STUDY OF ALPHA PARTICLE TRACK REGISTRATION CELLUOLOSE ACETATE DETECTOR

By

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Abstract :

The characteristics of cellulose acetate foils as alpha particle track registration detector has been investigated. The sensitivity, etching kinetics, track stability, fading effects and energy resolution have been discussed on the bases of experimental data. The environmental effects such as presence of oxygen, humidity and temperature on the track formation is described.

Introduction :

In the last few years fine tracks were observed along the heavy charged particle trajectory when passing through some insulators. Silk and Barnes (1) 1959, observed directly by electron microscope tracks of 100 A° diameter caused by fission fragments in mica. Fleischer, Price and Walker (2,3) 1962, showed that tracks could be made visible by chemical etching in a variety of dielectrics such as mica, glass and especially organic polymers. The latter category of track detectors proved to be considerably more sensitive than inorganic detectors, permitting not only the detection of heavy, densely ionizing charged particles, but also alpha particles up to several Mev in energy. Even proton tracks have been registered at energies near the Bragg's peack i.e. about 100 Kev (4).

Since then the method of charged particle track imaging in insulators, particularly organic polymers, by etching found several applications in numerous fields of science including nuclear physics e.g. neutron spectroscopy (5,6), nuclear reactions and neutron flux distribution in nuclear reactors, space physics such as studies of heavy charged particles in space (7), dating of meteorites, minerals, archeological artificts etc. (8,9).

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Compared to the widespread interest in seeking new applications of the track etching technique, research on the basic characteristics and mechanism of these detectors has been relatively neglected.

In the present paper the main characteristics, such as relative sensitivity, etching kinetics, fading stability and energy resolution of cellulose acetate as an alpha particle detector has been studied.

Mechanism of track formation in polymers :

Two mechanisms have been proposed to explain the etchable tracks in dielectrics. One for inorganic materials depending on the ion explosion spike model (10) which suggests that a region of positive charges is produced along the path of heavy charged particles due to the ejection of electrons, and that the mutual repulsion of the remaining heavy positive ions result in atomic displacement in the crystal lattice. These regions of disordered imperfections are more easily attacked by an etching reagent than the surrounding undamaged material. Besides this mechanism others such as «thermal spike» (local heating) or «displacement spike» (elastic collision) may play a minor role.

The ion explosion spike mechanism as applied to organic polymers has not been successful (11). The most acceptable theory for organic polymers is based on radiochemical damage mechanism (12,13). According to this mechanism the ionization and excitation caused by charged particles lead to chain fracture of long polymer chains, the production of free radicals, ion molecule reactions and the subsequent production of excited, chemically altered species which are more susceptible to etching than the original polymer molecules.

Etching kinetics, sensitivity and track stability :

Cellulose acetate foils supplied by VEB-Wolfen have been used. The samples have thickness varying between 100 to 80 micron. It was irradiated orthogonally with respect to their surfaces by an alpha emitter for different periods of time ranging from several minutes to several hours.

The samples were then etched in 30% K OH solution at 60°C under identical conditions. They were then rinsed in tap water, washed with distilled water and dried perior to counting.

Fig. 1 shows how the diameter of alpha particle tracks very with the etching time. The curve follows the empirical formula given by Somogyi (14) for alpha particle trails in cellulose nitrate.

The track density in irradiated cellulose acetatac foils show a maximum at an etching time of two hours, as clear in fig. 2. This is mainly due to the fact that the tracks of alpha particles which has a LET below threshold registration when passing through the original surface of the plastic may be above that threshold LET close to the end of their tracks in deeper layers by bulk etching, and so smaller etch pits become more visibile with increasing etching time. If etching is continued the track density passes over a maximum then decreases, because larger etch pits become over etched and some of them grow on the expence of smaller ones.

