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NRP-9 A STUDY ON ALPHA PARTICLES RANGE IN CR-39

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ABSTRACT

CR-39 plastic nuclear track detector has been used in range determination of alpha particles. A set of experiments was carried out for studying alpha energy and track diameter relationships.

This work was done under the optimum conditions of CR-39 etching in *6.25* N NaOH at 70^0C for various etching times. Determination of alpha range in CR-39 recorders was studied at different energy values using the overetched track profile technique. Data are discussed within the framework of track formation theory in plastic foils, comparison between experimental and theoretical values of alpha range is included.

Key words: CR-39;Plastic detectors; Range.

INTRODUCTION

The increasing advantages of plastic detectors and their applications in radiation dosimetry have grown rapidly. They became more and more useable in light and heavy particles detection and identification. Because of their advantages, many authors (1-8) recommend plastic detectors.

Plastic recorders have many properties such as, the high registration sensitivity of data analysis, successfully using in long term exposure experiments without any additional cost and relatively low background events, CR-39 detector is the most available sensitive one than other plastic detectors which have been used in radiation detection (9-11).

In this work we used NaOH as an etching solution by which we can see tracks under an optical microscope. Track formation in plastic recorders can be studied through the determination of etching velocities (12-13), namely bulk etches rate (V_B) and track etches rate (V_T).

The aim of the present work is to study alpha particle spectroscopy using CR-39 detector. Response function (V) of CR-39 detector and alpha range were deduced.

EXPERIMENT

In this work, sheets of CR-39 plastic detector (TASTRAK) of uniform thickness (300 μm), density 1.31 gm/cm^3 and chemical composition $C_{12} H_{18} O_7$ were used. All recorders were etched chemically in *6.25* N NaOH solution at 70^0C.

CR-39 plastic foils were then exposed to normally incident alpha particles emitted from Am-241 thin source of active diameter 5 mm and activity 3.7×10^{8} Bq. The source was covered by a 100 μ g/cm^2 thin layer gold. For energy degradation a collimator arrangement of 0.5-mm hole diameter was used for adjustment of CR-39 samples.

Track diameter measurements were carried out by using eyepiece screw micrometer (MOB-I-I6x) each division corresponds to 0.24 μm attached to EUROMEX transmission optical microscope with magnification of 640 x.

The etch rate (V_B) has been determined by the weight loss method given by following formula:

$$V_B = \frac{\Delta m}{2A\rho t_e}$$

where Δm is the dissolved mass of the detector during an etching time t_e, A and ρ are the density of the detector material, Respectively.

The alpha range determination:

Alpha range determination has been measured at various energies using the overetched track

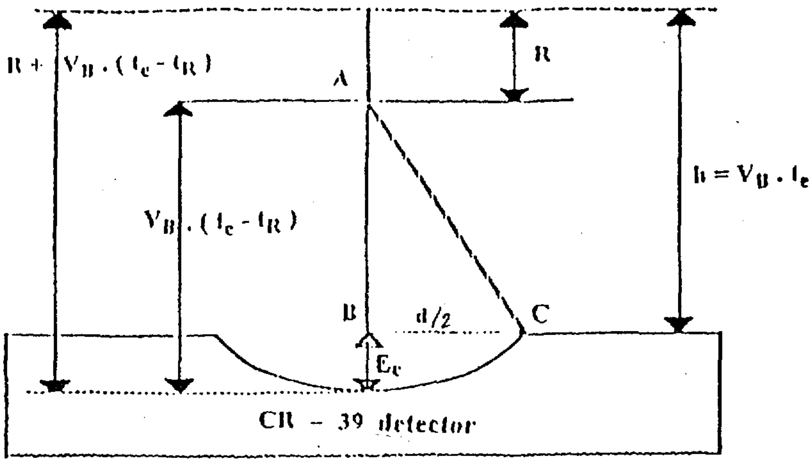

Figure 1: Track profile geometry for etching time t_e>>t_R (overetching stage)

profile method [14].

