Multi-fragmentation of nucleus recorded on a plastic detector (SSNTD) at excitation energy E ≈1 MeV/n

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Abstract*:* Multi-prong tracks have been recorded in the polyethylene terepthalate ($C_{10}H_8O_4$) solid state nuclear track detector by exposing a ^{252}Cf fission source. After chemical etching, two-prong to six-prong tracks along with single tracks have been observed under the optical microscope. The origin of multi-prong tracks could be attributed to the multi-fragmentation of nuclei. Observation of multi-fragmentation at this low energy (E/n ≈1 MeV) is important and possibly will give new information about nuclear interaction and nuclear force. This detector is also suitable for detection of fragmentation of cosmic rays.

Introduction:

The polyethylene terephthalate ($C_{10}H_8O_4$) solid state nuclear track detector commercially known as PET, has been used for the detection of heavy charge particles for many years. This detector has some important advantages over the standard solid state nuclear track detectors CR-39, Lexan etc. This detector (PET) has much higher detection threshold ($Z/\beta \geq 150$) than that of CR-39 ($Z/\beta \geq 6$) and lexan ($Z/\beta \geq 57$). From our earlier studies it has been found that this detector does not detect 6 MeV alpha particles from ^{252}Cf fission source [1].

With an aim to use the PET detector for future application in cosmic ray studies because of the above advantages, we have further studied it with a ^{252}Cf fission source in order to detect the charge particles emitted from this source. From present studies we have observed some new interesting events. It has been observed that when the PET detector was exposed with a ^{252}Cf fission source it produces several multi-pronged tracks. We have exposed both CR-39 and PET of two plates each with this fission source. One of the plates of these PET detectors registered clear multi-pronged charged particle tracks along with single tracks. These multi-prong tracks indicate fragmentation of nuclei, which have been identified with the help of the calibration curve. The calibration curve (dE/dx vs V_t/Vg) was obtained from the studies of different charge particles from natural source as well as from the accelerator ion beam. The fragmented events that were identified lie between Oxygen and Strontium. These are intermediate mass fragments (IMF). Zamani et al [2] in their experiment using CR-39 detector obtained multi-fragment emission at excitation energies 17.7, 27, 35 MeV/n., which are IMF. Then the observation of multi-prong events in our experiment indicates multi-fragmentation of nuclei at excitation energy of ~1 MeV/n, and may be at lower energy. This detector is suitable for study of multi-fragmentation of cosmic rays.

Experiment:

To investigate detection efficiency and range of Z/β detection for both light and heavy ions, CR-39 (Intercast Europe Co.,Italy) and PET film, each of area 3.5 x 3.5 cm^2 were exposed inside a vacuum chamber to the normally incident alpha particles and fission fragments from a ^{252}Cf source of strength ~1 μCi. The thickness of the PET detector was 100 ± 5 μm and that of CR-39 was 600 μm. The detector was exposed for two minutes inside a vacuum chamber (pressure ~ 10^{-5} bar). The shutter was removed for exposure after the desired vacuum was achieved. The chemical development of PET detector was carried out in 6.25N NaOH at a