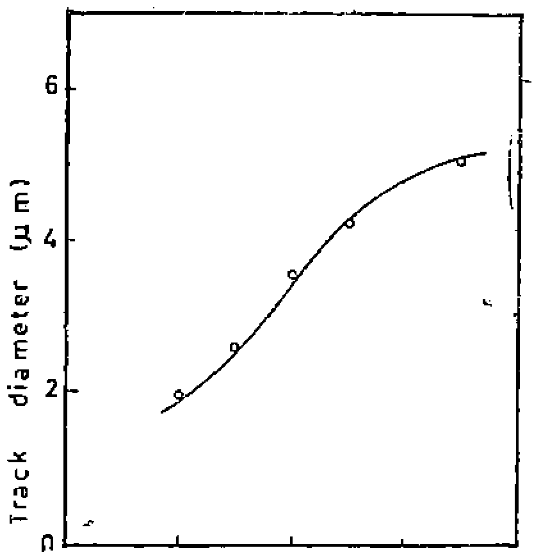


Fig. 1

In fig. 3 the number of visible tracks versus etching time for cellulose acetate foils kept one day perior and during irradiation in vacuum — to remove any chemically unbound oxygen —, nitrogen and air is drawn. The difference between vacuum and nitrogen exposed foils may be attributed to small oxygen content of the impure nitrogen used.

Not only the number but also the size of the etch pits is affected by the presence of oxygen. It was found that for a given etching time the diameter is about 30% larger for foils treated in air than for those treated in vacuum.

If the foils treated in vacuum were kept perior to etching in air

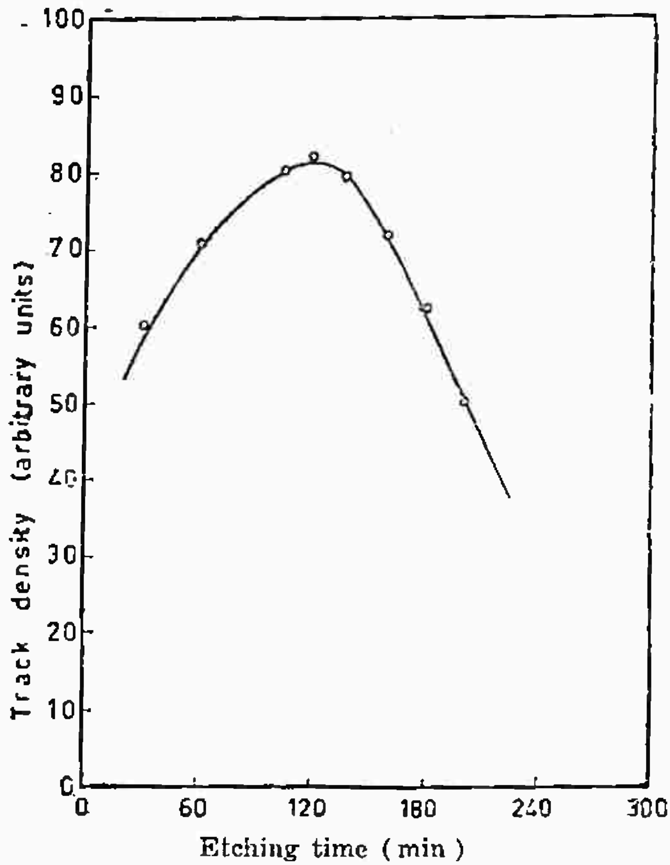
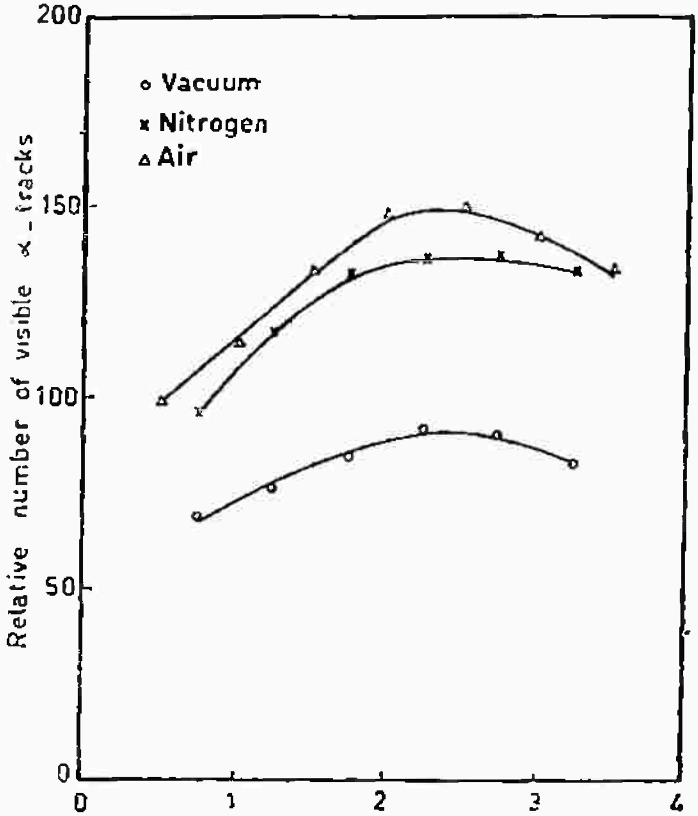


