PTR, PCR and Energy Resolution Study of GAGG:Ce Scintillator

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Abstract. In this paper, the peak to total ratio (PTR), the peak to Compton ratio (PCR) and the energy resolution of cerium doped gadolinium aluminium gallium garnet (GAGG:Ce) scintillator are measured in the range of energy from 511 keV to 1332 keV using the radioactive source Na-22, Cs-137 and Co-60. The crystal is coupled with the PMT number R1306 and analyzed by the nuclear instrument module (NIM). The results found that the PTR and PCR of GAGG:Ce scintillator decrease with the increasing of energy. The results of energy resolution show the trend is decrease with the increasing of energy which corresponding to the higher energy resolution at higher energy. Moreover the energy resolution found to be linearly with $E$.

1. Introduction

Normally, the photo detectors coupled with crystal scintillators instruments [1] are used to count of high-energy photons and particles. Scintillator materials are important in many applications such as X-ray computed tomography (CT), positron emission tomography (PET), Single-photon emission computed tomography (SPECT) and other medical imaging techniques and special applications in high energy, nuclear, space and medical physics [2,3]. There are several parameters to confirm good scintillators, i.e. the highest light yield, good energy resolution, high effective atomic number, fast scintillation response, chemical stability and capability of large crystal growth [4]. The researchers were interested in the cerium doped materials such as silicates, LSO:Ce or LYSO:Ce because of the best combination of parameter factors. They have been developed as promising scintillators for PET due to high density, high effective atomic number, fast decay time and high light yield [5,6]. Also cerium-activated lanthanum halides, such as LaBr$_3$:Ce and LaCl$_3$:Ce are-reveal very good energy resolution, fast emission and excellent temperature and linear characteristics [7,8]. Oxide materials based on the garnet structure are appropriate choice for applications as scintillators because of high developed technology and easy doping by rare-earth elements for laser hosts and other applications.
Recently, gadolinium aluminium gallium garnet (GAGG:Ce) single crystal is grown by the micropull-down method and the results show that the light yield (LY) is 42,000 photons/MeV and energy resolution of 8.3% at photon energy 662 keV which is measured with the avalanche photodiode (APD). The single crystals can be grown by the Czochralski method which show the highest of LY is 46,000 photons/MeV and an emission peak at 530 nm and the range of good energy resolution is 4.9–5.5% at 662 keV [4]. GAGG:Ce is a new single crystal scintillator with several properties that make it interesting for applications such as gamma spectroscopy. GAGG:Ce has high density is 6.5 g/cm$^3$, similar to LSO, YAG or LuAG, which are generally used for high energy gamma-ray measurements, high gamma-ray absorption coefficient [9].

In this paper, the investigation of the peak to total ratio (PTR), the peak to Compton ratio (PCR) and the energy resolution of GAGG:Ce scintillator were measured in the range of energy from 511 keV to 1332 keV using the radioactive source Na-22, Cs-137 and Co-60.

2. Theory

2.1. Energy Resolution (R)

The Energy resolution (R) is the ability of the detector to determine accurately the energy of the incoming radiation. Energy resolution was calculated from the full width at half maximum (FWHM) of electron energy in the range of energy range from 511 keV to 1332 keV and it can be calculated by the following relation [10]:

$$R = \frac{FWHM}{E_0} \times 100\%,$$

where $E_0$ is the electron energy peak.

2.2. Peak to total ratio (PTR)

Peak to total ratio (PTR) is the relation between the area of photopeak and the total area in the spectrum. It can be calculated by this formula [11].

$$\text{PTR} = \frac{\text{The area of the photopeak}}{\text{The total area in the spectrum}}.$$

2.3. Peak to Compton ratio (PCR)

Peak to Compton ratio (PCR) is the ratio between the height of the photopeak and that of the Compton continuum, which is defined for source of the gamma ray spectrum as the ratio between the height of the photopeak and the average height of the Compton peak [12].

$$\text{PCR} = \frac{\text{The height of the photopeak}}{\text{The average height of the Compton peak}}.$$

3. Experimental

Experimental setup shown in Figure 1. The study of cerium doped gadolinium aluminium gallium garnet (GAGG:Ce) scintillator with a size of $10 \times 10 \times 0.8$ mm$^3$ was measured with a photomultiplier tube (PMT) number R1306, the Hamamatsu Photonics was a manufacturer. Using silicone grease for was coupled between scintillator and PMT, and wrapped in several layers of white teflon tape and wrapped again in black tape and then that covered with aluminium housing. The signal output from the PMT anode was passing through a canberra 2007B preamplifier and was sent to canberra 2022 an amplifier. These experimental set up was using nuclear instrument module (NIM) and shaping time of the spectroscopy amplifier were controlled at 0.5 µs for all measurements. The energy spectra
analyzed with software of canberra MCA to record data [13]. In this work the study of the peak to total ratio (PTR), the peak to Compton ratio (PCR) and the energy resolution of GAGG:Ce scintillator were measured the radioactive source Na-22, Cs-137 and Co-60 in the energy range of 511 keV to 1332 keV.

**Figure 1:** The diagram of gamma ray spectroscopy

### 4. Result and Discussion

#### 4.1. Energy Resolution

The energy resolution of the GAGG:Ce scintillator was determined using Eq. (1) by the different radioactive source in the energy range from 511 keV to 1332 keV and shown in Figure 2. The results of the energy resolution of GAGG:Ce scintillator increase proportional to the decreasing of energy from 511 keV to 1332 keV.

**Figure 2:** Energy resolution of GAGG:Ce in the energy range 511 keV to 1332 keV

#### 4.2. Peak to total ratio and Peak to Compton ratio

The peak to total ratio (PTR) and peak to Compton ratio (PCR) are determined by using Eq. (2) and Eq. (3) of GAGG:Ce in the energy range from 511 keV to 1332 keV. In Figure 3 presents the results of the peak to total ratio of GAGG:Ce in the energy range from 511 keV to 1332 keV and show that the values decrease from 1.096 to 0.196 with the increasing of the energy from 511 keV to 1332 keV.
Figure 3: Peak to total ratio of GAGG:Ce in the energy range from 511 keV to 1332 keV
The peak to Compton ratio for GAGG:Ce scintillator is shown in Figure 4. The results of peak to Compton ratio decrease from 2.98 to 0.60 with the increasing of the energy range from 511 keV to 1332 keV and the trend is also the same as the peak to total ratio.

Figure 4: Peak to Compton ratio of GAGG:Ce in the energy range from 511 keV to 1332 keV

5. Conclusion
In this paper, the peak to total ratio (PTR), the peak to Compton ratio (PCR) and the energy resolution of cerium doped gadolinium aluminium gallium garnet (GAGG:Ce) scintillator were measured in the energy range from 511 keV to 1332 keV using the radioactive source Na-22, Cs-137 and Co-60. The trend of energy resolution is inversely proportional to the square root of the energy and it increased with the decreasing of the energy. The results of the peak to the total ratio and the peak to the Compton ratio of GAGG:Ce scintillator decreased with the increasing of the energy.
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