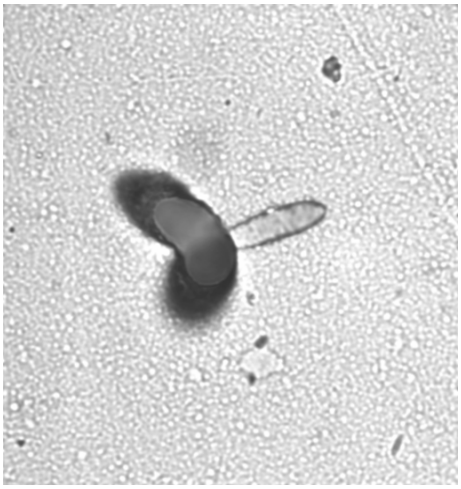

Fig.1a: three prong track

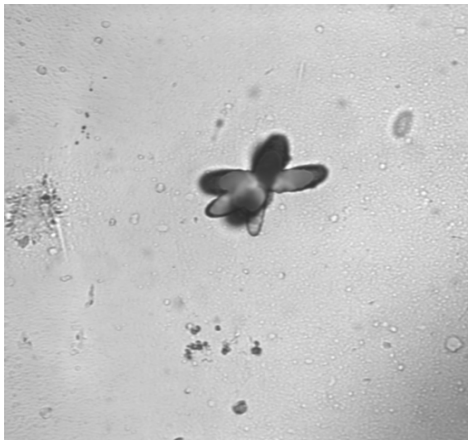

Fig.1b: six prong track

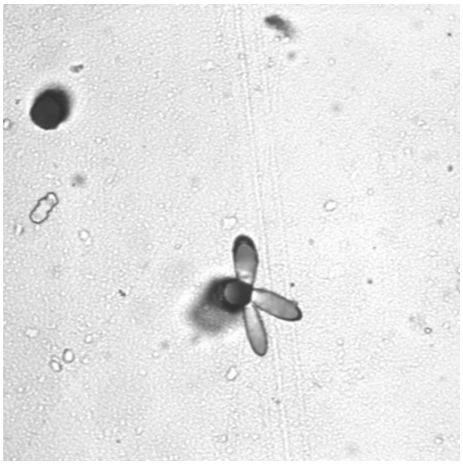

Fig.1c: three prong track and a single track

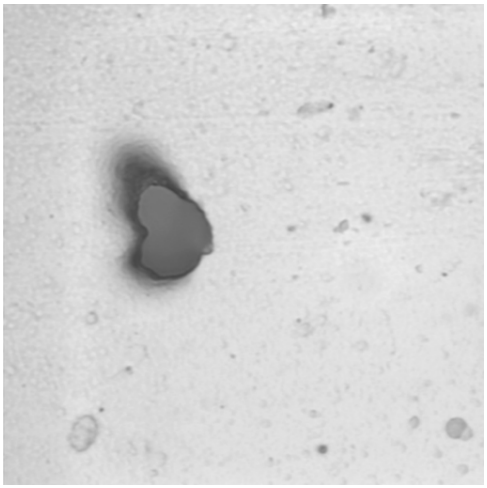

Fig.1d: two prong track

temperature 55^0 C. Exposed CR-39 plates were etched in 6.25N NaOH solution at a temperature 70^0C. Etching time was 4 hours which produced well developed tracks. The plates were scanned under different dry objectives (x100, x50, x20) of a Leica DMR microscope, interfaced with a computer for automated image analysis. One of the two exposed PET detectors registered several multi-prong tracks as well as single tracks. Two to six prong tracks are present along with single tracks. Photographs of some multi-prong tracks are shown in figs.1a-1d. These multi-prong events are observed at localized area of the detector. Track parameters viz. track lengths, etch-pit diameters, angle of emissions have been measured.

Results and discussions:

Multiplicity (no. of prong) of an event vs number of events (yield) of that particular event is shown in fig.2. The plot shows cross section (yield) decreases with the increase of multiplicity of events.

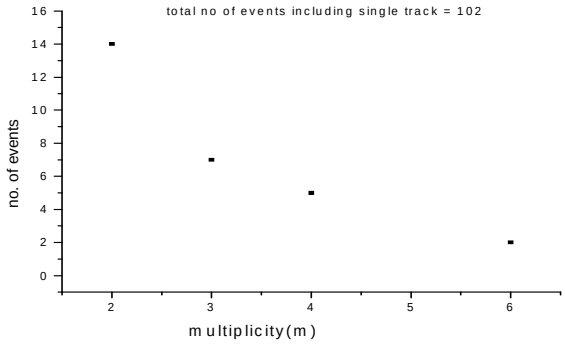

Fig.2 multiplicity vs no of events

The charge, mass and energy of the detected fragments are determined using our calibration curve and SRIM-2006 Program. Identified fragments lie in between Oxygen and Strontium. Charge (Z) Vs yield (N) is shown in fig.3. The distribution show a maxima around Z=20. Few fragments remain unidentified. The error in determining charge is of the order of ±5. Energies of the fragments are few tens of MeV, and E/M is of the order of 2 MeV.

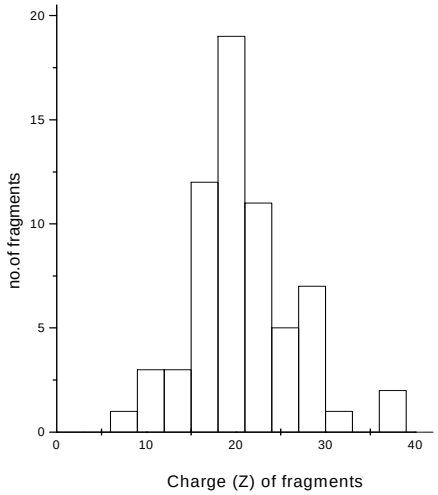

Fig 3.Charge (Z) vs Yield (N)

Now, we try to find out the origin of these multi-prong events. Multi-prong tracks areprobably due to fragmentation of nuclei or nuclear interaction. The ^{252}Cf source emits fission fragments, alpha particles, neutrons and gamma rays. The neutron induced charge particle production with ^{12}C and ^{16}O have different thresholds for different reactions. The threshold energies for different reactions [3] are known to be from 8-15 MeV. On the other hand, the average energy of the neutrons which are emitted from ^{252}Cf source are much lower (2-3 MeV) than the threshold values. If any higher energy neutron is emitted from the source and any of those reactions takes place, whish produces alphas and protons, neutrons along with heavier ion like carbon, a PET detector will not detect alpha and lighter charge particles. In

that case multi-prong tracks will not be formed in this detector material. Therefore, we can conclude that multi-prong events are not due to neutron induced nuclear reaction with the detector material.

Inside the scattering chamber there are few metallic substances like aluminum wire, copper wire and lead .The fragmentation could be due to the interactions of fission fragments with any other nuclei present in side the scattering chamber. To confirm the reaction we have exposed the PET detector attached with 1um thick aluminized mylar foil. After etching it shows few two-prong tracks, one three prong track and one four prong track Photograph of one such event is shown in fig.4, which shows two prongs at right angles to each other.

Fig.4. photograph of a two prong event on aluminized mylar.

Conclusion:

We can conclude that observed tracks are due to multi-fragmentation of nucleus at excitation energy 1MeV/n. Up to my knowledge this is the first observation of multi-fragmentation at such excitation energy. This detector is quite suitable to study multi-fragmentation phenomena of cosmic rays.

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