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TRACK ETCH RATE CHARACTERISTICS OF MAKROFOL POLYCARBONATE PLASTIC DETECTOR EXPOSED TO XENON IONS

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ABSTRACT

Track etch rate characteristics of makrofol polycarbonate plastic detector exposed to $_{54}Xe^{129}$ heavy ions of 7.5 MeV/n energy at GSI, Darmstadt have been investigated. It is observed that the bulk etching rate, V_b, as well as track etching rate, V_t, by keeping the concentration of the etchant (6.25N NaOH) constant, increase with the increase of etching temperature. Complete etching times have been found to be 32, 15, 9 minutes at etching temperatures of 50°C, 60°C and 65°C, respectively. The activation energies for bulk etching and track etching are determined to be 0.9 eV and 1.38 eV, respectively. The etching efficiency (η) has been found to be independent of the etching temperature. The threshold value of energy loss rate of makrofol polycarbonate has been determined from a semi-empirical relation between V_t, V_b and REL, and has been found to be 4.29 MeV mg^{-1} cm^{-2}. The suitability of single sheet charged particle identification method has been examined. Using this method, makrofol detector has been found to quite suitable for identifying low energy Xe ions.

KEY WORDS

Makrofol polycarbonate plastic detector; $_{54}Xe^{129}$ ions; bulk etching rate; track etching rate; REL; cone length; residual range; solar particles.

INTRODUCTION

During last two decades an extensive amount of effort has been directed towards the utilization of SSNTD s in several diversified research fields including physics, astrophysics, solar particles, geophysics and medicine (Fleischer et al., 1975; Griffith et al., 1983). Radiation damage caused by the passage of a charged particle through an SSNTD can be revealed by chemical etching. The tracks after chemical etching are generally in conical shape. By measuring some cone parameters (Dwivedi and Mukherji, 1979; Henke and Benton, 1971), it is possible to reveal the identity of the charged particle.

The present paper deals with the study of the tracks of $_{54}Xe^{129}$ ion of energy 7.5 MeV/n in makrofol polycarbonate plastic detector. An attempt has also been made to examine the suitability of single sheet identification method to identify the Xe ions in makrofol.

EXPERIMENTAL PROCEDURES

Makrofol polycarbonate sheets were irradiated at angles of 45° and 90° w.r.t. the detector surface with $_{54}Xe^{129}$ ion beam of energy 7.5 MeV/n at GSI, Darmstadt, West Germany. The irradiated samples to Xe ions at 90° were etched in 6.25N NaOH solution at 50°, 60°, 65° and 70°C in a reflux type condenser

assembly. These samples were used to determine bulk etching rate V_b. V_b was determined with two well known techniques, e.g., thickness measurement technique and the cone-diameter technique (Enge, 1975). The samples exposed to Xe ions at 45° were etched at 50°, 60°, and 65°C. These samples were used to determine the cone length, L, (Dwivedi and Mukherji, 1979) and the track etching rate, V_t. The value of V_t (Fleischer et al., 1975) is given by

$$V_t = \frac{\Delta L}{\Delta t} \qquad \ldots \quad (1)$$

where ΔL is change in cone length in etching time Δt. The etching efficiency can be then obtained from the relation

$$\eta = 1 - \sin^{-1} (V_b/V_t) \qquad \ldots \quad (2)$$

The cone diameters were measured under a total magnification of 1000 whereas the cone lengths under a total magnification of 500 or 1000 depending upon the length of the cone.

RESULTS AND DISCUSSION

Variation of cone length versus the etching time is shown in Fig.1. The etching time at which the cone length just attains the saturation value is called the complete etching time (t_c). In the present experiment, the complete etching times at 50°, 60°, and 6° 65°C are 32, 15 and 9 minutes, respectively. From Figs. 2 and 3, it is observed that with constant concentration (6.25N NaOH) of the etchant both V_b and V_t increase with the increase of etching temperature.,T. This is also obvious from Table 1. It can be seen from this table that the etching efficiency, η, increases only by 2.5 as the etching temperature is raised from 50° to 65°C. Therefore, the etching efficiency is almost independent of the etching temperature for Xe ions hitting the detector surface at 45°. From Figs. 2 and 3, it is also clear that both V_b and V_t may be represented by an exponential relation

$$V_b \text{ or } V_t = A\, e^{-E/kT} \qquad \ldots \quad (3)$$

where A is a constant, k is Boltzmann's constant, T is the etching temperature (°K) and E is the activation energy. The values of activation energies for V_b and V_t from Figs. 2 and 3, have been found to be 0.9 eV and 1.38 eV, respectively.

