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ETCHING STUDIES OF CR-39 PLASTIC TRACK RECORDER

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Abstract - The etching studies are carried out in CR-39 plastic track recorder. The bulk etch rate V_B, the track etch rate V_T, and etching efficiency η, are determined at the temperatures of 65, 70, 75 and 80^oC using 6.25N NaOH as the track etchant. The activation energies for bulk and track etching are determined. The new track etchant $Ba(OH)_2 \cdot 8H_2O$, proposed earlier in this laboratory for Lexan[1], is tested for CR-39. The etching parameters measured using this new etchant are compared with NaOH and $LiOH.H_2O$ etchants. It is found that etching rates are higher with $Ba(OH)_2 \cdot 8H_2O$ as compared with these etchants.

1. INTRODUCTION

CR-39 plastic has a unique sensitivity which promises many novel applications in connection with both the heavy and light particle detection. So the knowledge on track recording behaviour is very promising[2-3].

It is a common experience that hydroxides of alkali metals (group 1) viz. Li, Na and K are capable of etching nuclear tracks in plastics[4]. When low concentration of these metal hydroxides are employed, the time needed to reveal tracks is quite large, as such the etch-induction time becomes quite appreciable. In the present investigations we have tried $Ba(OH)_2 \cdot 8H_2O$, the metal hydroxide of group II as the track etchant and obtained good results with low etch-induction time for CR-39.

The effect of temperature and concentration on the etching parameters of CR-39 plastic using NaOH as the etchant is also reported.

2. THE EFFECT OF ETCHANT TEMPERATURE

CR-39 samples exposed to a Cf^{252} source in 2π geometry were etched in 6.25N NaOH at four temperatures; viz. 65, 70, 75 and 80^oC respectively. At each temperature the successive etching was carried out. After each etching interval the projected track length due to fission-fragments was recorded. For the track diameter measurements we have chosen only those tracks which correspond to almost normally incident particles in a certain specified area and their average was taken. For the track-length measurements, only those tracks were chosen which correspond to obliquely incident particles (having low incidence angle and thus maximum projected length).

The variation of average track diameter of fission-fragments with etching time at different temperatures is plotted in Fig.1. This shows that the bulk-etch response of CR-39 is linear (upto a depth of 25 μm). The bulk etch rate V_B, was calculated using the thickness measurement technique, and the track etch rate V_T, from the linear portion of curves drawn between the average projected track length vs etching time (Fig.2), assuming that V_T remains constant for very small etching time, during which a small segment of particle trajectory is etched out[5].

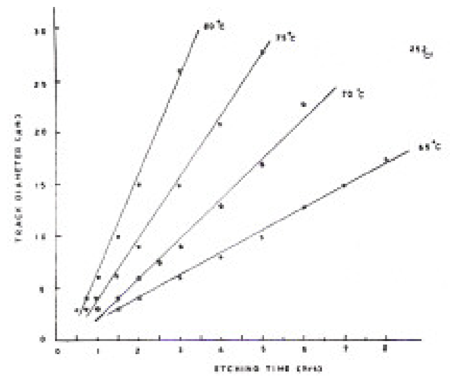

Fig.1 Track diameter vs etching time at different temperatures.

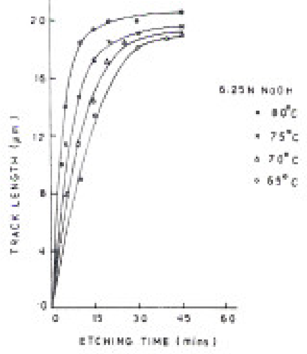

Fig.2 Projected track length vs etching time at different temperatures.

The values of V_T, V_B and η are reported in Table 1.

Table 1. The values of V_T, V_B and η at different temperatures.

Temp. (°C)	V_T (µm/hr)	V_B (µm/hr)	η (%)
65	60	0.890	98.52
70	96	1.519	98.42
75	135	2.243	98.34
80	165	3.550	97.85

V_T and V_B are found to increase with the temperature, however η decreases.

The activation energy for bulk-etching E_B, was calculated from the plot of $\ln V_B$ vs $10^3/T$ (Fig.3), using the relation:

$$V_B = A\ e^{-E_B/kT}$$

The value of $E_B = 0.92$ eV determined here agrees with the already reported value[6] (0.88 ± 0.04 eV). From the slope of the plot of $\ln V_T$ vs $10^3/T$ (Fig.3), the value of activation energy for track etching E_T, is found to be 0.68eV.

3. THE EFFECT OF ETCHANT CONCENTRATION

For this study the etching of CR-39 was carried out with 6.25, 2.5 and 1N NaOH at 75°C. The results for the variation of V_T and V_B (with the concentration of the etchant are reported in Table 2.

Table 2. The values of V_B, V_T and η for CR-39 plastic detector using different concentration of NaOH at 75°C.

Concentration	V_T (µm/hr)	V_B (µm/hr)	η (%)
1.00N	22	0.180	99.18
2.50N	40	0.576	98.56
6.25N	135	2.243	98.34

The dependence of bulk etch rate V_B, on the concentration C, of the etchant at a temperature T, is given as[6]:

$$V_B = f_B\, C^{n_B} \exp\,(\,-\,E_B/kT)$$

The value of n_B calculated from the plot of $\ln V_B$ vs ln C (Fig.4), is found to be 1.38. Similarly for track etching process the value of n_T, calculated from the plot of $\ln V_T$ vs ln C (Fig.4), is found to be 0.99. This shows an almost linear dependence of V_B and V_T on the concentration of the etchant. The variation in track diameter with the concentration of NaOH is plotted in Fig.5.

