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# Study of $^{40}_{18}Ar$ ion tracks in cellulose nitrate

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**Abstract.** Sample of cellulose nitrate (Russian) is exposed to $^{40}_{18}Ar$ ions. The bulk etch rate has been studied at different etching temperatures and the activation energy for bulk etch rate has been calculated. The etched track lengths are measured for different etching times. The energy loss rate and range of $^{40}_{18}Ar$ ions in CN(R) is also calculated. The critical threshold value for etchable track in CN(R) is determined by comparing the theoretical and experimental values of track length. The response curve of CN(R) is also presented.

**Keywords.** Cellulose nitrate; chemical etching; activation energy; track length; response curve.

## 1. Introduction

In recent years, solid state nuclear track detectors (SSNTDs) have been used increasingly in various branches of science and technology (Fleischer *et al* 1975; Fleischer 1977). Track etching technique has successfully been employed in many insulating materials for revealing the path of charged particles and for their identification. SSNTDs are currently being used in the study of heavy particles, search of super heavy elements, fission fragments studies, cosmic ray studies etc. The cellulose nitrate (Russian) (CN(R)) is one of the most sensitive plastic track detectors available. The various track parameters, which can be measured experimentally, can be used for particle identification.

In this paper the tracks of $^{40}_{18}Ar$ ion of energy 7·5 MeV/N and 4·22 MeV/N at an angle of 10° with respect to detector surface in CN(R) are studied. The bulk etch rate has been measured at different etching temperatures and the activation energy for bulk etch rate is calculated. We have also measured the track etch rate $V_t$ and the range of this ion in CN(R). We have calculated the total energy loss $\mathrm{d}E/\mathrm{d}X$ and range of $^{40}_{18}Ar$ ions in CN(R) using the relations of Mukherji and Nayak (1979) and the value of critical threshold for track etching $(\mathrm{d}E/\mathrm{d}X)_c$ for this plastic has been estimated. The response of this plastic is also studied.

## 2. Experimental details

Samples of CN(R) with composition $C_8H_8O_9N_2$ and thickness 1000$\mu$m were exposed at JINR, Dubna, USSR to $^{40}_{18}Ar$ ions with energies 7·5 MeV/N and 4·22 MeV/N at angles

90° and 10° to the plane of the samples. The exposed samples were etched in stirred 6·25 N sodium hydroxide solution at (60 ± 1)°C. The thickness difference method was preferred for measuring bulk etch rate $V_b$ over the weight-loss method. This was because the latter method is not applicable since water absorption by the plastic (≃ 4% by weight at 70°C, Blandford *et al* 1969) makes it difficult to measure the dissolved weight accurately. We have also measured bulk etch rate $V_b$ by the diameter measurement technique using fission fragment of $^{252}$Cf (Rao *et al* 1981). For $V_t \gg V_b$, the average diameter $D$ of fission fragment is obtained by the relation.

$$D = 2\, V_b\, t, \tag{1}$$

where $V_b$ is the bulk etch rate and $t$ is the etching time.

The etch pit diameter and length were measured with a transmitted light microscope 'Olympus' BH(Japan) having an eyepiece micrometer whose least count = 0·215 $\mu$m at a magnification of 900 $X$. The $V_t$ value was calculated on the assumption that it remains constant for very small etching time during which a small segment of particle trajectory is etched (Fleischer *et al* 1975). The correlation between the $V_t$ and the track length for an etching time $t$, is given by relation

$$L = \int_0^t V_t\, \mathrm{d}t, \tag{2}$$

or

$$V_t = \delta L/\delta t, \tag{3}$$

where $\delta L$ is the small change of track length in small etching time $\delta t$.

## 3. Results and discussion

Figure 1 shows the variation of log $V_b$ against $1/T$, where $T$ is the etching temperature in °K, to find out the activation energy $E_b$ for bulk etching which is found to be

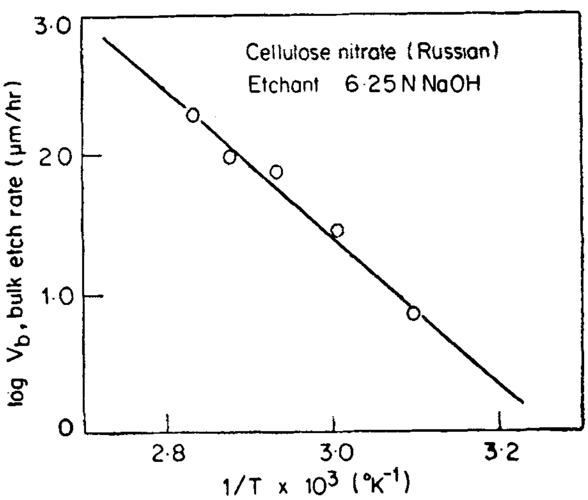


Figure 1. Plot of log $V_b$ vs $1/T \times 10^3$ (°K$^{-1}$).

