Pergamon

Radiation Measurements, Vol. 28, Nos 1-6, pp. 177-180, 1997

1350-4487/97 $17.00 + 0.00

PII: S1350-4487(97)00063-2

STUDIES ON THE TRACK FORMATION MECHANISM OF THE HEAVY IONS IN CR-39

ZS. KOCSIS*, K.K. DWIVEDI† AND R. BRANDT‡

*Departement of Physics, University of Veszprem, H-8201 Veszprem, Hungary;
†Departement of Chemistry, North-Eastern Hill University, Shillong 793 003, India; and
‡Kernchemie, FB 14, Philipps Universität, D-35032 Marburg, Germany

ABSTRACT

The bulk etch rate for two types of CR-39 detector was measured as a function of temperature and the activation energies of bulk etching was determined. Experimental values of track etch rate were derived directly from the function of the succesive measured track length vrs. etching time for ^{209}Bi, ^{129}Xe and ^{20}Ne ions.

The maximum etchable track length of 13 MeV/u ^{209}Bi and 13.04 MeV/u ^{129}Xe ions have been measured at and below these energies. A comparison of the measured and calculated track length data is presented.

KEYWORDS

Heavy ion track, CR-39 detector, etching properties, maximum etchable track length.

INTRODUCTION

In several fields of heavy ion research like nuclear reaction, particle identification and related fields the track detectors are employed with good results (Spohr, 1990). These studies require reliable and accurate data of the track registration parameters as bulk and track etch rate, sensitivity and etching efficiency of the detectors and range-energy correlation of heavy ions.
The aim of the present paper was the realisation of the following studies:(i) the measurement of the bulk etch rate for two types of CR-39 detector, (ii) the experimental determination of the track etch rate for several heavy ions and (iii) the experimental determination of the maximum etchable track length for energetic ^{209}Bi and ^{129}Xe ions.

EXPERIMENTS

CR-39 samples having a thickness of 680μm were irradiated at UNILAC, GSI, Darmstadt, with 13 MeV/u ^{209}Bi and 13.04 MeV/u ^{129}Xe ions at an incident angle of 45°. Aluminium foils of different thicknesses (measured with an accuracy of ±1μm) were used to degrade the ion energy.
The irradiated samples were etched in 5M NaOH solution at a temperature of (70±1)°C to develop the tracks.

The bulk etch rate was measured by gravimetric method:

$$v_B = \Delta m / 2A\rho t$$

where Δm is the weight loss (measured with an accuracy of ± 2 μg) for the etching time period t, A is the surface area and ρ is the density of the detector.

The track etch rate was determined directly by successive measuring the track length for etching times increasing with 5 min. intervals. Track length measurement were made using an optical research microscope with an accuracy of 0.25 μm for depth measurement and 1.1 μm for the measurement of projected length at a magnification of 600X.

RESULTS AND DISCUSSION

The bulk etch rate (v_B) for two types of detector (Italian made and Hungarian made CR-39) was determined at four different temperatures 20°,50°,60° and 70°C in 5M NaOH. A part of the data measured was given in a previous work (Kocsis and Brandt, 1993). The variation of ln v_B vrs.1000/T is given in Fig. 1. Activation energies of bulk etching have been obtained from the slope of lines on the basis of least square fit. The activation energy was found 0.72eV for Hungarian made and 0.75eV for italian made detector.

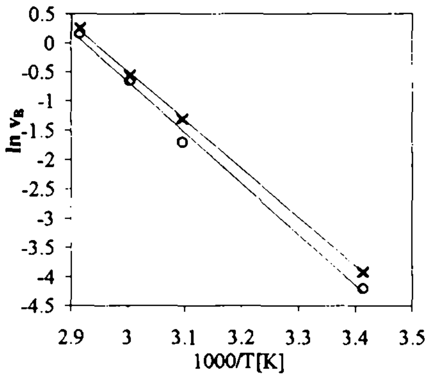

Fig. 1 Variation of bulk etch rate with the etching temperature for Italian made (o) and for hungarian made (×) CR-39 detector.

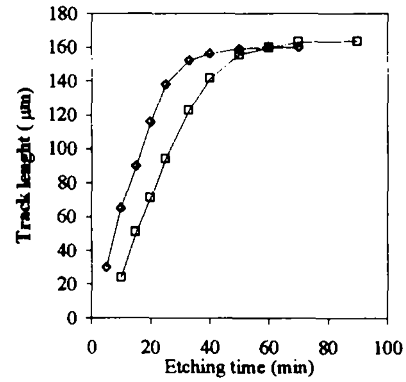

Fig. 2 Etched track length as a function of etching time for ^{209}Bi (◊) and for ^{129}Xe (□) ions in CR-39.

The variation of track length as function of etching time for ^{209}Bi and ^{129}Xe ions is given in Fig. 2. From the slope of linear part of the curve the track etch rate was fitted.The results are given in Table 1. The track etch rate for ^{20}Ne was derived from the measurements of a previous work (Kocsis et al., 1993).

Table 1. Values of track etch rate in CR-39. Etch condition: 5M NaOH 70°C

Ion	Energy (MeV/u)	Track etch rate v_T [μm/h]
^{20}Ne	11.40	44.0±5
^{129}Xe	13.04	234.5±6.5
^{209}Bi	13.00	320.4±7.9

As $(dE/dx)_t$ slightly increases along the track trajectory therefore the increase of v_T is probable with increasing etched track length. However, the etchant penetrates slowlier into the longer tracks. As a result of the two contrasting effects mentioned the curve is nearly linear for a rather large interval.

