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A STUDY OF ETCHING CONDITIONS AND RESOLUTION POWER OF PLASTIC DETECTOR CR-39

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ABSTRACT

Two Pershore Stacks (32 h cure cycle and 1% DOP and 96 h cure cycle and no additive) have been exposed to the Berkeley Bevalac Argon beam at 285 MeV/nuc and 425 MeV/nuc, respectively. Optimum etching conditions have been found to be 70°C temperature and 18 h etching time in 6.25 N OHNa aqueous solution, corresponding to a mean bulk etch rate $V_B = (1.37 \pm 0.09) \mu\text{m/h}$. The charge and mass resolution power of the detector has been evaluated as $\Delta Z \approx 0.3 e$ and $\Delta A \approx 2 \text{ a.m.u.}$

KEYWORDS

CR-39, Argon, charge and mass resolution power.

INTRODUCTION

Efficient isotope resolution of heavy ions is an old aspiration of the SSNTD cosmic ray research. Our laboratory has devoted a considerable effort to this problem using CN and Lexan (Ortega, 80; Gonzalo, 82; Vidal-Quadras, 82, 83). Much hope was deposited in this respect on CR-39 since its discovery (Cartwright 78). In this paper an evaluation of charge and mass resolution power of CR-39 for Argon is presented and compared to more favourable results in the literature, which are critically discussed.

EXPERIMENTAL METHOD

Two stacks of CR-39 were exposed to an ^{40}Ar beam of 285 MeV/nuc and 425 MeV/nuc, respectively. The first stack (A) consisted of 76 plates, each of size $(50 \times 40 \times 0.6) \text{ mm}^3$, and the second (B) of 108 plates, $(85 \times 40 \times 0.6) \text{ mm}^3$. Both stacks were supplied by Pershore Moulding Ltd. Stack A was manufactured according to a 32 h cycle (Adams, 82) and had a 1% of DOP additive (Tarlé, 81; Price, 82). Stack B was pure CR-39 cured according to a 96 h cure cycle (Fowler, 80). Etching of stack A was carried out in 6.25 N OHNa aqueous solution with 0.05% Dowfax surfactant, at $(40.0 \pm 0.1)^\circ\text{C}$ for 144 h and 20 of the revealed tracks in a scanned area of 6 cm^2 , all stopping in plate 71, were measured with a total of 748 experimental (L,R) points. Bulk etch rate was determined for each plate separately by the direct measurement of its thickness and a great dispersion was observed both in surface and from plate to plate with a mean value $V_B = (0.080 \pm 0.008) \mu\text{m/h}$, with $11 \mu\text{m}$ of removed thickness from each surface. The experimental (L,R) points can be seen in Fig. 1, where the low sensitivity of the material can be appreciated. Between $Z/\beta \approx 30$ and $Z/\beta \approx 90$, etch rate is flat and equal to $V_T \approx 0.15 - 0.20 \mu\text{m/h}$. Only in plate 70 there is some steepness in the L-R curve, showing a response to increasing ionization. Similar conclusions can be reached when examining the behaviour of the ratio V_T/V_B .

Etching of stack B was done at $(70.0 \pm 0.1)^\circ\text{C}$ during 18 h, also in 6.25 OHNa solution, conditions that proved to be optimal. A test was performed at 55°C and also several etching times were tried with 4 h intervals. Total number of measured tracks in a scanned area of 11 cm^2 was 60, 30 stopping in plates 92-94 and 30 in plates 104-108, in order to introduce fragmentation ions

in the spectrum. Total number of experimental (L,R) points was 870. Bulk etch rate was much more uniform in surface and from plate to plate than in stack A and its mean value was $V_B = (1.37 \pm 0.08) \mu\text{m/h}$, with $25 \mu\text{m}$ of removed thickness. The bulk etch rate for 55°C was $V_B = (0.511 \pm 0.05) \mu\text{m/h}$, a third of that at 70°C . The experimental (L,R) points for stack B can be seen in Fig. 2, where the behaviour of the material is much nicer than that in Fig. 1. The steepness of the L-R curve starts to manifest clearly at $Z/\beta \approx 45$.

