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CRITICAL ETCHING PARAMETERS OF MICA, LEXAN AND CELLULOSE ACETATE TRACK DETECTORS

K.K. DWIVEDI

Department of Chemistry, North-Eastern Hill University, Shillong-793 003, India.

ABSTRACT

Chemical etching characteristics of mica, Lexan and cellulose acetate have been studied for fission fragment tracks. Under suitable etching conditions a few critical etching parameters for these three track detectors have been determined. An empirical relationship between complete etching time and the etching temperature has been established.

KEYWORDS

Mica; Lexan; cellulose acetate; critical track diameter; complete etching time; critical angle of incidence; fission fragment

INTRODUCTION

The latent damage trails of energetic heavy ions in solid dielectrics are conveniently revealed by a suitable chemical etching process and the optimal use of any track detector is largely dependent on standardization of various etching parameters. The formation of etchable tracks in a track detector depends on certain critical etching parameters which must be experimentally determined under suitable etching conditions. The determination of critical etching parameters is essential for applications of track detectors in diverse fields such as micro-analysis (Chambaudet *et al.*, 1995); particle identification (Majeed *et al.*, 1993); and in determination of the true track length of heavy ions (Dwivedi and Mukherji, 1979; Singh *et al.*, 1988 and Bhattacharyya *et al.*, 1992).

Under a given etching condition, the time required by an etchant to develop damage trails to their maximum length is defined as the complete etching time (t_c). This parameter has to be known for the determination of the true track length of a heavy ion in any track detector from the experimentally observed track length (Dwivedi, 1977 and Dwivedi and Mukherji, 1979). Since it requires a laborious experiment for obtaining t_c at each temperature, an empirical method for calculating t_c would be very useful.

While studying track-etching kinetics it has been observed that for each solid state track detector there exists a critical value of track diameter D_c at which all the fission fragment tracks were found to be etched to their full length. At different temperatures the time t_c, required to enlarge the track diameter to a value D_c have been obtained for mica, Lexan and cellulose acetate. An empirical relationship between the complete etching time t_c and temperature τ has been obtained. From the measured track parameters, the critical angle of incidence for these track detectors have also been determined.

EXPERIMENTAL PROCEDURE

Samples of muscovite mica, Lexan polycarbonate and cellulose acetate were used as track detectors. These were exposed in vacuum to a collimated beam of fission fragments from a ^{252}Cf source. The irradiation time was of the order of 24-36 hours. The angle of incidence was 30°. Mica, Lexan and cellulose acetate were etched in 40% HF, 6.25N NaOH + ethanol (1:1) and 6.25N NaOH respectively. The etching was done successively and in each case the increase in track diameter and projected etched track length with etching time have been measured for different etching temperatures. The experimental errors in measuring the track lengths and diameters were found to be ± 1 μm and ±0.3 μm respectively.

RESULTS AND DISCUSSION

In this experiment, it was observed that the complete etching time (t_c) always corresponds to a critical value of the track diameter (D_c) which is independent of the temperature for a given etchant and dielectric material used for track registration. The values for D_c were found to be 1.5±0.3 μm, 2.0±0.3 μm and 2.5±0.3μm for mica (etched in 40% HF), cellulose acetate (etched in 6.25N NaOH) and Lexan (etched in 6.25N NaOH + ethanol, 1:1) respectively. At different temperatures, the time (t_c) required to develop the track diameter equal to these critical values were determined from the plots of track diameter versus etching time. Table 1 lists the values of t_c and the etching temperature for mica, Lexan and cellulose acetate.

The plots of $\ln(t_c)$ as a function of etching temperature τ (in°C) for mica, Lexan and cellulose acetate track detectors have shown a linear response which can be represented by an expression

$$t_c = A.e^{-\alpha\tau} \tag{1}$$

where t_c is in minutes, A and α are constants for each track detector, and τ is the temperature in °C. Our results have indicated that the values of coefficients α are -0.084, -0.092 and -0.104 for mica, Lexan and cellulose acetate respectively.

Table 1 : Values of complete etching time for fission fragment tracks in mica, Lexan and cellulose acetate etched in suitable etchants at different temperatures.

Mica (40% HF)		Lexan (6.25N NaOH+Ethanol) (1:1)		Cellulose Acetate (6.25N NaOH)	
τ (°C)	t_c (min.)	τ (°C)	t_c (min.)	τ (°C)	t_c (min.)
21	48.0	25	200.0	40	192.0
24	43.2	30	120.0	50	64.0
26	36.0	33	89.0	60	21.3
30	28.8	40	48.0	70	8.0
40	9.8	50	20.0	80	3.4
50	4.8	--	--	--	--

The values of constant A for mica, Lexan and cellulose acetate are listed in Table 2 alongwith the etching conditions and critical diameters. The most probable true track lengths (L) of ^{252}Cf fission fragments in mica, Lexan and cellulose acetate have been measured and found to be 10.7±1.0 μm, 20.4 ± 1.0 μm and 19.3 ± 1.0 μm respectively (Dwivedi and Mukherji, 1979). Using the values of L and D_c for these track detectors the critical angle of incidence (ϕ_c) for mica, Lexan and cellulose acetate were derived and found to be 4°, 3°30' and 3° respectively. These values are within the range of the cone angle θ (0°-5°) for most of the plastic detectors as reported by Fleischer *et al.* (1975).

Table 2 : Values of constants α and A and critical diameter (D_c) alongwith etching conditions for mica, Lexan and cellulose acetate.

SSNTDs	Chemical etchant	Critical diameter	Constants	
		D_c (μm)	α	A(min)
Mica	40% HF	1.5 ± 0.3	-0.084	311.0
Lexan	6.25N NaOH + ethanol (1:1)	2.5 ± 0.3	-0.092	1925.0
Cellulose acetate	6.25N NaOH	2.0 ± 0.3	-0.104	12076.0

CONCLUSION

With the help of equation (1) and the values of constants α and A, one can easily determine the complete etching time (t_c) for fission fragment tracks in mica, Lexan and cellulose acetate at any desired temperature. The concept of critical track diameter and the critical cone angle have been utilized to determine the critical angle of incidence for a track detector.

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