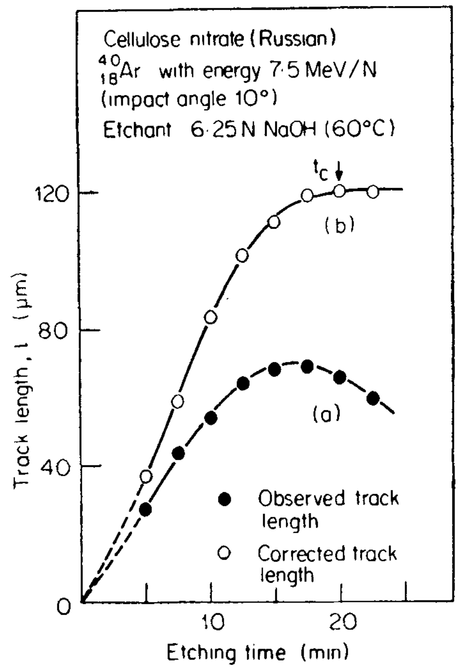


**Figure 2.** Variation of **a** observed track length with etching time; **b** corrected track length with etching time; for $^{40}_{18}$Ar having the energy 7·5 MeV/N at an angle 10°.

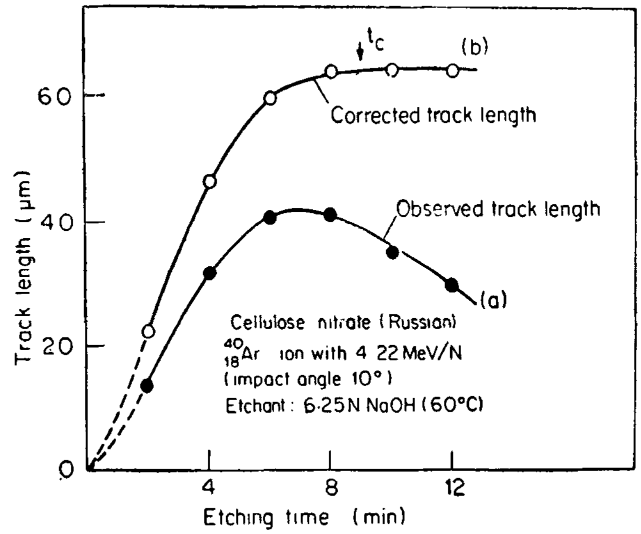


**Figure 3.** Variation of **a** observed track length with etching time; **b** corrected track length with etching time; for $^{40}_{18}$Ar having the energy 4·22 MeV/N at an angle 10°.

(0·86 ± 0·02) eV. Figures 2a and 3a show the variation of observed length of $^{40}_{18}$Ar tracks for energies 7·5 MeV/N and 4·22 MeV/N. It is seen that the observed track length first increases and then starts decreasing after a certain etching time, $t_c$ which is required to etch the tracks completely. The observed track length first increases with etching time due to $V_t$ along the track till the end point is reached. Beyond this point the material is undamaged and is etched at the speed $V_b$. Further etching causes a decrease in the observed track length due to over etching. Figures 2b and 3b show the variation of corrected track length with etching time for both the energies. The corrected track length ($L$) is determined by using the relation

$$L = \frac{l}{\cos\phi} + \frac{V_b\, t}{\sin\phi} - V_b\,(t - t_c), \tag{4}$$

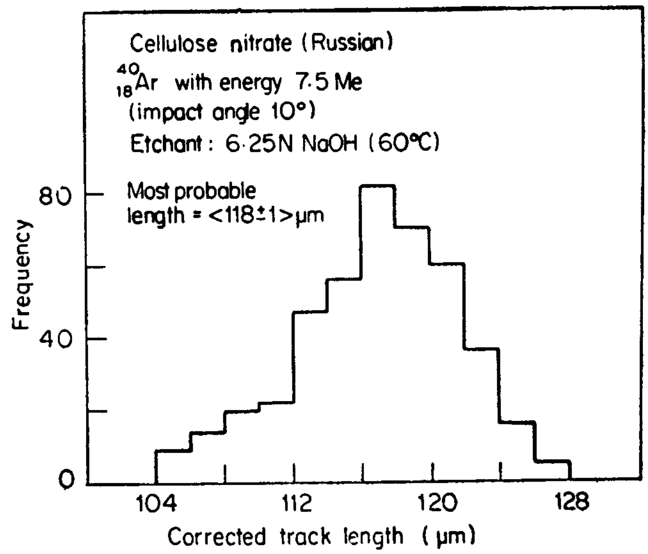


Figure 4. Corrected track length distribution of $^{40}_{18}$Ar ion track having the energy 7·5 MeV/N.