DETERMINATION OF CHARGE AND MASS RESOLUTION POWER

The information contained in each track has been reduced to a single parameter, its mean residual range $\bar{R}$, and this parameter allows to calibrate the detector obtaining a charge and mass $\bar{R}$ -scale for the region of interest (Siegmund, 78; Gonzalo, 82; Vidal-Quadras, 83). The histogram of $\bar{R}$ -values for stack B is shown in Fig. 3, as well as the superimposed charge scale. Tracks in the peak have been considered to be ^{40}Ar and used as calibration points. The theoretical L-R curves for different charges can be seen in Fig. 2. The fitted values for parameters g and h in the interval $3 \times 10^3 \text{ MeV}\cdot\text{cm}^2/\text{g} \lesssim \text{REL}_{200} \lesssim 6 \times 10^3 \text{ MeV}\cdot\text{cm}^2/\text{g}$ for the relation $V_T = g \text{REL}_{200}^h$ are printed on the L-R plot. Threshold for restricted energy loss REL has been chosen $\omega_0 = 200 \text{ eV}$ (Henshaw, 82). The experimental uncertainty in the determination of $\bar{R}$ for each track is $\Delta\bar{R} \approx 100 \mu\text{m}$ and the comparison between the mass $\bar{R}$ -scale and the uncertainty can be seen in Fig. 4. Charge uncertainty turns to be $\Delta Z \approx 0.3 e$ and mass uncertainty $\Delta A \approx 2 \text{ a.m.u.}$

Fig. 1. Experimental L-R points for stack A. Etch rate is almost flat for a very wide REL interval.

Fig. 2. Experimental L-R points for stack B and theoretical L-R curves for different charges. Steepness of etch rate vs. REL is satisfactory.

Fig. 3. Histogram of experimental $\bar{R}$ -values and superimposed charge scale.

DISCUSSION OF RESULTS

The chosen optimal etching conditions agree with those recommended by other authors (Somogy, 82; Green, 82). No saturation of response of the type reported by Hayashi (82) for Fe ions is observed. The very low sensitivity of the stack A to increasing REL over such a wide interval indicates a problem in the material. The same unsatisfactory results for this particular batch have been observed in other Laboratories (O'Sullivan, 83). The reproducibility of CR-39 response is not yet a closed question and uncontrollable lack of reproducibility and homogeneity over large stacks, so essential for cosmic ray work, seems far to be overcome (Thompson, 80; Somogy, 82). The value of h for the semiempirical relation $V_T = g \text{REL}_{200}^h$ agrees with that reported by Henshaw (81) for a similar REL interval. Charge resolution $\Delta Z \approx 0.3 e$ is consistent with previous measurements in analogous conditions (Thompson, 82), but worse than some other more optimistic predictions (Cartwright, 78) or determinations (Tarlé, 81). In this sense, it must be emphasized the difference between working with a single foil and wedge energy dispersion or with a large stack. As for mass resolution $\Delta A \approx 2 \text{ a.m.u.}$, it is very poor compared to initial expectancies (Cartwright, 78; Cassou, 78) and extremely disappointing compared to Hayashi's promising $\Delta A = 0.4 \text{ a.m.u.}$ (Hayashi, 82). In order to clarify this discrepancy we have applied Hayashi's method to our Argon measured tracks in stack B. The mean standard deviation of cone lengths around the fitting ^{40}Ar curve is 3%, the mean mass deviation is $\bar{C}_M = (1.1 \pm 0.5) \text{ a.m.u.}$, the average of reduced cone number is $\bar{N} = 2.50 \pm 0.31$ and mass resolution turns finally to be $\Delta A = \bar{C}_M / \sqrt{\bar{N}} = (0.68 \pm 0.31) \text{ a.m.u.}$ It is clear that a purely statistical handling of data with no reference to experimental errors in the measurement of cone length and residual range leads to "wishful" estimations of resolution which are unhappily not realistic.

Fig. 4. Comparison between the mass $\bar{R}$ -scale and the experimental uncertainty $\Delta \bar{R}$.
 $\Delta A \approx 2 \text{ a.m.u.}$

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