Figure (1) shows an overetched track where the etching time (t_R) is assumed to etch out thickness R (range) from the plastic recorder where (d) is the formed track diameter.

From the geometry of figure (1) we can write the following relationships:

$$\overline{AC}^2 = \overline{AB}^2 + d^2/4 \qquad (1)$$

where

$$AC = V_B(t_e - t_R) \qquad (2)$$

$$AB = (V_B t_e - R) \qquad (3)$$

Substituting from equations (2) and (3), into equation (1) we get the following relationship:

$$d^2 = 8(V_B R - t_R V_B^2)t_e + 4(V_B^2 t_R^2 - R^2) \qquad (4)$$

It is clear from equation (4) that d^2 exhibits linearity with t_e where $t_e >> t_R$.

The range (R) of alpha particle can be calculated from the slope (S) and the intercept (I) of equation (4) where:

$$SS = 8(V_B R - V_B^2 t_R) \quad \text{and}$$
$$I = 4(V_B^2 t_R^2 - R^2) \tag{5}$$

and finally R is obtained from:

$$R = \frac{S}{16V_B} - \frac{1}{S} V_B \tag{6}$$

RESULTS AND DISCUSSION

The bulk etch rate (VB) of the CR-39 detector was determined using *6.25* NaOH solution at 70^0C and it was found to be equal 1.24 $\mu m/\mathrm{hr}$ [15].

In normal incidence case, the resulted track opening in plastic foils takes the shape of circles whose diameter is strongly dependent on the energy of the incident particles as long as the etching conditions are fixed. Figure (2) shows the variation of track diameter (d) with energy of alpha (E) at different removal thickness layers (h) which indicates that (d) shows an increase with increasing E and it falls down at a certain E values which depend on etching time (t_e).

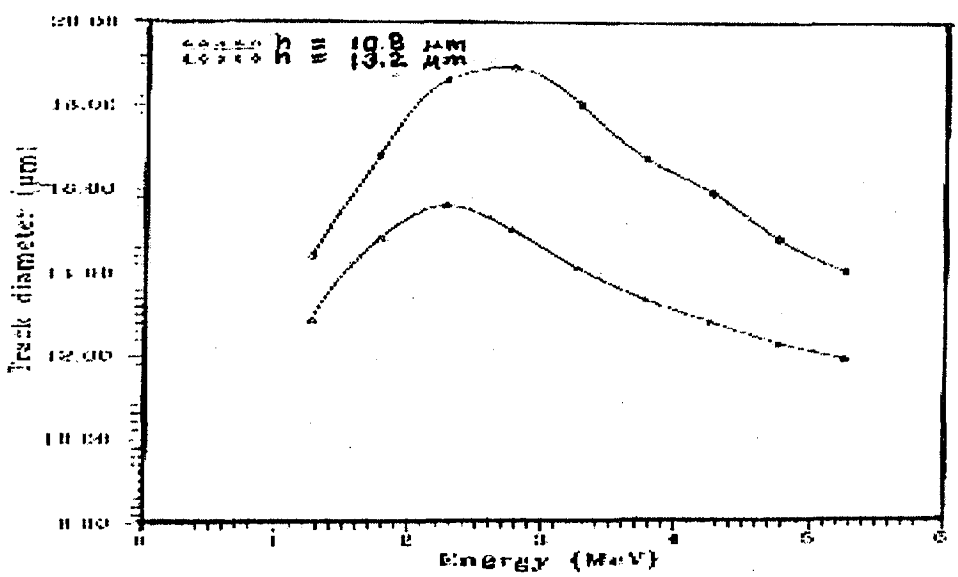

Figure 2: Variation of track diameter as a function of incident Alpha particle energies at different removal thickness layers.