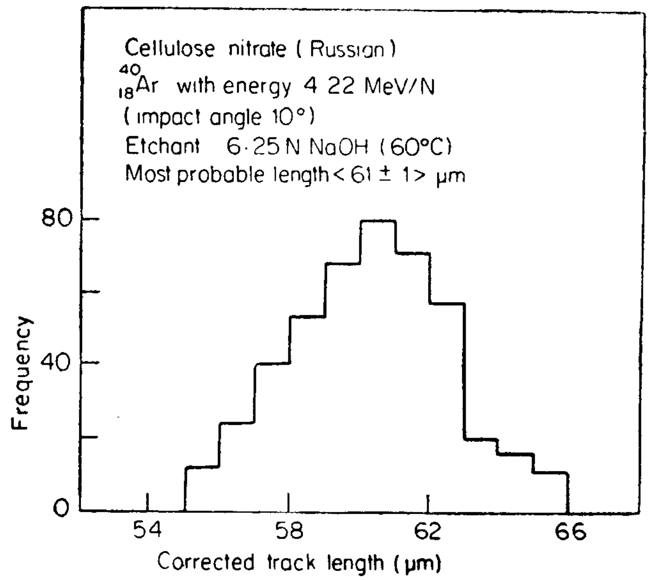


Figure 5. Corrected track length distribution of $^{40}_{18}$Ar ion tracks having the energy 4·22 MeV/N.

where $l$ is the observed length and $\phi$ the angle of incidence to the detector surface. It is clear that the corrected track length first increases and then becomes constant beyond $t_c$.

The corrected track length distribution was observed by plotting the frequency against the corrected track length as shown in figures 4 and 5 for an angle of 10° with energies 7·5 MeV/N and 4·22 MeV/N respectively. From these histograms the most probable track length come out as (118 $\pm$ 1) $\mu$m and (61 $\pm$ 1) $\mu$m for ${}^{40}_{18}Ar$ ions of energy 7·5 MeV/N and 4·22 MeV/N respectively.

Assuming the validity of Bragg's additive rule and using the Mukherji and Nayak (1979) range energy equations, we have calculated the energy loss rate $dE/dX$ and range of ${}^{40}_{18}Ar$ ions in CN(R), using the computer TDC 316. The value of range for this ion is found to be 121·4 $\mu$m and 64·4 $\mu$m for energies 7·5 MeV/N and 4·22 MeV/N respectively.

By comparing the theoretical values of range with the total etchable track length, we have calculated the critical threshold value $(dE/dX)_c$ for CN(R). The $(dE/dX)_c$ value for ${}^{40}_{18}Ar$ comes out to be (3 $\pm$ 1) MeV mg$^{-1}$ cm$^2$.

The $V_t$ values were obtained from the values of corrected track length at different etching times. A plot of the track etch rate versus corresponding energy loss $dE/dX$ in cellulose nitrate (Russian) is shown in figure 6. The $dE/dX$ at which $V_t$ equals the $V_b$ is taken as the cıitical energy loss for etchable track and below this energy loss no ' etchable track ' is produced. From this plot the value of critical energy loss $(dE/dX)_c$ was found to be (2·8 $\pm$ 0·5) MeV mg$^{-1}$ cm$^2$ for ${}^{40}_{18}Ar$ ion tracks in cellulose nitrate (Russian).

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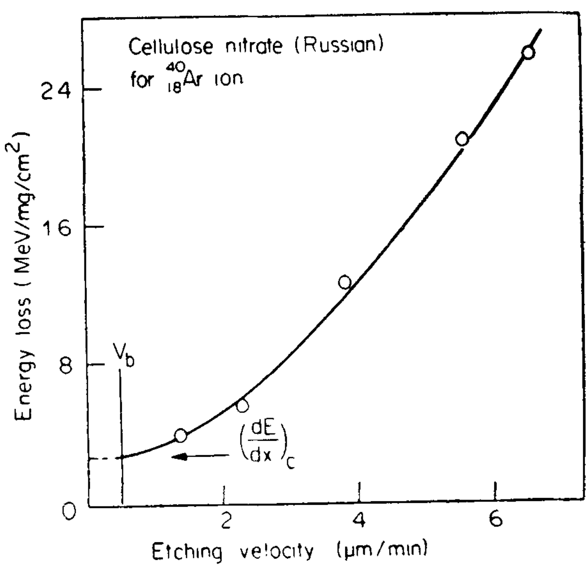


Figure 6. Plot of energy loss vs etching velocity.

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