ON THE TEMPERATURE DEPENDENCE OF SENSITIVITY OF CR-39 PLASTIC TRACK DETECTOR

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SUMMARY: CR-39 plastic track detector has been irradiated with different ions from the cyclotron at JINR, Dubna (USSR) in order to investigate the sensitivity of this detector. Etching in 6N NaOH Solution is carried out at temperatures of 40°, 50°, 60° and 70°C. The measurements are taken with an 'Olympus' microscope. The bulk etch rate, Vb and track etch rate, Vt are measured for different temperatures and hence the activation energies are determined. We also present Vt versus range, R and Vt as a function of energy-loss, dE/dx of the ions. It is observed that both Vt and V = Vt/Vb depend on dE/dx as well as on etch bath temperature. The results indicate the absence of a well-defined threshold in the detector. The sensitivity (V vs Z) of the detector can be adjusted by altering the etch bath temperature.

Key Words: Track detector, activation energy.

INTRODUCTION
The etch ratio, V=Vt/Vb as a function of Z of the ions indicates the sensitivity of solid State Nuclear Track Detectors (SSNTDs) (1,2). CR-39 is now widely used because of its high sensitivity (5,7). The dependence of sensitivity on etching temperature is very important for particle identification with SSNTDs. The aim of the present study is to show the dependence of sensitivity of CR-39 detector on etching temperature. The variation of Vt and V along the trajectory of the particle is shown for different temperatures. The dependence of Vt and V on the energy-loss, dE/dx and on the etching temperature is also studied.

EXPERIMENTAL PROCEDURE
The samples of CR-39 obtained from Pershore Moulding Ltd (England) have been exposed to different ions from Cyclotron beams a JINR, Dubna (USSR). The exposure conditions are given in Table 1. The irradiated samples are etched in stirred NaOH (6.00 ± 0.05) N solution. Four different etch temperatures, namely 40°, 50°, 60°, and 70°C have been employed. The stability of etching temperature is ± 0.5°C. The measurements are taken with an 'Olympus' microscope having an eyepiece micrometer of least count L.C. = 0.215 µm at magnification 900x. In all figures the accuracy of the measurements is better than the size of the symbols used, unless the error bars are specially shown.

RESULTS AND DISCUSSIONS
Effect of temperature on bulk etch rate Vb
The measurement of bulk etch rate, Vb and its dependence on etching temperature were reported in our earlier papers (3-5). The plot of ln Vb vs 1/T was found to be a straight line. This can be expressed by a relation of the form.

\[ V_b = A \exp \left( -\frac{E_b}{KT} \right) \]

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\[ V_t = B \exp \left(-\frac{E_a}{K T}\right) \]

where \( B \) is a constant, \( K \) is the Boltzmann's constant, \( E_a \) is the activation energy for track etching and \( T \) is the etching temperature in absolute scale. From the slope of the straight line, the value of \( E_a \) was calculated to be \( E_a = (0.75 \pm 0.03) \) eV which agrees well with the value reported by other workers (7).

**Effect of temperature on track etch rate, \( V_t \)**

Detector samples exposed to different ions are etched in 6N NaOH Solution at a particular temperature. Following the procedure discussed in earlier papers (5,6), the track etch rate, \( V_t \) at different points on the track, is determined. The \( V_t \) versus residual range curves for \( ^{12}\text{C} \) ions and \( ^{16}\text{O} \) ions are shown in Figures 1 and 2 respectively for different temperatures. Similar curves are also drawn for \( ^{20}\text{Ne} \) and \( ^{40}\text{Ar} \) ions for different temperatures. But they are not shown here.

From these curves, \( V_t \) corresponding to a particular range (40 µm in this case) of a particular ion is obtained for different temperatures. The dependence of \( V_t \) on etching temperature, \( T \) (in absolute Scale) follows an Arrhenius correlation of the form

\[ \ln V_t = \ln B - \frac{E_a}{K} \left(\frac{1}{T}\right) \]
ions. But this decrease is within the limits of uncertainty of the measurements. The mean value is found to be $E_t = (0.78 \pm 0.03)$ eV. It is noted that $E_{b}$

In Figure 3 data of the excess track etch rate ratio, $(V-1)$ are plotted vs residual range of temperatures. It is observed from Figures 1 and 3 that both $V_t$ and $V = V_t/V_b$ along the particle trajectory depend on the etching temperature. The same conclusion is valid for other ions and hence $V(R)$ curves of these ions are not presented here. The observed flattening of $V$ vs $R$

curves of the highest ranges indicates the absence of a well-defined threshold in the detector under study. Somogyi et al. have made similar remarks after investigating tracks of different ions in plastic detectors.

The 'response Curve.'

We have used the range and stopping power equations of Mukherji and Nayak (9) to calculate the energy-loss, $dE/dx$ of the ions in the detector material. Using these equations a computer program is made and with the help of computer the energy-loss, $dE/dx$ of different ions in CR-39 is computed. From the computer output, the plots of $dE/dx$ vs residual range have been drawn (not
shown) for different ions. The variation of \( V_t \) with residual range is shown in Figures 1 and 2. Combining these figures, the ‘response curves’ (\( dE/dx \) vs \( V_t \)) of CR-39 detector are plotted in Figure 4 for different etching temperatures. The plot of reduced etch rate, \( V/V_b \) vs \( dE/dx \) is also drawn for different temperatures. This is shown in Figure 5. It is observed that both \( V_t \) and \( V \) depend on \( dE/dx \) as well as on etching temperature. Luck (8) also observed similar response with CR-39 plastic detector.

**Dependence of sensitivity on etching temperature**

The theoretical plots of \( dE/dx \) vs residual range for different ions are known. From these curves the residual ranges of different ions corresponding to a particular \( dE/dx \) are determined. The track etch rates, \( V_t \) corresponding to these residual ranges are obtained from Figures 1, 2 and similar figures for different ions. The relationship between \( (V_t/V_b-1) \) and \( Z \) thus determined is shown in Figure 6 for three different etching temperatures. It is evident from the figure that the sensitivity of the CR-39 detector depends strongly on etching temperature. Thus the sensitivity of CR-39 detector can be adjusted by altering the etch bath temperature.

**REFERENCES**


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