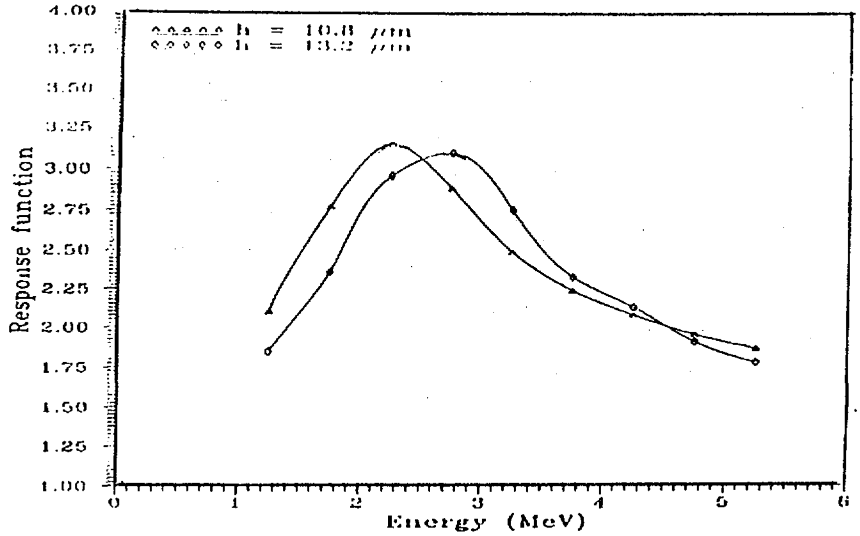

Figure 3: Response function (V) as a function of Alpha energies at different values of removal thickness.

To study the responıse function (V) of CR-39, it is given by;

$$V = \frac{h^2 + r^2}{h^2 - r^2}$$

where h is the removal thickness, r is the track radius.

Figure (3) shows the variation of response function V versus alpha energy at different values of removal thickness (h). It shows that the response function decreases with increasing energy beyond a certain value of energy.

Alpha range determination was obtained from studying track profile in the region beyond the particle range (R). samples of CR-39 detectors were perpendicularly exposed to alpha energies of 1.25, 1 .75, 2.25, 2.75, *3.25, 3.75, 4.25, 4.75* and *5.25* MeV and etched in 6.25 NaOH at 70^0C.

