Nuclear Instruments and Methods in Physics Research A 629 (2011) 149–153

Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research A

journal homepage: www.elsevier.com/locate/nima

Pulse height and timing characteristics of CsI(Tl)-Si(PIN) detector for γ-rays and fission fragments

Y.K. Gupta *, D.C. Biswas, P. Roy, B.K. Nayak, R.G. Thomas, A.L. Inkar, R.P. Vind, B. John, A. Saxena, R.K. Choudhury

Nuclear Physics Division, Bhabha Atomic Research Centre, Trombay 400085, Mumbai, India

ARTICLE INFO

Article history:
Received 18 May 2010
Received in revised form
22 November 2010
Accepted 28 November 2010
Available online 7 December 2010

Keywords:
CsI-Si(PIN) detector
Photodiode
Scintillation light response
Charged particles and γ-ray detection
Fission fragment measurement
Time response

ABSTRACT

Pulse height and timing characteristics of CsI(Tl)-Si(PIN) detector have been investigated for γ-rays and fission fragments (FFs). Energy dependence of the scintillation light output has been studied for FFs from a ^{252}Cf source by degrading their energy in P-10 gas at different pressures. It is seen that the light output for both heavy and light mass groups increases linearly with energy in the interval of 0.2–0.9 MeV/A. At a given energy, the light output is more for the heavy mass fragments than for light mass fragments. The time resolution for γ-rays was determined to be 134 ± 3 ns using a BaF_2 as start and CsI(Tl)-Si(PIN) as stop detector.

1. Introduction

CsI(Tl)-Si(PIN) detectors have been used in the multi-detector arrays all over the world [1–3] for charged particle measurements. They have also been used in γ-ray measurements [4], and for X-ray imaging in medical applications [5,6]. These detectors have following advantages: (i) CsI(Tl) scintillator coupled to photodiode Si(PIN) makes a compact geometry; (ii) particle identification is possible due to strong dependence of pulse shape on the type of ionizing radiation; (iii) radiation damage is much less; and (iv) large size crystals can be grown and they are cheaper in comparison to the conventionally used silicon detectors.

Light output response of CsI(Tl) detectors for charged particles up to $Z=36$ has been studied in detail earlier in the intermediate energy region [7–10]. Investigation of the light output response of CsI(Tl) detectors for fission fragments (FFs) is quite limited. In heavy-ion reactions, separation of fission fragments from projectile like fragments ($Z \geq 3$) using conventional methods such as pulse shape discrimination (zero cross over) [11] or ballistic deficit [12] is not feasible. Therefore, these detectors have not been used for the measurement of fission fragments in heavy-ion reactions. But these detectors can be used for FF measurements in light charged particle ($Z \leq 2$) or neutron induced fission reactions. In particular, CsI(Tl) detectors can be very useful as a FF-tagging device in reactor based neutron induced fission reactions for spectroscopic studies of FFs, where neutron damage to a detector is a serious issue.

It has been reported in the past [8–10] that the differential scintillation efficiency, dL/dE has a strong dependence on the specific energy loss (dE/dx) for charged particles ($2 \leq Z \leq 36$). dL/dE decreases as dE/dx increases and for the same value of dE/dx, the scintillation efficiency is higher for particles with larger atomic number. Since dL/dE depends on dE/dx, it gives rise to a nonlinear relationship between light yield (L) and energy (E) of the incident particle. This nonlinear behavior is more pronounced at energies below 6 MeV/nucleon. These observations for charged-particles up to $Z=36$ have been understood in the framework of a model first proposed by Meyer and Murray [13,14].

In spontaneous fission of ^{252}Cf, FFs are produced in a wide range of mass and charge having energies in the range of 0.5–1.3 MeV/nucleon. The dE/dx behavior of FFs is quite different in comparison to the higher energy charged particles ($2 \leq Z \leq 36$) because of the dependence of effective charge (Z_{eff}) of the FF on energy [15,16]. In order to explore the possibility of using CsI(Tl)-Si(PIN) detector for FF measurement, we have investigated in the present work the light output response of the detector for fission fragments produced from a ^{252}Cf source. The energy dependence of the light output for FFs was studied by degrading the energies of the FFs in P-10 gas (90% Ar+10% CH_4 mixture) at different pressures.

We have also investigated the time response of the detector for γ-rays. The time resolution of the detector for γ-rays has been measured by detecting the two prompt γ-rays of energies 1.17 MeV and 1.33 MeV emitted in a cascade from ^{60}Co source where one of

* Corresponding author.
E-mail address: ykgupta@barc.gov.in (Y.K. Gupta).

0168-9002/$ - see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.nima.2010.11.119

the γ-rays is detected by a BaF_2 detector and the other by the CsI(Tl)-Si(PIN) detector. The measured time resolution of the CsI(Tl)-Si(PIN) detector is observed to be somewhat poor for γ-rays among all other radiations, and it has been discussed in Section 4. These CsI(Tl)-Si(PIN) detectors are being planned to be used in a charged particle detector array at the BARC-TIFR Pelletron/Linac facility, Mumbai [17].

2. Details of detector setup

The CsI(Tl)-Si(PIN) detectors have been supplied by M/s SCIONIX, Holland. The CsI(Tl) crystal has entrance surface area of 25×25 mm^2 and thickness of 10.0 mm. Except the back surface, all other faces were covered with 1.2 μm thick reflecting foil of aluminized mylar. A Si-PIN photodiode manufactured by Hamamatsu Photonics is coupled to the back surface via a $25 \times 25 \times 15$ mm^3 light guide. The photodiode type S3204-08 is 300 μm thick with an active area of 18×18 mm^2. A rectangular collimator of opening area 22×22 mm^2 was placed at the front surface of the crystal to avoid the edge effects. The signal readout was achieved by a charge sensitive pre-amplifier attached to the photodiode. The low power dissipation of ~ 120 mW of the pre-amplifier allowed it to be operated in vacuum without special cooling. Signals from pre-amplifier had a DC off-set of 2–3 V, which was eliminated by using a capacitor of 6.0 μF. The required +12 V to the pre-amplifier was supplied using a battery which improves the signal to noise ratio in comparison to supplying the voltage from a NIM module. The gain of the pre-amplifier was 6 mV/MeV for α-particles with output impedance of 50 Ω. Pre-amplifier signals were amplified and shaped using a spectroscopy amplifier (CAEN N968).

