Charged particle detection with the low-cost BPW21 Si Photodiode

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Introduction

Silicon (Si) surface barrier and silicon strip detectors are well-known detectors for charged particle detection in nuclear physics experiments [1, 2]. Although these detectors are used extensively by the experimentalist for the charged particle spectroscopy over a long time, however, above mentioned detectors cannot be used for the long time run due to the radiation damage. These detectors are quite expensive as well. It has been frequently observed that radiation damage occurs rapidly for the monitor detectors those are usually the silicon surface barrier detectors [1, 2]. As a result, energy resolutions become worsen. Usually, monitor detectors are placed symmetrical to the beam direction at the extreme forward angles (depending upon the experiment) with respect to the beam direction, such that the scattered particles detected by monitors are originated from pure Coulomb scattering. One can compare the number of events with the known Rutherford cross-section and, can get the product of the numbers of beam and target particles.

Therefore, an alternative cost-effective charged particle detector is required that can operate with the lifetime comparable to the detectors as discussed above. This prompted us to investigate the low-cost (~ 5 euro) commercially available BPW21 Si photodiode (OSRAM Opto Semiconductors) [3] which can stand to achieve our goal.

Experimental details and Results

Commercially available BPW21 Si photodiode [3] from OSRAM Opto Semiconductors has been taken for charged particle detection. The BPW 21 is a photodiode within a TO-39 metal can package. It is designed for applications from 350 to 820 nm, similar to the visible range. The borosilicate glass window was removed in order to expose the active area (2.45 mm^2) directly to a charged particle. The ^{252}Cf source was placed in front of the diode device at a distance of 1.2 cm in order to measure the alpha and fission fragment. The data have been collected with a reverse bias of 100 V which optimizes the energy resolution of 5.48 MeV alpha (from ^{241}Am source). In this configuration, the dark current of the diode found to be 0.004 μA.

A representative alpha spectrum from ^{252}Cf source has been shown in Fig. 1. The energy resolution has been found to be 245-KeV at 6.12 MeV alpha (four percent) which is decaying from^{252}Cf source.

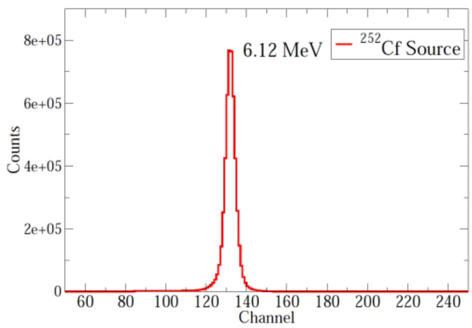

Fig. 1: The alpha spectrum from ^{252}Cf source.

After that, we have checked the sustainability of the diode against the radiation in an online experiment at VECC Kolkata with energy 34.5 MeV alpha beams that were bombarded onto a 1.5 mg/cm^2 thick ^{9}Be target. The diode has been placed at a laboratory angle around 20.0° with respect to the beam direction, in the horizontal plane, inside the target chamber and the distance between diode and target position was 25.5 cm. It was estimated that the elastic count rates in the active area of the diode will be around 2 × 10^5 per hour and the experiment was running about 6 days. During the experiment reverse bias was kept at 100 V and the dark current was found to be less than 0.01 μA throughout the experiment.

After the online experiment, we have placed the diode in front of ^{252}Cf source (for 3 days) at a distance of 1.2 cm with the 100 V reverse bias in order to find out the resolution of 6.12 MeV alpha particle again to check the radiation damage. The energy resolution has been found to be 245-KeV at 6.12 MeV alpha. The dark current of the diode again found to be 0.004 μA. Therefore, this diode can sustain against the radiation in a typical online nuclear physics experiment.

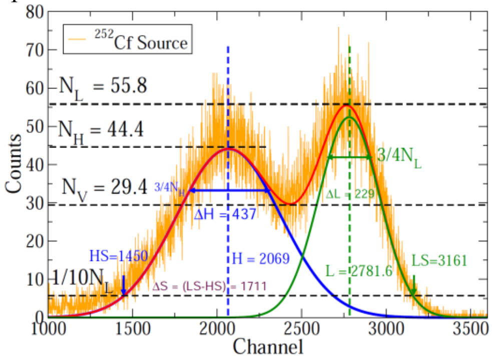

Fig. 2: Pulse height spectrum of fission fragments (FF) from ^{252}Cf with spectrum shape parameters [4, 5].

Fission fragments (FF) of ^{252}Cf source with the spectrum shape parameters [4, 5] have been shown in Fig. 2. Heavy fragments are shown by a fitted blue (Gaussian fit) line. Whereas light fragments have been shown with the green fitted line. The ratio of area under the curve of the heavy and light fragment has been found to be 1.4.

Suitability of this diode for FF detection has been checked following the prescription of Schmitt et al,. [4, 5]. The shape parameters obtained by fitting the spectrum with the two Gaussian distributions under the constraint of equal area for both peaks. The measured values are close to the parameters of "reasonable limit parameters" as set by Schmitt et al,. [4, 5]. The shape parameters obtained without the constraint of the equal-area are also corroborated reasonably well with the expected values.

Mass-dependent energy calibration has also been carried out as described in Refs. [6, 7] and the energies of light (102.0 ± 1.0 MeV) and heavy fragments (78.5 ± 0.6 MeV) have been estimated. The estimated values of the fragment energies compare well with those reported in the literature [4, 6, 7]. The energy of the symmetric fragments (91.7 ± 0.8 MeV) has also been estimated.

Therefore, the low cost (~ 5 euro) commercial photodiode BPW21 can be used for the detection of charged particles such as alpha particles and fission fragments.

Our next goal is to separate the evaporation residues (for heavy mass compound nuclei (~ A= 200)) from other reaction products (Scattered projectiles, fission fragments as well as light nuclei produced in fusion reactions with target impurities) by their time-of-flight (ToF) [8] using this diode.

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