Gamma-ray responses of organic single crystal grown by unidirectional Sankaranarayanan-Ramasamy technique

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Introduction

Scintillator crystals play a significant role in the detection of invisible radiation. Nowadays the organic molecule crystals are used for particle identification process due to its better pulse shape discrimination property. This advantage of an organic molecule is motivated to develop low cost and an efficient detector for wide range application. In the experimental setup of nuclear nonproliferation and high energy particle detections in astrophysics are obvious interest to detect the different energies of radiation. Over the existing organic scintillator the 1, 3, 5-Triphenylbenzene ($C_{24}H_{18}$) single crystal is one of the active organic molecules to detect the neutron in the gamma-ray background [1]. The authors reported the unidirectional growth of 3PB single crystal by Sankaranarayanan-Ramasamy (SR) technique, ampoule design, and its preliminary studies for device fabrication [2]. The aim of present work is a measurement of gamma ray detection of 1, 3, 5-Triphenylbenzene (3PB) crystal grown by unidirectional SR technique with different energy sources.

Experimental Technique

The grown crystal was in a cylindrical shape which was cut in the form of circular discs, and the orientation of crystal was determined by XRD technique which was found to be <200> plane [2]. The cut and polished cylindrical crystal (Fig.1b-40mm length and 30mm diameter) were mounted on the photomultiplier (Philips, Xp-2971) tube (PMT). Silicon grease (DC 200) was used for coupling the crystal with photomultiplier tube to minimise the loss of light produced in the scintillator. The PMT coupled crystal (Fig.1a) was covered with reflecting aluminium foil for preventing the escaping scintillation light. The energy information derived from the output of the detector by processing the signal through the spectroscopic amplifier. The data were collected for sufficient time (1hr) to get a smooth spectrum for each radioactive spectrum. The schematic diagram of experimental setup was as shown in the Fig.1. The energy response of 3PB crystal was investigated using ^{137}Cs, ^{60}Co, ^{22}Na, and ^{133}Ba source. All the measurements were performed in similar circumstances.

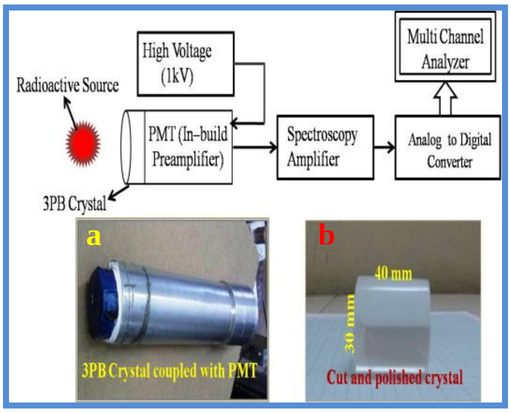

Fig.1 Schematic diagram of experimental setup (a) 3PB crystal coupled with PMT (b) cut and polished crystal grown by SR technique

Result and Discussion

Small effective atomic numbers of organic molecules are advantages over the inorganic molecules to detect the neutron and short-range charged particles (alpha and beta particles) in gamma-ray experiments. Due to their low atomic number, the organic molecules yield only Compton continuum with Compton edge (maximum energy transfer to the electron) for incident gammas [3]. In a general case, the energy calibrations of these detectors are done by the energy at the edge of Compton pulse height spectrum corresponding to an incident monoenergetic gamma-ray. The scattering of incident gamma photon energy (E) and the momentum gained by the electrons are due to Compton scattering. The Compton edge (E_c) is given by the following relation

$$E_c = \frac{2E^2}{0.511 + 2E} \quad \text{---------} \ (1)$$

Where, 0.511 is the rest mass energy (m_0C^2) of the electron in MeV. By using the gamma ray energies 356 keV (^{133}Ba), 662 keV (^{137}Cs), 1333 keV (^{60}Co), 511 keV (^{22}Na), and 1275 keV (^{22}Na) the maximum energies (Compton edge) transferred to the electron was determined by using the above relation (1) and calculated values are noted in the spectrum (Fig.2).

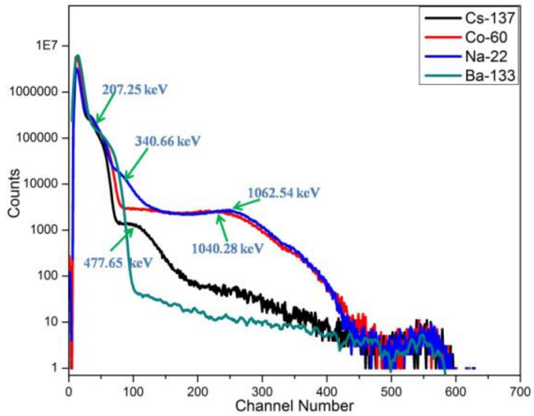

Fig.2 Energy spectrum of 3PB single crystal with different radioactive sources

Calibration of the linearity of the detector was done by using Compton peak position of gamma sources and the corresponding channel number (Fig.2). The graph is plotted count vs. gamma ray energy. The extracted parameters from the linear fit for 3PB crystal are shown in the table (Fig.3 inset). The linear fit quality was evaluated by inspection of residual value. The straight line (linear fit) gives the uncertainty of position and energies corresponding to the channel number of MCA (Multichannel analyser).

Summary

The experimental arrangement of 3PB detector was demonstrated and energy calibration organic scintillator was measured which gives the proper approximation of pulse height spectra (Fig. 2). The energy calibration (Fig. 3) indicates that the pulse height distribution maximum is approaching Compton edge energy increasing with respective of incident energy of gamma rays of radioactive sources. The response changes of gamma rays to be caused by effective changes of singlet energy level concentration in the 3PB material [1]. This experimental calibration of gamma energy of 3PB detector will be a useful alternative detector for complicated detector design (Gamma-ray and Neutron Spectrometer).

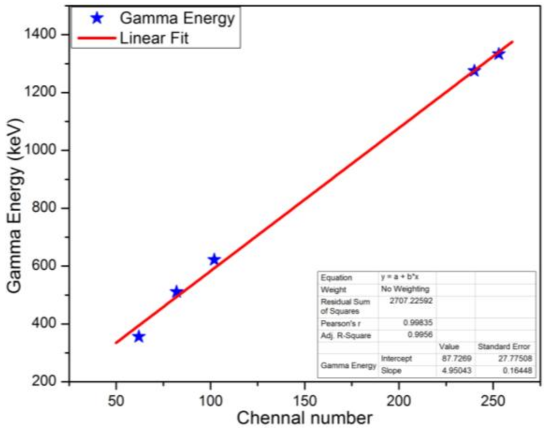

Fig.3 Energy Calibration

Future Scope

For better pulse shape discrimination (PSD) to distinguish between gammas and neutrons, the bias voltage of the detector will be optimised in future. By combining the PSD and TOF analysis the neutron-gamma, Alpha-gamma pulses will be clearly separated. It will be helpful to the research community to detect the neutron and other pulses more accurately and search for best-fit forms to improve the accuracy and precision of neutron detection.

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