The pulse height and energy resolution of the detector were studied as a function of bias voltage applied to the photodiode. The leakage current of the photodiode varied in the range of 3–9 nA over the voltage range of 2–100 V. Figs. 1 and 2 show the pulse height and energy resolution (FWHM) for α-particles (from ^{241}Am–^{239}Pu source) as a function of (i) bias voltage applied to the photodiode (Figs. 1(a) and (b)) and (ii) shaping time of spectroscopic amplifier (Figs. 2(a) and (b)), respectively. It is observed that for achieving full light amplification from the crystal, the applied bias voltage and shaping time are around +35 V and 3 μs, respectively. A typical energy spectrum for α-particles (from ^{241}Am–^{239}Pu source) and γ-rays (from ^{60}Co) is shown in Fig. 3. The broad peak below 1.17 MeV in Fig. 3 is due to Compton scattering of γ-rays of energies 1.17 and 1.33 MeV. The energy resolution at shaping time of 3 μs and bias voltage of +35 V is $\sim 3.6\%$ for ~ 5 MeV α-particles and $\sim 7.8\%$ for 1.33 MeV γ-rays, respectively.

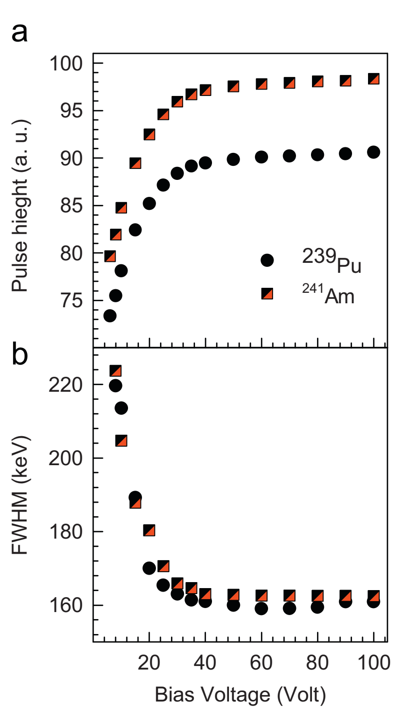

Fig. 1. Pulse height (panel (a)) and FWHM (panel (b)) for the α-particles from ^{241}Am–^{239}Pu source as a function of bias voltage applied to the photodiode. Circles are for ^{239}Pu and squares are for ^{241}Am.

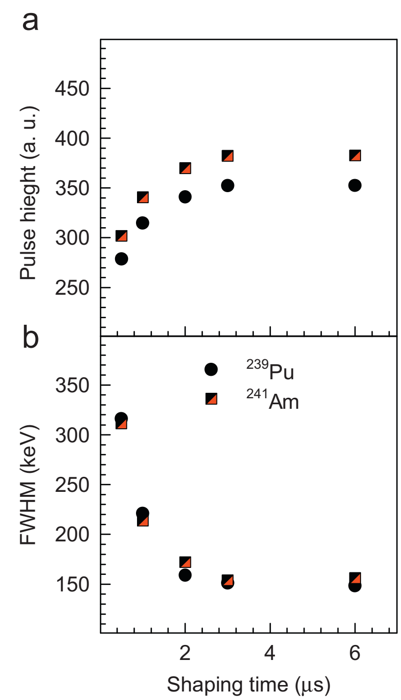

Fig. 2. Pulse height (panel (a)) and FWHM (panel (b)) for the α-particles from ^{241}Am–^{239}Pu source as a function of shaping time of spectroscopic amplifier. Circles are for ^{239}Pu and squares are for ^{241}Am.

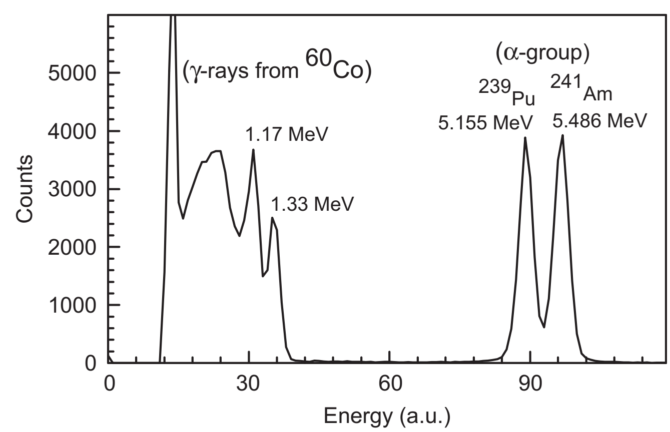

Fig. 3. Pulse height spectrum for α-particles from ^{241}Am–^{239}Pu and γ-rays from ^{60}Co at operating voltage +35 V and shaping time 3 μs.

3. Light output response for fission fragments (FFs)

The light output response of CsI(Tl)-Si(PIN) detector has been investigated for FFs of two different mass and charge groups produced from a ^{252}Cf source. The most probable fragments are ^{104}Mo and ^{144}Ba with corresponding energies of 104 and 80 MeV, respectively [18]. The pulse height spectrum from a ^{252}Cf source