ISOTROPIC ETCHING CHARACTERISTICS OF MAKROFOL-E

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Abstract: In Solid State Nuclear Track Detectors (SSNTDs), passage of individual heavily ionizing charged particles are revealed by selective chemical etching of the radiation damaged material along the particle's trajectory. In the present work, Makrofol-E track detectors were irradiated with ^{58}Ni ions of 11.56 MeV/u energy at UNILAC, GSI, Darmstadt, Germany, to create the latent tracks. Irradiated sample were successively etched in 6N NaOH at three different temperatures 40^{o}C, 55^{o}C and 70^{o}C respectively. Isotropy of the bulk etch rate of the detector is studied using both diameter and thickness measuring techniques. From the measured diameter of the etched nuclear tracks and the thickness loss measurement of the detector, the bulk etch rates (V_G) along and perpendicular to the surface are determined respectively.

Keywords: SSNTDs; Makrofol-E; chemical Etching; track diameter; bulk-etch rate; isotropy

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1. Introduction:

Fast heavy ions can produce latent tracks in some dielectric materials. After adequate treatment, such as chemical or electrochemical etching, these latent tracks can be made visible under the optical microscope. This is the operational principle for solid state nuclear track detectors (SSNTDs). The technique has been extensively investigated in literatures [1-3], and has been widely applied in many fields of science and technology [1-6]. During the etching of heavy ion tracks to the full extent by chemical etchants, a portion of the track near the surface is dissolved out by the etchant, necessitating a correction to the observed track length, the magnitude of which depends on the bulk etch rate [6-8]. In this paper we present our results of bulk etch rate and comment on the isotropic character of Makrofol-E detector.

2. Experimental Technique:

2.1. Sample preparation and irradiation:

Small rectangular pieces of the Makrofol-E (Bisphenol-A-Polycarbonate: $C_{16}H_{14}O_3$, density ~1.14 g/cm^3) detector foils were cut from thin (~405μm) commercially available sheets. The detectors were irradiated with a well collimated beam of 11.56 MeV/u $^{58}Ni^{14+}$ ions (flux ~10^4) at an incident angle of 45^{o} with respect to detector surface. All the irradiations were done at XO-channel of UNILAC, GSI Darmstadt.

2.2. Chemical etching for track development:

The chemical etching of the detectors were carried out in aqueous solution of 6N NaOH at 40^{o}C, 55^{o}C and 70^{o}C in a constant-temperature water bath, having an accuracy ±0.5^{o}C.

Bulk Etch Rate:

Bulk etch rate (V_G) is the speed with which surface material of the detector is dissolved out by an etchant solution. V_G is determined by two different techniques:

2.2.1. Track Diameter Technique:

The increase of track diameter of the developed track with etching time gives a measure of the bulk-etch rate along the surface [6]. If 'D' is the diameter of the track efter etching for a time 't', then

$$V_{G||} = {}^{D}/_{2t} \qquad \text{or} \qquad V_{G||} = R/t$$

where R =$D/2$ is the track radius

2.2.2. Thickness Measurement Technique:

V_G by thickness measuement technique is a measure of etch rate normal to the surface [5]**.** If X_i and X_f are the thickness of the detector before and after etching for an interval of time 't' then V_G for the detector can be calculated from

$$V_{G\perp\perp} = \left({}^{(X_i - X_f)}/_{2t}\right) = \frac{\Delta X}{2t}$$

If V_G along the surface and normal to the surface is same i.e $V_{G||} = V_{G\perp\perp}$ then the detector is considered as isotropic [3,4].

3. Results and discussion:

Table 1 list the diameter of the tracks formed and total surface of detector dissloved when chemically etched with 6 N NaOH at temperatures 40, 55 and 70^{o}C. Figure 1 and 2 show the variation of diameter and surface removed of detector with etching time at different etching temperatures. For etching temperature 40^{o}C the measurable track diameter was obtained only after etching the detector for 6 hours. Bulk etch rate along ($V_{G||}$) and perpendicular ($V_{G\perp}$) to the surface of the detector at these etching temperatures are calculated and are listed in table 2.

