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, V_b and track etch rate, V_t are measured for different temperatures and hence the activation energies are determined. We also present V_t versus range, R and V_t as a function of energy-loss, dE/dx of the ions. It is observed that both V_t and $V = V_t/V_b$ depend on dE/dx as well as on etch bath temperature. The results indicate the absence of a well-deined 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, $V=V_t/V_b$ 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 V_t and V along the trajectory of the particle is shown for different temperatures. The dependence of V_t 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 $\pm$ 0.05) N solution. Four different etch temperatures, namely 40°, 50°, 60°, and 70°C have been employed. The stability of etching temperature is $\pm$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.

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RESULTS AND DISCUSSIONS

Effect of temperature on bulk etch rate V_b

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

$$V_b = A \exp (-E_b / KT)$$

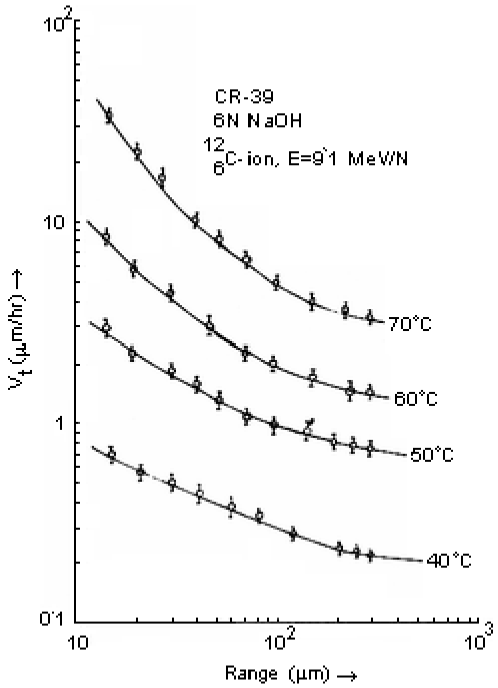

Figure 1: Variation of track etch rate, V_t with residual range of $^{12}_{6}C$ -ions in the CR-39 plastic track detector for different temperatures.

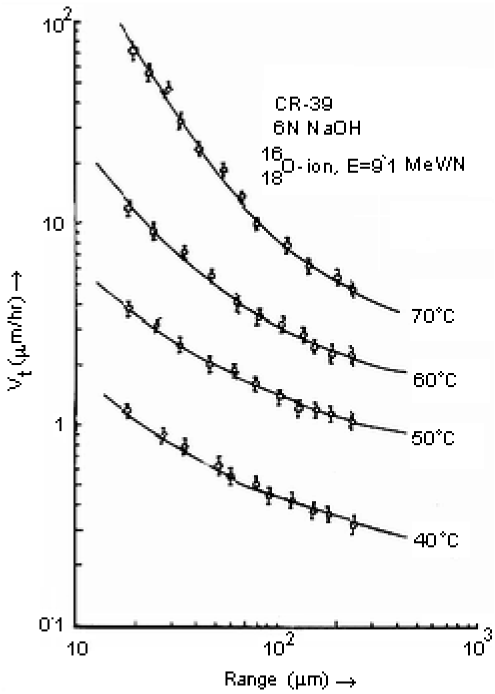

Figure 2: Variation of track etch rate, V_t with residual range of $^{16}_{8}O$ -ions in the CR-39 plastic detector for different temperatures.

where A is a constant, K is the Boltzman's constant, E_b is the activation energy for bulk etching and T is the etching temperature in alsobute scale. From the slope of the straight line, the value of E_b was calculated to be $E_b = (0.75 \pm 0.03)$ 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 $^{12}_{6}C$ – ions and $^{16}_{8}O$-ions are shown in Figures 1 and 2 respectively for different temperatures. Similar curves are also drawn for $^{20}_{10}Ne$ and $^{40}_{18}Ar$-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

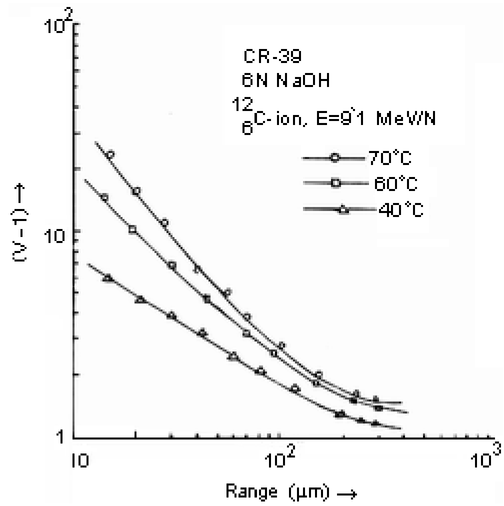

Figure 3: Variation of excess track etch rate, (V-1) with residual range of $^{12}_{6}C$-ion in CR-39 for different temperatures.

$$V_t = B \exp(-E_t / KT)$$

where B is a const, K is the Boltzman's constant and E_t is the activation energy for track etching. The value of E_t is calculated for different ions from the slope of the straight line obtained by plotting ln V_t vs 1/T. The value of E_t is found to decrease with an increasing Z of the bombarding

Table 1: Ions and their enegies used in the study.