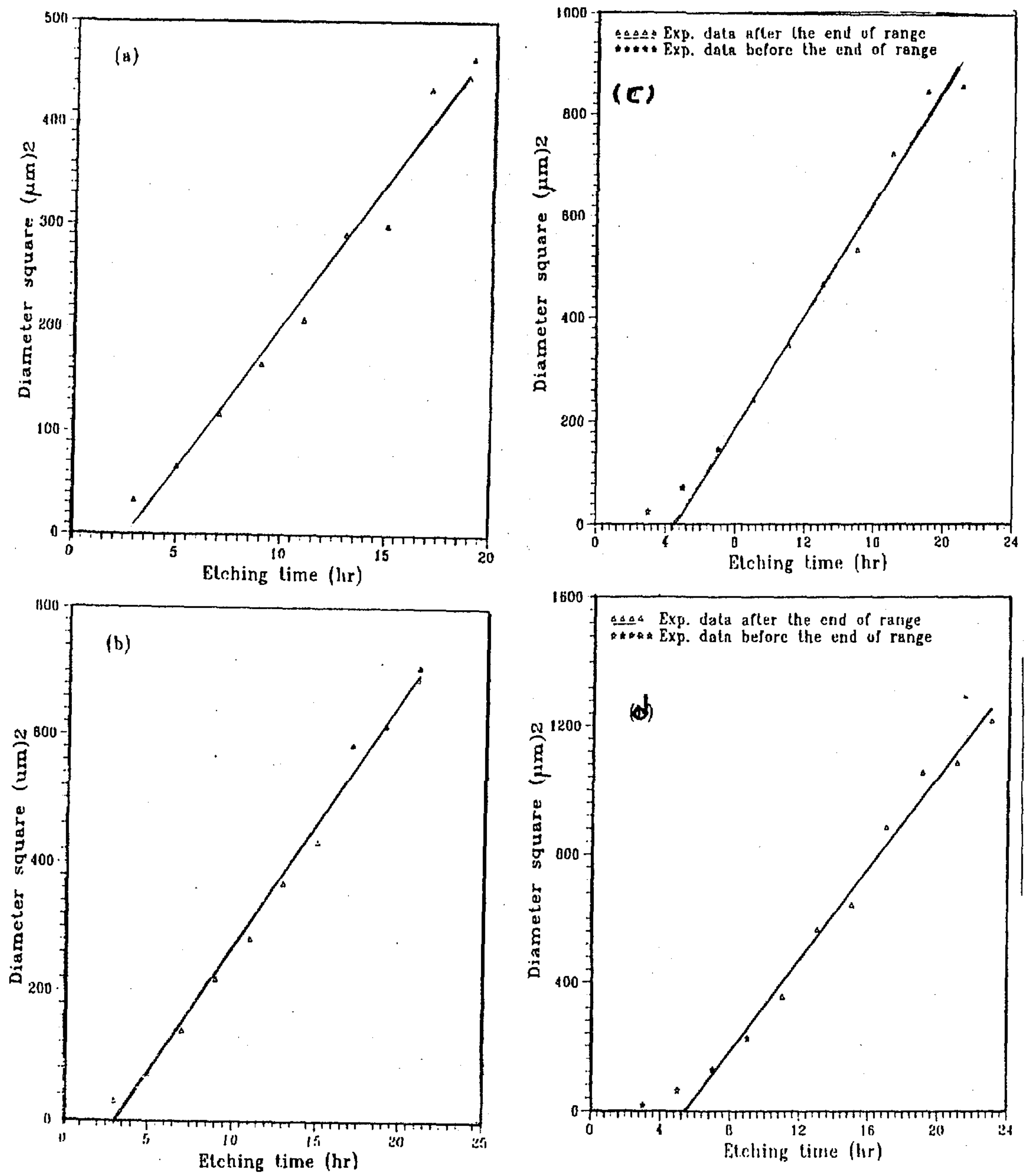

Figure 4: The variation of diameter square (d2) as a function of etching te (hr) at different Alpha particles energies; (a) E=1.25, (b) E=2.25, (c) E=3.25, and (d) E=4.25 all in MeV.

It shows some examples of the relation between' the track diameter square and etching time (t_e) using detectors exposed to the residual energies. Figure (4) shows that the variation of (d^2) with (t_e) is linear beyond a certain time which is bigger than that needed to etch out the whole range of the incident projectile.

By using the least square fit method, the range R can be determined from the slope and the intercept resulting from the straight line part of fig (4). Therefore, one can then use equation (6) for range determination. Figure (5) shows the measured and calculated alpha ranges as a function of alpha energies, it indicates that there is a good agreement between measured calculated values of energy for energies less than 3 MeV. In range from *3-4.25* MeV there is less agreement.

Beyond this value of energy the measured values of alpha ranges are less than the theoretical ones. This behavior may be explained on the basis that in the theoretical evaluation of R the contribution from δ rays is limited i.e. there is a restriction in the energy loss evaluation that is deposited along the track trajectory in the plastic detectors [16].