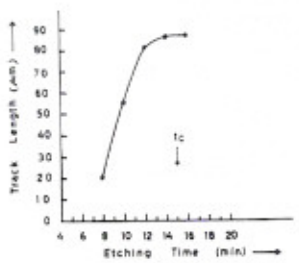

Fig.1 Variation of cone length with etching time at 60°C.

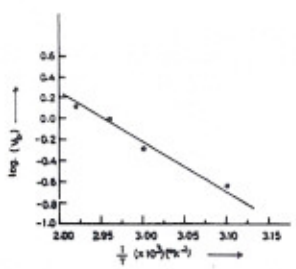

Fig.2 Variation of $\log_{10} V_b$ as a function of $(10^3/T)/°K$.

For plastics, a polynomial dependence between V_t and REL (restricted energy loss) has been proposed by several investigators (Tripier and Debeauvais, 1977; Enge, 1980; Farid and Sharma, 1984). For makrofol detector, if we also

include the V_b dependence, the polynomial becomes

$$V_t = a\, V_b\, (REL)^c \qquad \ldots \quad (4)$$

where V_t is in μm/min. and REL is in MeV mg^{-1} cm^{-2}. In the present investigation we have used $a = 2.44 \times 10^{-2}$ and $c = 2.55$. A plot between V_t and REL is drawn in Fig. 4, when the etching was done at 60°C. Also displayed in this plot are experimental points of Tripier and Debeauvais (1977) for Ar^{40}, Fe^{56}, Cu^{63}, Kr^{84} and I^{127} ions for makrofol detector etched at 60°C. The critical value of $(REL)_c$ at which V_t equals V_b has been found to be 4.29 MeV mg^{-1} cm^{-2}. This value of $(REL)_c$ agrees very well with the values determined by Fleischer et al. (1965) and Farid and Sharma (1984) for Lexan detector.

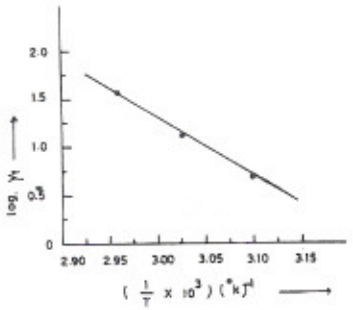

Fig.3 Variation of $\log_{10} V_t$ as a function of $(\frac{1}{T} \times 10^3)/°K$.

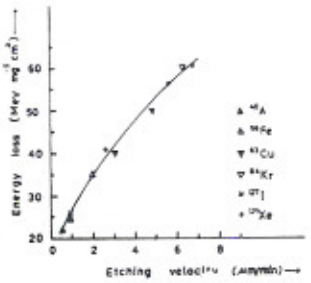

Fig.4 Variation of energy loss with track etch rate at 60°C.

TABLE 1 Bulk etching rate, track etching rate and efficiency at different temperatures.

Etching temp. (°C)	V_b (um/min)	V_t (um/min.)	η
50	0.004	4.26	0.946
60	0.008	12.80	0.964
65	0.017	22.69	0.971

Dwivedi and Mukherji (1979) have given an empirical co-relation of the type

$$(REL)_c = 25.5(\rho - 1)/\rho \qquad \ldots \quad (5)$$

where REL is in MeV mg^{-1} cm^{-2} and ρ is the density of a given SSNTD in gm/cm^3. The value of ρ for makrofol was determined to be 1.2 gm/cm^3. Hence the value of $(REL)_c$ calculated from Eq.(5) is 4.25 MeV $mg^{-1}cm^{-2}$. This value of $(REL)_c$ is nearly the same as obtained from polynomial dependence of V_t, V_b and REL.

The single sheet identification method is of immense use to identify the low energy solar particles (Stern and Price, 1972). We have used this method to

identify Xe ions of energy 7.5 MeV/n in makrofol plastic detector. To test the method a graph between cone length, L, and residual range (RR) was made (Fig.5). Clustering of the points on a single curve clearly indicates the suitability of the method. Very small spread of the points is a measure of good charge resolution obtained with makrofol detector. Thus, we conclude that this detector is capable of identifying the low energy ions having charges at least upto Z = 54, using single sheet identification method.

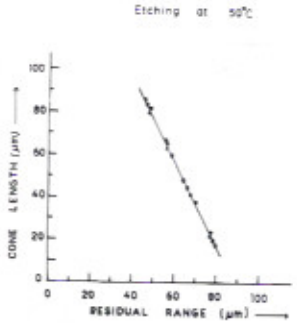

Fig.5 Cone length versus residual range plot.

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