Detector	Ion	Energy (MeV/N)	Angle of Exposure (w.r.t. detector surface)
CR-39	$^{12}_{6}C$	9.1	30
$C_{12}H_{18}O_7$ p=1.30 g/cm^3	$^{16}_{8}O$	9.1	30
	$^{20}_{10}Ne$	9.1	30
	$^{40}_{18}Ar$	7.5	30

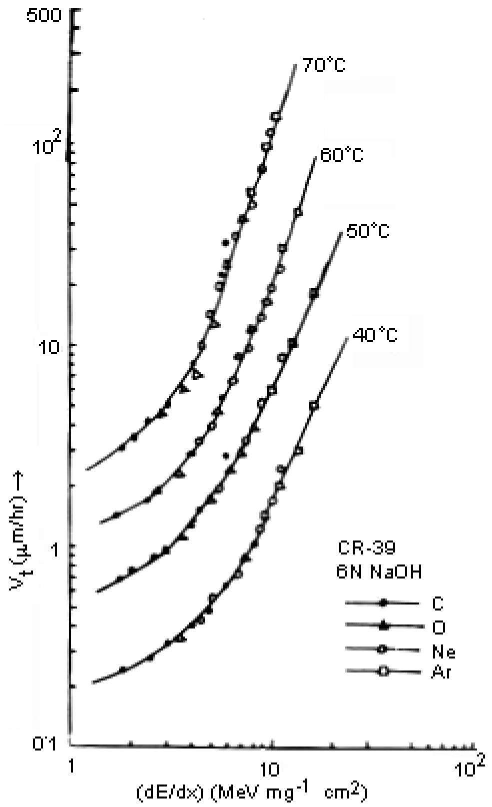

Figure 4: Dependence of track etch rate, V_t on the energy-loss, dE/dx of different ions in CR-39 for different etching temperatures.

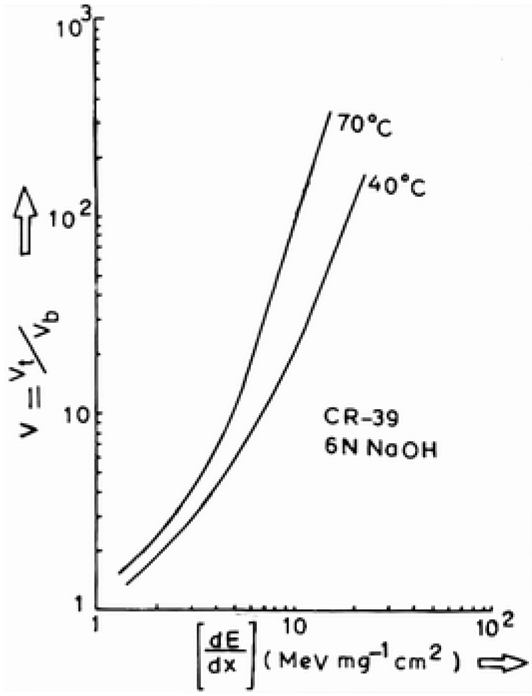

Figure 5: Dependence of reduced etch rate, $V=V_t/V_b$ on the energy-loss, dE/dx of different ions in CR-39 for different etching temperatures.

ions. But this decrease is within the limits of uncertainty of the measurements. The mean valve is fund to be E_t = (0.78±0.03) eV. It is noted that $E_b \simeq E_t$ for CR-39 detector.

In Figure 3 data of the excess track etch rate ratio, (V-1) are plotted vs residual range of $^{12}_{6}C$-ion for different 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

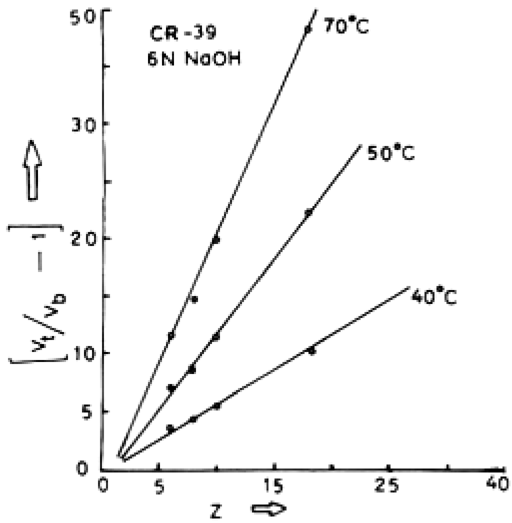

Figure 6: Dependence of sensitivtiy of CR-39 plastic track detector on etching temperatures.

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, $V = V_k/V_b$ 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

1. Fleischer RL, Price PB, Walker RM : Nuclear Trakcs in solids. University of California Press, Berkeley, p 1174, 1975.

2. Fujii M, Nishimura J, Kobayashi T : Improvements in the sensitivity and the etching properties of CR-39 detector. Nucl Instr Meth, 226:496-500, 1984.

3. Farid SM : Track recording properties of CR-39 plastic track detector for accelerated heavy ions. Int J Appl Radiat Isot, 36:451-454, 1985.

4. Farid SM : Response of a Cellulose nitrate plastic track detector. Int J Appl Radiat Isot, 36:463-467, 1985.

5. Farid SM : Determination of ranges of accelerated heavy ions in plastic track detectors. Int J Appl Radiat Isot , 37:111-114, 1986.

6. Farid SM : Determination of Sensitivity of Different plastic track detectors on etching temperature. JIASci, 2:137-146, 1989.

7. Henshaw DL, Amin S, Clapham VM, Fowler P, Webster DJ, Thompson A, Sullivan DO : Study of heavy ion tracks in CR-39 polymer, Proc 11th Intr conf on SSNT DS, Pergamon Press, 116-120, 1981.

8. Luck HB : Response of CR-39 plastic track Detector Rad Eff, 67:141-146, 1982.

9. Mukherji S, Nayak AK : Range, stopping power equations of heavy ions in dielectrics. Nucl Instr Meth, 159:421-429, 1979.

10. Somogyi G, Grabisch K, Scherzer R, Enge W : Ranges of heavy ions in plastic track detector. Nucl Instr Meth, 134:129-137, 1976.

11. Somogyi G : On the threshold of plastic track detectors. Nucl Instr Meth, 173:21-28, 1980.

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