Fig. 2

or oxygen atmosphere they exhibited the same sensitivity, which means that oxygen playes its role during exposure rather than after exposure. The oxygen affects the etching speed along the particle trajectory and this causes the registration thresholds in the plastic irradiated in oxygen free environment to be smaller than these in the plastic irradiated in air.

To investigate the humidity effect, the etch pit diameter of alpha particles was drawn versus the etching time in fig. 4 for foils treated in vacuum, dry air and 100% relative humidity. It is clear that the diameter is considerably greater in case of foils treated in humid air. The presence of water causes softening of the plastic and enhances the etching speed along the particle trajectory.

The latent alpha tracks are quite stable at storage temperatures up to 60°C, as clear from fig. 5. At 90°C there was fading and at 120°C (near the softening point of the plastic) about 20% ofthe latent



Etching time (hours)

Fig. 3

tracks were destroyed. After one day at 120°C only 10 to 20% of the initial tracks become visible if etching was extended. This indicates that the fading may be more a surface than volume effect.

In order to illustrate the energy resolution of this track registration method, the diameter distribution of alpha holes belonging to Am^{241} (energy about 5.5 Mev), Po^{210} (energy about 5.3 Mev) and U^{236} (max. energy 4.2 Mev) is shown in fig. 6. It is clear that the resolution of this method for track imaging in cellulose acetate is fairly high. It could also be noticed that low energy particles create large holes while the high energy particles create smaller holes. This is because the width of the damage region is corrolated to the local energy loss of the particle. It seems plausible that the relation $d^2 \propto \frac{dE}{dX}$ will hold. The energy loss varying along the trail is given by Bethe-Bloch formula, according to which it is approximately inversely proportional to the energy of the particle consequently the radius of the hole is determined by its initial energy.

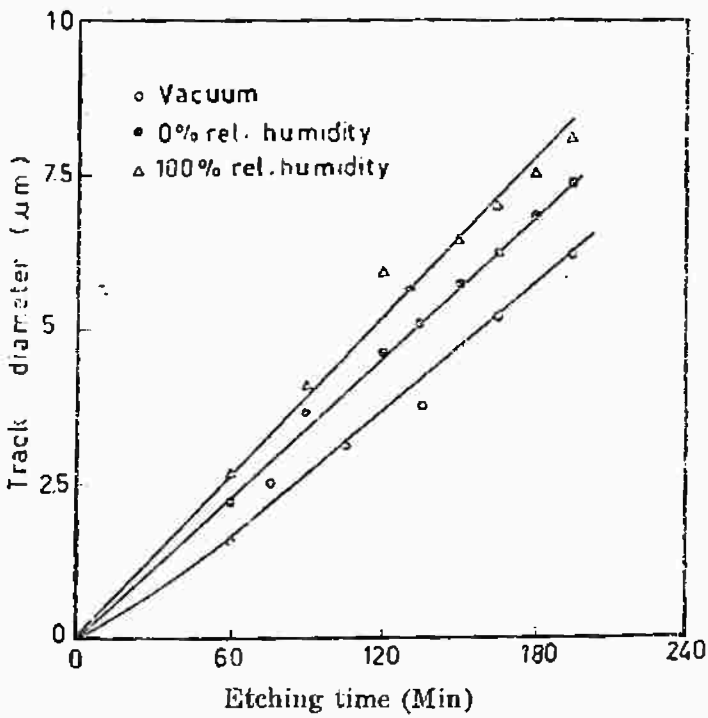

10
7.5
5
2.5
0
Track diameter (μm)
○ Vacuum
● 0% rel. humidity
△ 100% rel. humidity
0
60
120
180
240
Etching time (Min)