Table 1: Diameter of ^{58}Ni ion tracks and Surface Removed for Makrofol-E etched in 6N NaOH with etching time at various etching temperatures.

Etching time t (hr)	**Diameter (µm)**			**Surface Removed (µm)**		
	40^{o}C	**55^{o}C**	**70^{o}C**	**40^{o}C**	**55^{o}C**	**70^{o}C**
0	0.0	0.0	0.0	0.0	0.0	0.0
1.5	-	2.2±0.6	3.8±0.7	2.2±0.9	2.7±1.1	6.0±2.5
2.0	-	2.5±0.5	4.4±0.6	2.6±0.9	3.0±1.0	9.0±2.0
2.5	-	3.2±0.8	5.1±0.6	3.2±0.9	3.8±0.9	10.0±1.5
3.0	-	4.1±0.8	5.7±0.6	3.6±0.9	4.2±0.9	12.1±2.0
3.5	-	4.7±0.6	6.3±0.7	3.9±0.9	5.0±0.9	14.1±2.0
4.0	-	5.2±0.5	7.6±0.6	4.6±0.9	5.8±0.9	15.8±2.0
4.5	-	5.8±0.5	8.5±0.7	5.5±0.9	6.6±1.0	18.0±2.0
5.5	-	6.9±0.6	10.1±0.6	6.3±0.9	7.4±1.0	22.0±2.0
6.5	0.92±0.4	8.2±0.6	11.5±0.5	8.0±0.9	8.2±0.9	26.2±2.0
7.0	0.99±0.4	8.8±0.6	11.8±0.7	8.6±0.9	9.4±0.9	28.3±1.1
8.0	1.13±0.4	10.1±0.6	13.1±0.6	9.8±0.9	10.4±0.9	29.9±1.4
9.0	1.27±0.4	11.3±0.5	14.5±0.5	10.9±0.9	11.8±0.9	31.9±1.0
10.0	1.41±0.4	12.6±0.6	15.5±0.6	11.8±0.9	13.0±0.9	33.7±1.0

*the error indicated is standard deviation

Table 2: Bulk Etch Rate along and perpendicular to the surface of makrofol-E along with etching temperature.

Etching Temperature T (^{o}C)	Bulk Etch Rate (µm/hr)	
	$V_{G\|\|}$	$V_{G\perp}$
40	0.07± 0.004	0.60± 0.04
55	0.63± 0.04	0.67± 0.06
70	0.89± 0.04	1.9± 0.1