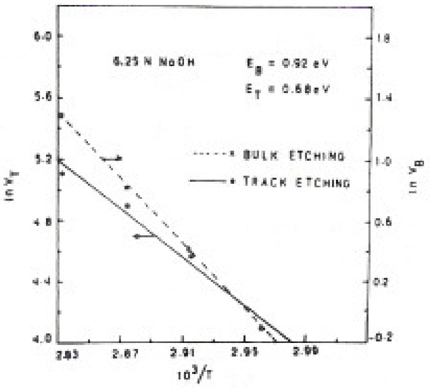

Fig.3. Plot of $\ln V_B$, $\ln V_T$ vs 1/T.

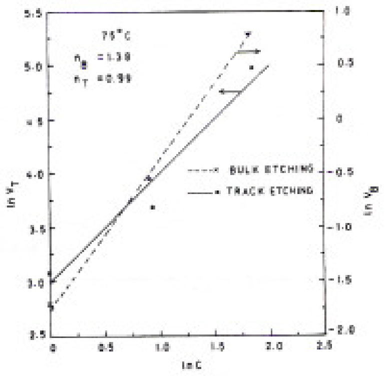

Fig.4. Plot of $\ln V_B$, $\ln V_T$ vs ln C.

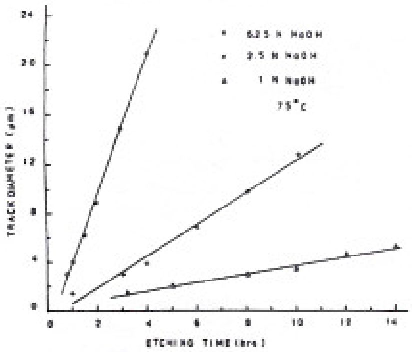

Fig.5. Track diameter vs etching time for different concentrations of NaOH.

4. RESPONSE OF CR-39 TO DIFFERENT ETCHANTS

In order to observe the applicability of the new track etchant viz. $Ba(OH)_2 \cdot 8H_2O$ for CR-39 plastic, etching was carried out using 1N concentration of this etchant at 75°C. For comparison the etching was also carried out with NaOH and $LiOH \cdot H_2O$ etchants, under the same temperature and concentration conditions.

A variation in track diameter and track length due to fission fragments with etching time for these etchants is plotted in Figs.6 and 7 respectively. With $Ba(OH)_2 \cdot 8H_2O$ the tracks were revealed within 25 mins. of etching at a magnification of 1000X whereas the corresponding time for track revelation with the other two etchants was about 1 hr. in each case. On extraploting the curves an etch-induction time of 15, 25 and 30 mins. is found with $Ba(OH)_2 \cdot 8H_2O$, $LiOH \cdot H_2O$ and NaOH respectively. The values of V_T, V_B and η for these etchants are reported in Table 3.

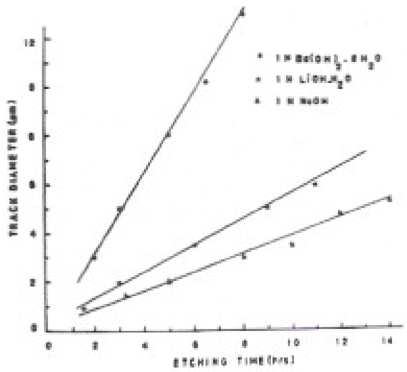

Fig.6. Track diameter vs etching time for different etchants.

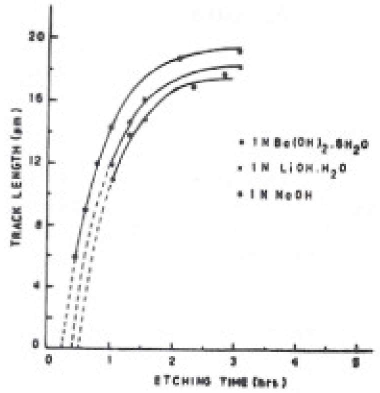

Fig.7. Projected track length vs etching time for different etchants.

Table 3. The values of V_T, V_B and η with different etchants at 75°C.

Etchant	V_T (μm/hr)	V_B (μm/hr)	η (%)
1N $Ba(OH)_2 . 8H_2O$	30	0.81	97.28
1N $LiOH. H_2O$	24	0.28	98.83
1N NaOH	22	0.18	99.18

From the results it is evident that the etching rate of CR-39 is faster with $Ba(OH)_2 . 8H_2O$ as compared to $LiOH. H_2O$ and NaOH, however the etching efficiency is nearly the same for all these etchants.

5. CONCLUSIONS

V_B and V_T increase with the temperature and concentration of the etchant, however the etching efficiency shows a reverse behaviour. The etching rates are higher with $Ba(OH)2. 8H_2O$ as compared to $LiOH. H_2O$ and NaOH etchants. As such the new track etchant is the best one when low concentrations are to be employed.

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