Fig. 4

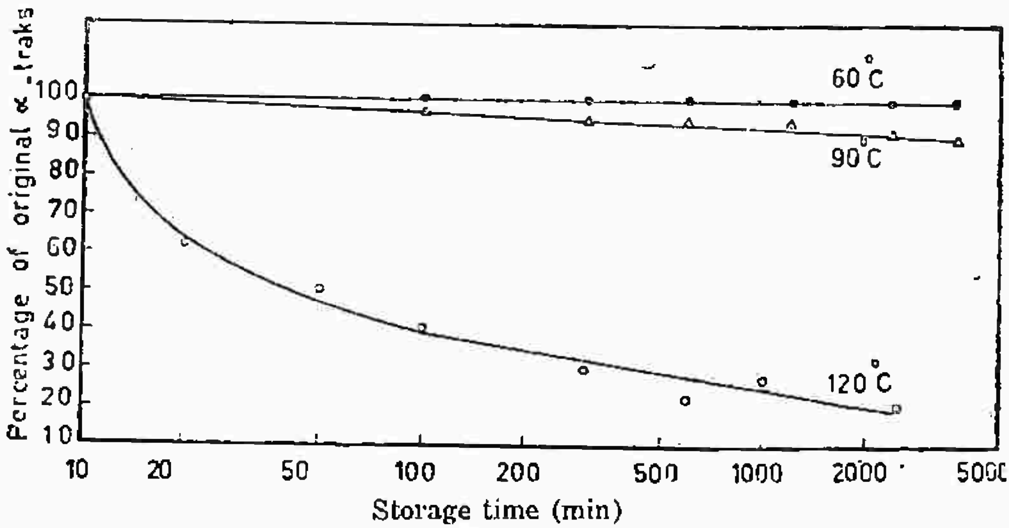
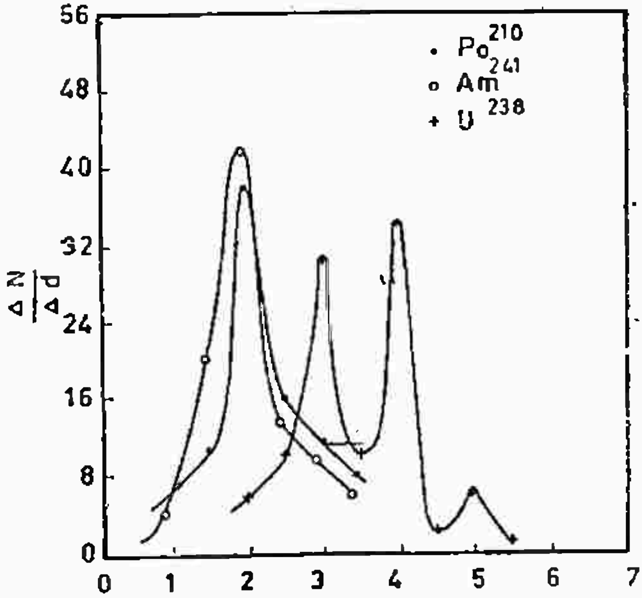

Percentage of original α_traks
100
90
80
70
60
50
40
30
20
10
60°C
90°C
120°C
10
20
50
100
200
500
1000
2000
5000
Storage time (min)

Fig. 5



Diameter (um)

Fig. 6

Conclusion :

It might be concluded that the presence of oxygen increases the sensitivity of the detector by making tracks etchable which would have not contained sufficient concentration of brocken or displaced bonds. free radicales etc. in the absence of oxygen. The oxygen present in air is sufficient for the saturation of this effect. The presence of water causes softening of the plastic material without affecting the actual damage mechanism.

So the method of track imaging in cellulose acetate is one of the most suitable, high resolving and stable methods for alpha particle studying techniques.

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