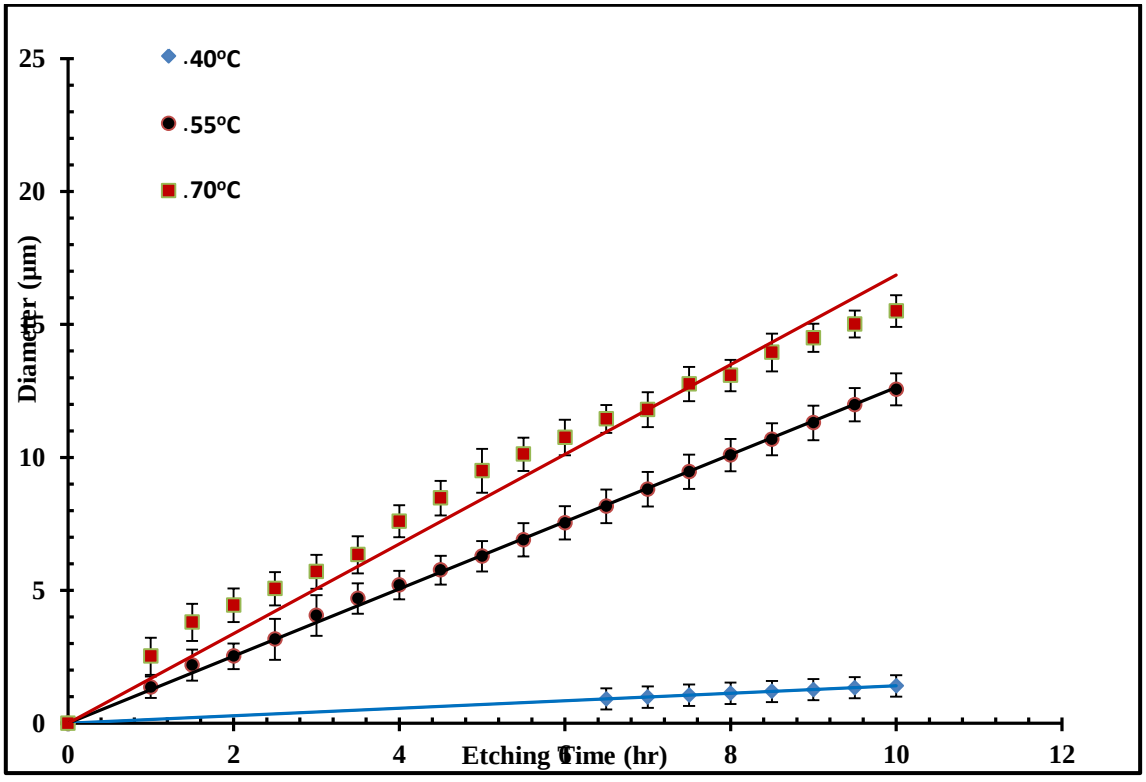

Figure 1: Track Diameter of ^{58}Ni ion in Makrofol-E etched at 40, 55 and 70^{o}C with etching time.

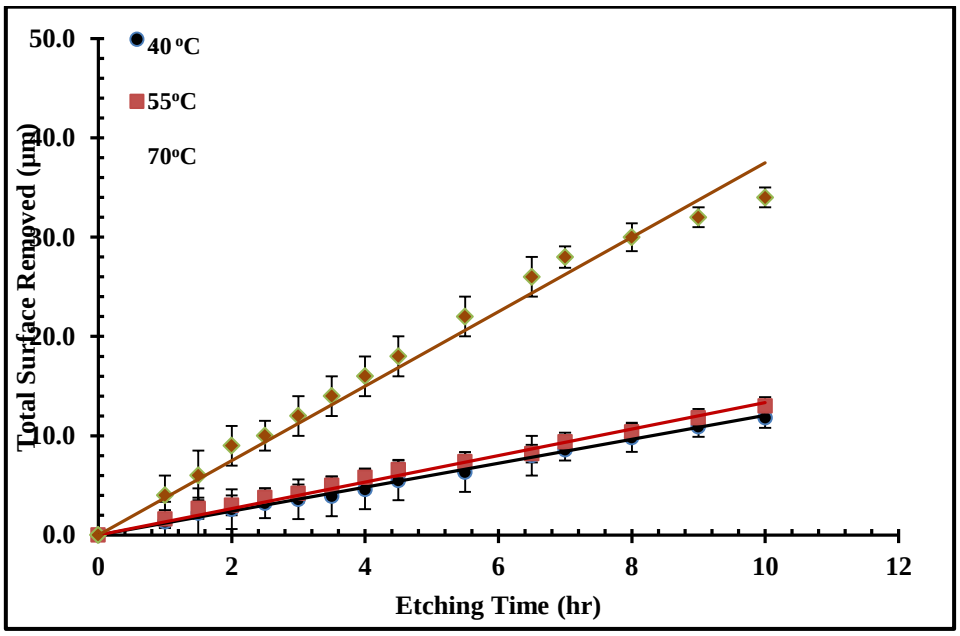

Figure 2: Variation of Total surface removed with etching time for Makrofol-E detector.

3. Conclusion:

Bulk etch rate is found to increase with increase in temperature of etchant. Table 2 shows that at T=55°C, $V_{G\parallel}$ and $V_{G\perp}$ for ^{93}Nb irradiated Makrofol-E are equal within experimental error (comparable to the values obtained in the reference 8). Thus we can conclude the detector shows isotropic character when etched at 55°C. $V_{G\parallel}$ and $V_{G\perp}$ shows anistropic behaviour for temperature of etchant at 40 and 70°C.

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