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EFFECT OF VARIATION OF INCIDENT ANGLE OF ALPHA PARTICLES AT VARIOUS FIELD STRENGTHS ON ECE RESPONSE OF CR-39

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Electrochemical etching study of CR-39 irradiated with a collimated beam of alpha particles of ^{241}Am at various angles has been carried out. The influence of incident angle of alpha particles on track density and treeing phenomenon for various ac field strengths has been investigated. The results thus obtained are compared with that of chemical etching.

1. Introduction

In electrochemical etching (ECE) process [1], two chambers filled with electrolyte, out of which one is etchant, are separated by the polymeric track detector keeping the irradiated side in touch with the etchant. An ac electric field is applied across the detector. Etchant penetrates into the channels produced by charged particles. Conductive paths are produced and due to large field concentrations at the tip of these paths development of "treeing" takes place. ECE of alpha tracks in various track etch detectors has been investigated for fluence [2] and energy discrimination [2–4].

In alpha dosimetry and neutron recoil trails we come across a variety of track lengths and orientations. Moreover, ECE has an advantage over CR for track revelation of low LET particles and nuclear fragments emitted at various angles in nucleus–nucleus collision [5]. It has been reported that with suitable choice of ECE parameters, tree initiation occurred preferentially for tracks along the electric field. The effect of incident angle on track revelation during ECE has not been investigated in sufficient detail so far. This study pertains to alpha recording at various incident angles in CR-39 which is extensively employed for dosimetric studies [6,7].

2. Experimental procedure

In the present investigation, CR-39 plastic foils of thickness 250 μm, procured from Pershore Mouldings Ltd., Worce, (UK), have been employed. A number of circular plastic foils having 12 mm diameter were irradiated under atmospheric pressure with collimated alphas from ^{241}Am source at various incident angles at 15°, 20°, 25°, 30°, 45°, 60°, 75° and 90°, respectively, with the surface of the detector as shown in fig. 1. The distance between the alpha source and the plastic detector was kept at 2 cm and the air column between them attenuated the energy of striking particles to approximately 3.5 MeV. Foils were also exposed in vacuum to 5.49 MeV alpha particles to investigate the effect of particle energy on angle of detection. In the first part of the experiment, chemical etching of the plastic foils of CR-39 irradiated with both 3.5 and 5.49 MeV alpha particles at various incident angles was carried out with 6M NaOH at 70 °C for 5 h. This experiment enabled us to find out the actual number of alpha particles recorded and their minimum angle of detection. The etching temperature was kept constant using a Haake constant-temperature bath.

In the second part of the experiment, a set of irradiated samples was electrochemically etched with a mixture of 6M NaOH and alcohal having ratio 4 : 1 (V/V) at 30 °C using the ECE cell described elsewhere [8,9]. To investigate the effect of field strength, ECE was carried out under various ac field strengths of 16, 20, 24 and 28 kV/cm at optimum frequency of 2 kHz for 4.5 h.

From the results of ECE alone, it is inferred that chemical etching known as pre-etching is essential before ECE to find the correct value of field strength

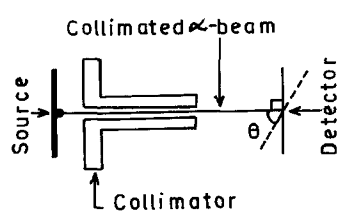

Fig. 1. Sketch showing incident angle of alpha particle beam with detector surface.

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adequate for "tree" initiation. Therefore, a different set of foils irradiated with 3.5 MeV alphas with an incident angle of 25° was pre-etched with 6M NaOH at 70°C for 1, 2 and 3 h, respectively. Tracks were counted to find the effect of pre-etching time on track density. The optimum pre-etching time of 2 h was selected for further investigations. The samples thus pre-etched were electrochemically etched under various ac field strengths ranging from 2 to 20 kV/cm at a fixed frequency of 2 kHz. The track densities were determined by counting the revealed tracks in both the techniques using a Carl Zeiss Binocular microscope.

3. Results and discussion

Chemical etching results of alpha irradiated CR-39 are given in table 1. The results show that chemical etching did not reveal alpha tracks in CR-39 with a dip angle $\leqslant 20°$ (table 1). We did not find any change in the results when the experiment was performed using 3.5 MeV alphas, in air or 5.49 MeV alphas, in vacuum.

Table 1 shows the results at various field strengths required to initiate "treeing" of alpha tracks incident at a variety of dip angles. It is evident from the results that track revelation and treeing did not take place for alpha particles having a dip angle of 25°, even under a field strength of 28 kV/cm. On the contrary, due to high electric field strength, the background was increased to a large extent. As ac field strength of 16 kV/cm, ECE did not reveal tracks having dip angles of 25°, 30° or 45°. A field strength of 14 kV/cm was found to be insufficient to reveal even those tracks that are aligned parallel to the electric field during a prolonged ECE. Unetchability of tracks under these high fields could only mean that tracks are lying deep below the detector surface and the upper surface prohibits the entry of chemical reagent into the tracks. The etchant would only enter the damaged region if the upper layer of the detector is removed by the chemical action of etchant known as pre-etching. However, due to electrophoretic force, the entry of etchant at low electric field strengths takes place for tracks aligned parallel or nearly parallel to the electric field direction.

The ac field strengths required to initiate treeing during ECE of 3.5 MeV alpha tracks having various dip angles, viz. 25°, 30°, 45°, 60°, 75° and 90°, are given in table 1. It is interesting to note that results obtained with CE + ECE very much differ from that of ECE alone. It is evident from the results that the minimum field strength required to initiate treeing for tracks parallel to the electric field is 4 kV/cm. The value of field strength adequate for tree initiation of oblique tracks goes on increasing as the incident angle decreases. The reason for this anomaly is not known at present but it may be attributed to the complex charge distribution at the track tips. It has also been observed that below a threshold field strength, the shape of tracks revealed resembles that of chemically etched tracks.

The track densities revealed separately by chemical etching and ECE are found to be the same for all angles of incidence of alpha beam.

4. Conclusions

1) The minimum angle of detection for 5.49 MeV alphas in CR-39 lies between 20° and 25° when etched chemically.
2) The field strength required to initiate treeing is a function of track orientation in the detector.
3) The threshold value of field strength for ECE followed by pre-etching of tracks having various orientations is 12 kV/cm in CR-39.
4) ECE is as efficient as CE for alpha dosimetry, provided it is followed by pre-etching.

Further investigations are in progress to find the quantitative relationship between the dip angle and

Table 1
ECE response of alpha tracks [a] at various inclinations and electric field strengths and their comparison with chemical etching (CE)

Incident angle of alphas (deg.)	CE	Field strength (kV/cm) 20–28	16	14	12	10	8	6	4	2–3
		ECE	ECE	ECE	CE+ ECE	CE+ ECE	CE+ ECE	CE+ ECE	CE+ ECE	CE+ ECE
90±1	+	+ *	+ *	–	+ *	+ *	+ *	+ *	+ *	+
75±1	+	+ *	+ *	–	+ *	+ *	+ *	+ *	+ *	+
60±1	+	+ *	+ *	–	+ *	+ *	+ *	+	+	+
45±1	+	+ *	–	–	+ *	+ *	+ *	+	+	+
30±1	+	+ *	–	–	+ *	+ *	+	+	+	+
25±1	+	–	–	–	+ *	+	+	+	+	+
20±1	–	–	–	–	–	–	–	–	–	–

[a] + tracks only, + * tracks and "treeing", – no tracks.

field strength which may help to understand the treeing phenomenon.

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