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Characterization of a polymer as a heavy ion detector

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A particular brand of polymer, commonly used as overhead projector transparencies, has been used as a solid state nuclear track detector with $Z/\beta > 35$. From the infra-red transmission spectrum by FTIR Spectrophotometer, the polymer was identified to be polyethylene terepthalate (PET). The charge response of this PET detector has been studied using 11.3 MeV/n ^{238}U-ion and 11.4 MeV/n ^{58}Ni-ions from GSI, Germany and 53.6 MeV ^{16}O-ions from Nuclear Science Centre, India.

1. Introduction

Solid state nuclear track detectors (SSNTD) are useful in studying heavy ion abundances in cosmic rays at high altitudes because of their light weight and certain detection threshold values of Z/β, which automatically exclude the enormous proton and α-particle background in the cosmic ray spectrum. A few previous experiments showed that commonly used overhead projector (OHP) films can be used as solid state nuclear track detector for detecting heavy ions [1-5]. We have identified a particular brand of OHP film as an SSNTD with a detection threshold value of $Z/\beta > 35$ [5]. So this polymer can reduce the huge low-Z background in an exposure to cosmic rays and may be useful in studying rare events in cosmic rays. In the rest of this paper we have referred to this particular brand of OHP film as the PET detector. A sensitive charge response characteristic is a pre-requisite for any detector of cosmic rays. In this paper we present the charge response characteristics of the PET detector over a wide range of Z/β. We have used 11.3 MeV/n ^{238}U-ion, 11.4 MeV/n ^{58}Ni-ions from GSI, Germany and 53.6 MeV ^{16}O-ions from Nuclear Science Centre, India, as known energetic projectiles to investigate the charge sensitivity of the PET detector.

2. Experiment

Several pieces of 100 μm thick PET detectors were exposed to 11.3 MeV/n ^{238}U-ion and 11.4 MeV/n ^{58}Ni-ions from GSI, Darmstadt. Aluminium (Al) foils of different thicknesses (84.0 μm, 73.5 μm and 63.0 μm) were interposed between the source and the detector surface as energy degraders. Detectors exposed to ions with degraded energies were etched in 6.25N NaOH solution at 55 ± 0.1^{o}C for 3 hours, maintaining the same etching conditions as in our previous experiment [5].

Eight sets, each containing 22 pieces of polymers, each of area 3.5×3.5 cm^2 were exposed to ^{16}O ions with eight different incident energies obtained by using different air gaps as energy degrader between the flange of the beam-pipe and the detector at the Nuclear Science Centre, New Delhi where a Pelletron delivered 53.6 MeV ^{16}O ions. Exposed PET detectors from each incident energy set were etched in NaOH solution keeping the etching condition the same as mentioned above, so that a comparative study of the detector response can be made.

Etch cones developed along each nuclear track after chemical processing of the exposed polymers in accordance with known principles. The diameters of the surface openings and the corresponding cone depths were measured under the x100 dry objective of a Leica DMR microscope, interfaced with a computer for automated image analysis.

The smallest scale division for diameter measurement was 0.132 µm and that for depth measurement was 1 µm. In this paper we present some preliminary results from different heavy ion exposures given to the PET detector.

3. Results and Discussion

Elemental analysis of this polymer was done to determine its composition. It was found that the polymer is a type of terephthalate with chemical formula $(C_5H_4O_2)_n$. The infra-red transmission spectrum of this polymer film obtained by using a Fourier Transform Infra Red (FTIR) Spectrophotometer indicated that this material is polyethylene terephthalate (PET). The bulk etch rate for this PET film was determined by the thickness loss method and we found it to be 0.78 ± 0.05 µm/hr under the above mentioned etching conditions[2].

Ni and U-ion tracks have elliptical surface openings as the paths of the ions were not normal to the detector surface. Lengths of both the major axis and minor axis of each pit openings as well as the depth of each cone were measured.

O-ions were made to fall normally on the detector. The diameters of the circular surface openings of the etch pits and the corresponding depths were measured.

The estimated values of the response parameter (V_t/V_g) for different projectiles have been plotted against their Z/β values in Figure1.

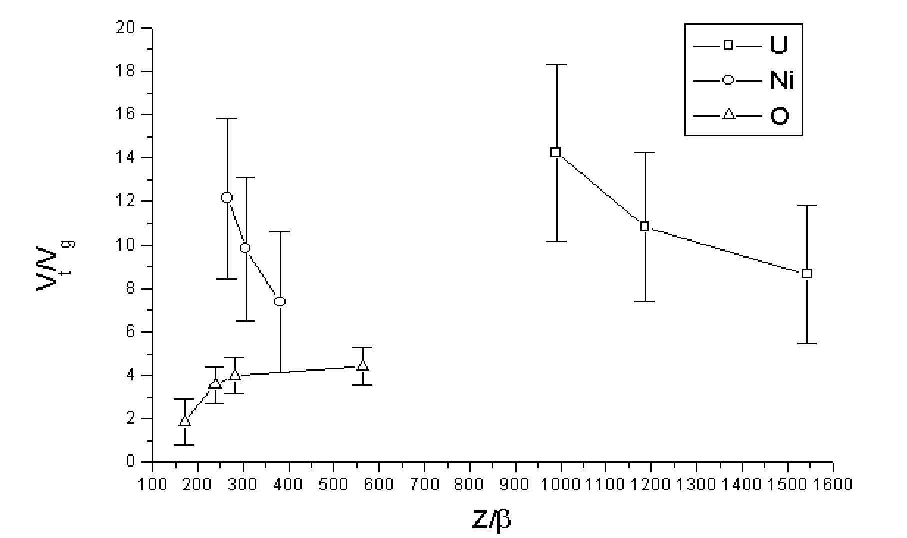

Figure 1. Response characteristics of the PET detector to ^{238}U, ^{58}Ni and ^{16}O ions

It is seen that the response parameter V_t/V_g decreases with increasing Z/β value for Ni and U-ions; but for O-ions, it increases with increasing Z/β and shows a tendency to become constant after $Z/\beta=450$.

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