Experimental values of maximum etchable track lengths at different ion energies for ^{209}Bi and ^{129}Xe ions are given in Fig.3.The line show the theoretical track length data obtained from the computer code Range (Dwivedi, 1988) .The degraded ion energies were calculated from the thickness of aluminium degrader foil using the cumputer code DEDXH (Dwivedi, 1988). The actual track length was determined on the basis of the measurement of the projected track length and the given incident angle of radiation (Dwivedi and Mukherjee, 1979). The track length and the real values of incident angle were also determined directly on the basis of depth measurement of the each track in plastic. In both cases the correction of bulk etching was accomplished.The data of energy, incident angle and maximum etchable track length are given in Table 2.

Table 2. The experimental values of maximum etchable track lengths of ^{209}Bi and ^{129}Xe ions at different energies in CR-39

^{209}Bi		^{129}Xe					
Energy MeV/u	Track length [μm]	Angle of irradiation	E (+) MeV/u	L_{max} (+) [μm]	Measured incident angle	E' (o) MeV/u	L'_{max} (o) [μm]
13.0	160 ±2	30°	13.04	165.5 ±2	30.7° ±1°	13.04	163.1 ±2
10.0	129 ±2	45°	10.62	134.3 ±2	43.5° ±1°	10.45	128.6 ±2
6.6	90 ±3	45°	7.98	97.1 ±2	43.9° ±1°	7.86	95.3 ±2
5.9	81 ±3	45°	4.97	63.8 ±2	46.2° ±1°	5.16	68.5 ±3
1.3	31 ±2	45°	1.92	32.7 ±3	44.5° ±1°	1.83	30.3 ±2
0.5	14 ±2						

Data received using the measured incident angle (o) and the given angle of irradiation (+)

The experimental values are in sufficient agreement with the theoretical ones. Since the calculation of degraded ion energy and of the track length depends on the incident angle, the values of track lengths calculated in these two different ways are slightly different and are shifted along the energy axis, while the deviation of the experimental values from the theoretical are practically invariable.

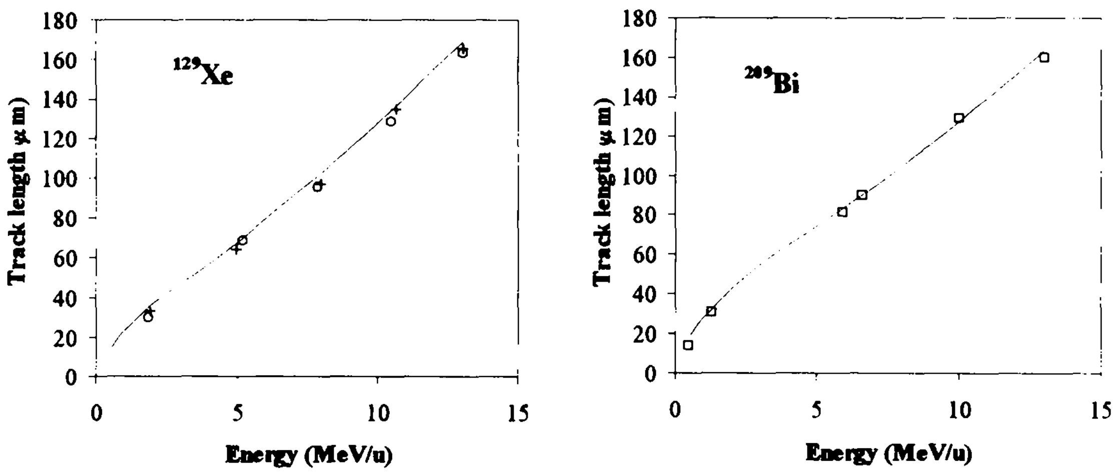

Fig. 3. Experimental and theoretical values of maximum etchable track length as a function of the particle energy received on the basis of the given angle of irradiations (+, □) and received on the basis of measured incident angle (o).

Acknowledgement--We thank Drs. R. Spohr and J. Vetter for their help in the irradiation of the samples at GSI. We are grateful to OTKA (Hungarian Research Foundation) for their support given to Zs. Kocsis.

REFERENCES

Dwivedi, K.K. and S. Mukherjee (1979) Heavy ion track lenghts in solid dielectric track detectors. *Nucl. Instrum. Meth.* **161,** 317-326

Dwivedi, K.K. (1988) A program for calculation of heavy ion ranges , track lenghts and energy-loss rate in elemetal and komplex media. *Nucl. Tracks Radiat. Meas.* **15**, 345-348

Kocsis, Zs. and Brandt, R. (1993) Sensitivity study of hungarian made CR-39 for heavy ion track. *Nucl. Tracks Radiat. Meas.* **22**, 215-216

Kocsis, Zs., K.K. Dwivedi, P. Vater and R. Brandt (1993) Track lenghts of 11.4 MeV/u ^{20}Ne ions in CR-39 *Nucl.Tracks Radiat.Meas.* **22**, 61-62

Spohr, R. (1990) *Ion Tracks and Microtechnology: Principle and Applications.* Vieweg, Braunschweig.