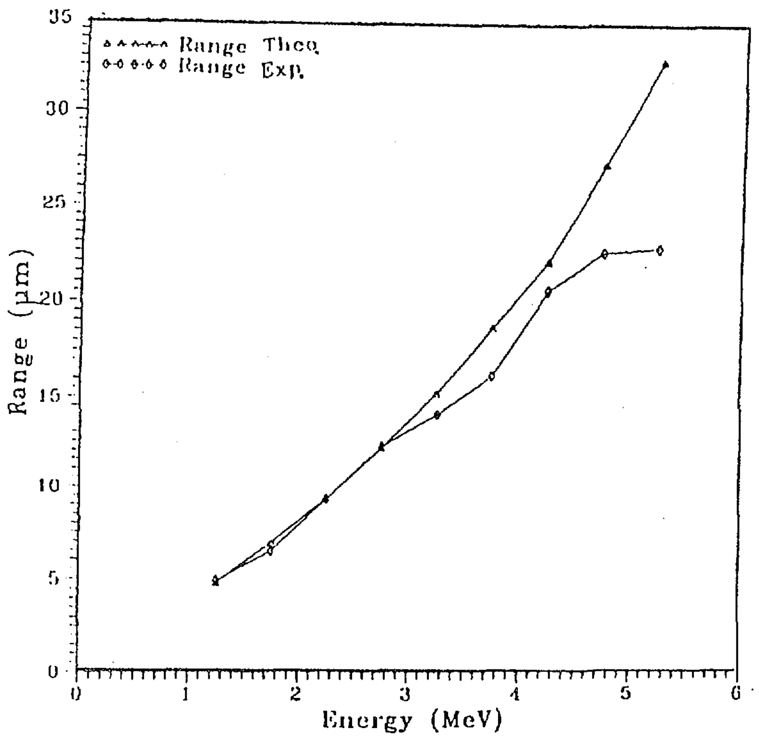

Figure 5: Measured and calculated Alpha ranges as a function a function of Alpha energies.

Generally we can say that the overetched track profile technique is proved to be successfully applicable in range determination.

Figure (6) shows the variation of track diameter (d) with the removal thickness layer (h) for alpha energies *2.25, 3.25* and *5.25* MeV respectively.

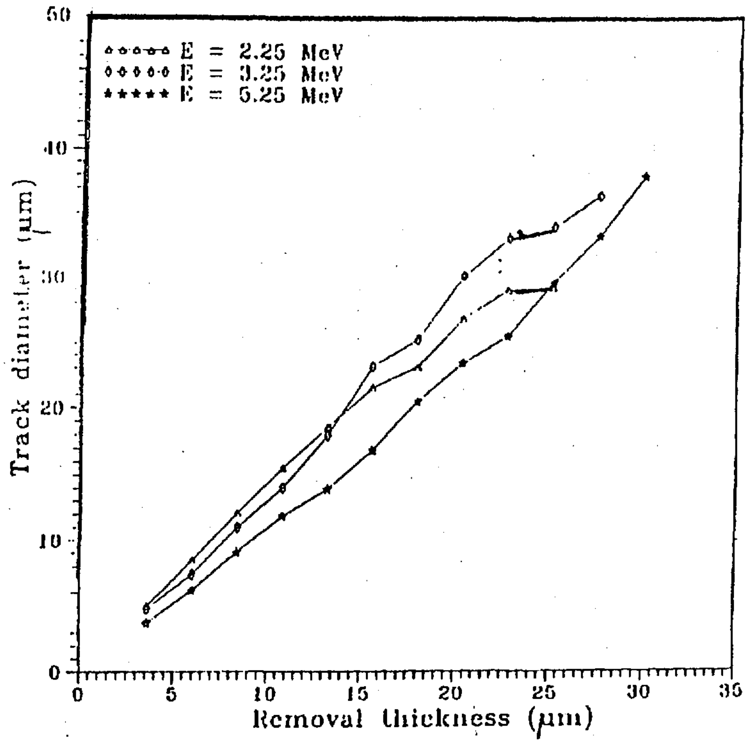

Figure 6: Track diameter (d) versus removal thickness (h) for Alpha energices: E=2.25 and E=5.25 MeV.

CONCLUSION

Range of alpha particles in CR-39 detectors is determined from studying track profile in the region beyond the particle range. When range is; plotted versus alpha energy we find that there is a good agreement between theoretical and experimental values of alpha range for energies less than 3 MeV and little agreement for energies less than *4.25* MeV.

Beyond this value of energy the theoretical values are lower than the calculated ones.

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