gamma energy of BGO and LYSO crystals but CsI(Tl) show decrease with increasing gamma energy. Based on phenomenological model, two main qualification shapes are observed in scintillator non proportionality response [8]. For this case, the different trend of the light yield were depend on host crystal and accidental doping by impurities [9].

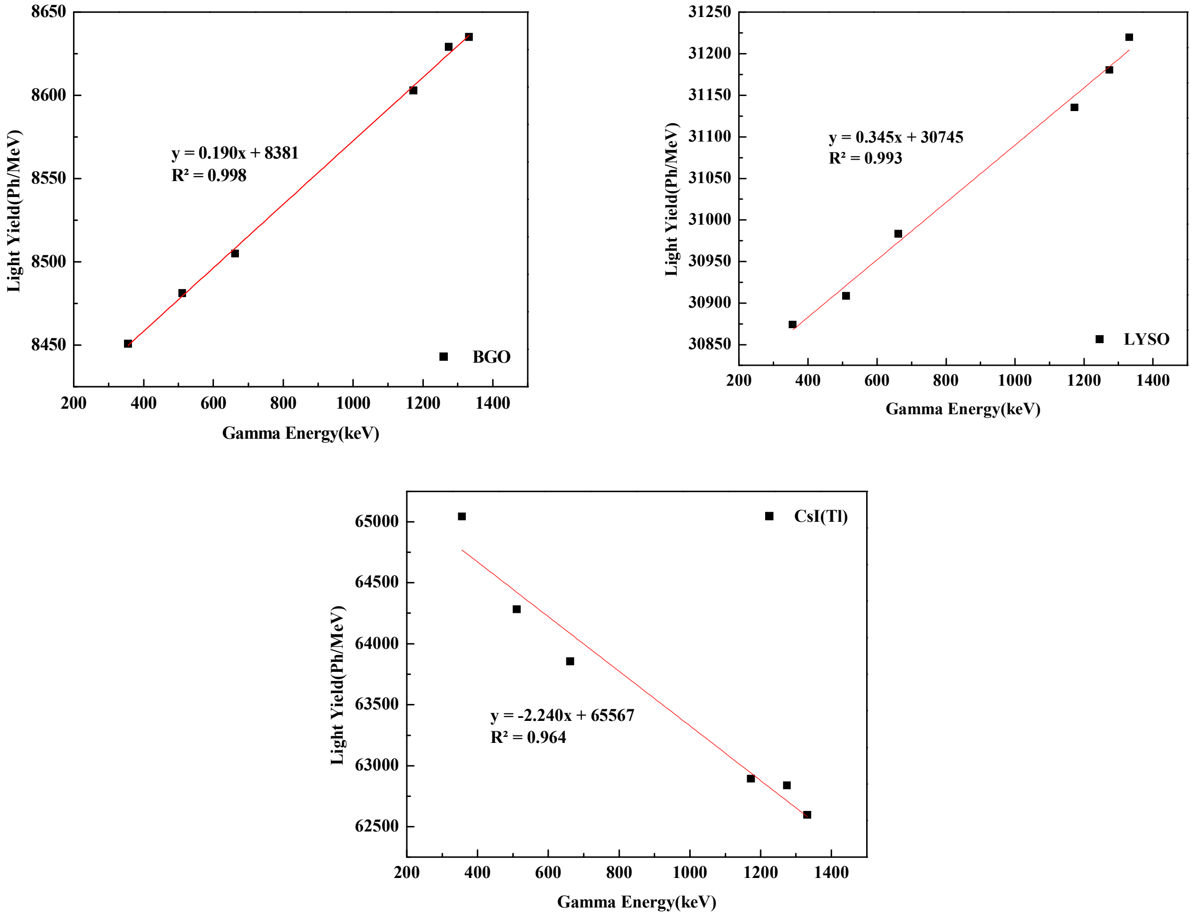

Fig. 2. The light yield of BGO, LYSO and CsI(Tl) crystals at gamma energies in range 356 keV to 1332 keV.

Table 1. Photofraction values of BGO, LYSO and CsI(Tl) crystals with 662 keV gamma rays

Properties	Scintillation materials		
	BGO	LYSO	CsI(Tl)
Photofraction [%]	47.20	28.98	15.58
σ - ratio [%]	34.49	23.54	21.02
Density [g/cm^3]	7.11	7.15	4.18
Z_{eff}	74	65	54

Photofraction is the ratio of counts under the photopeak to the total counts of the spectrum, measured with gamma ray energy [10]. In considering the photofraction in Table 1. it can learn several things. First of all, notice the difference in photofraction values between the three samples. These value is the similar trend with the cross-section ratio (σ-ratio) computed by WinXCom program [11]. The comparability show the BGO crystal higher values than LYSO and CsI(Tl) crystals. A second point is the difference values of each crystal came from the higher effective atomic number (Z_{eff}) and density. These properties are almost universally desirable because increased stopping power reduces the amount of scintillator material needed [12].

Summary

In this work, the photoelectron yield and the light yield of BGO, LYSO and CsI(Tl) crystals were studied and compared in gamma ray detection at gamma energies in range 356 keV to 1332 keV. The CsI(Tl) sample show a high light yield of 63855.25 ph/MeV is better than LYSO and

BGO crystals. The linearity trend of light yield were increase with increasing gamma energy of BGO and LYSO crystals but CsI(Tl) show decrease with increasing gamma energy. Very high effective atomic number and density are the main reason for the higher values of photofraction with BGO crystal.

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Applied Physics and Material Applications II

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