Irradiation effect of 60 Co gamma rays on bulk etch rate, track etch rate and activation energy of CR-39 Solid State Nuclear Track Detector

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Introduction

Solid State Nuclear Track Detectors (SSNTDs) are extensively used for registering nuclear tracks (Fleischer, Price and Walker 1975) [1]. CR-39 is one of the most commonly used as SSNTDs. CR-39 is transparent in visible spectrum and combines an exceptional range of qualities which are not available in other SSNTDS [2]. Gamma irradiation in CR-39 yields cross-linking and chain scission. Due to cross-linking, etch rate decreases. If the probability of cross- linking reaction is larger than chain scission, the material would become hardened. In chain scission process, emission of atoms and molecules (CO, CO_2, and H_2) occurs as a result of cut in the long chain. This process softens the material which increases etch rate. It is well known that track registration properties of latent tracks are affected by exposing such detectors to gamma rays radiation [3]. The effect of gamma irradiation on CR-39 with and without gamma dose before and after irradiation with 241Am source, have been studied.

Experimental Details

Samples of dimension 1cm x1cm were cut from CR-39 sheet of thickness 0.9 mm, density 1.30 g/cm3 manufactured by HARZLAS TD-1 (Nagase Landauer Ltd., Japan). Fifteen CR-39 samples were divided into three sets, each of five samples. The first one served as a control set and its samples were exposed only to alpha radiation with close contact to 241Am source. The second set (post exposed) was first exposed to the same alpha source and then treated in air with gamma source. The third set (pre-exposed) was irradiated in reverse process (gamma+alpha) with the same sources as the second set and under the same conditions. These CR-39 detectors were irradiated at normal to alpha particles using 241Am source of active diameter 6mm and activity nearly 3.7x108 Bq. at NPD, BARC, Trombay, Mumbai, India. Gamma irradiation was carried out with 60Co gamma rays in air at a dose ray of 2kGy/h by using gamma irradiator at Radiochemistry Division, BARC in the dose range of 102-105 Gy at room temperature in air. After irradiation and exposure the CR-39 detectors were etched in 6.25N NaOH solution at different temperatures viz. 60,70, 80, 90^{o}C for different time periods. The accuracy in the maintenance of temperature was 1^{o}C. The track diameters of alpha particles were measured by using an Olympus microscope fitted with an objective of 100 x (oil immersion). The bulk etch rate (V_B) at different etching temperatures was determined by the track diameter technique [3] using the formula

$D=2V_Bt$ or $V_B=D/2t$ because $V_T>>V_B$

The track etch rate V_T is then calculated by using the relation $V_T= \Delta L/\Delta t$

Where ΔL is the track length increase in etching time Δt.

The activation energy associated with bulk and track etch rate at a given temperature were measured using following formula [4]

$V_B = A \exp(-E_B/kT)$ and $V_T = B \exp(-E_T/kT)$

Result and Discussion

The bulk etch rate, track etch rate and activation energy for bulk etch rate and track etch rate are given in table 1. From this table it

clear that bulk -etch rate and track etch rate vary with these three different processes i.e. alpha,alpha+gamma, and gamma+alpha.

Table 1: Bulk etch rate, Track etch rate and activation energy of CR-39.

Irradiation Type	Temperature °C	Bulk Etch Rate (µm/h)	Track Etch Rate (µm/h)	E_B (eV)	E_T (eV)
Alpha	60	1.2	13.2	0.72 ± 0.55	0.54 ± 0.26
	70	3.1	25.0		
	80	5.8	42.0		
	90	10.07	64.07		
Alpha+ Gamma	60	1.3	15.1	0.71 ± 0.55	0.51 ± 0.29
	70	3.4	28.5		
	80	6.1	45.3		
	90	10.91	61.5		
Gamma + Alpha	60	1.1	12.4	0.73 ± 0.69	0.55 ± 0.25
	70	2.9	23.10		
	80	5.7	40.05		
	90	9.30	60.94		

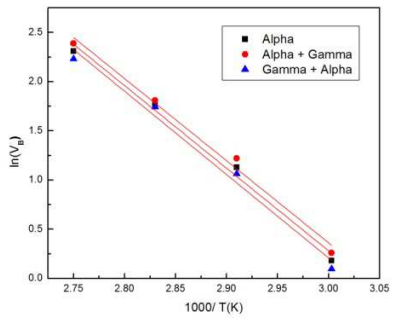

Fig.1: Variation of bulk etch rate (µm\h) with temperature for alpha, alpha+gamma, and gamma+alpha irradiated CR-39 detectors.

Figure 1 and Figure 2 shows variation of bulk etch rate and track etch rate for alpha, alpha+gamma, and gamma+alpha irradiated CR-39 detectors at different temperatures. From the figure 1 and 2, the activation energy related to bulk and track etch rate were calculated using the slope of the plot. The activation energy for bulk etching for gamma, gamma + alpha and alpha + gamma irradiated CR-39 is (0.72± 0.55) eV, (0.71± 0.55) eV and (0.73± 0.69) eV resp. The activation energy for track etching for gamma, gamma + alpha and alpha + gamma irradiated CR-39 is (0.54± 0.26) eV, (0.51± 0.29) eV and (0.55± 0.25) eV resp.

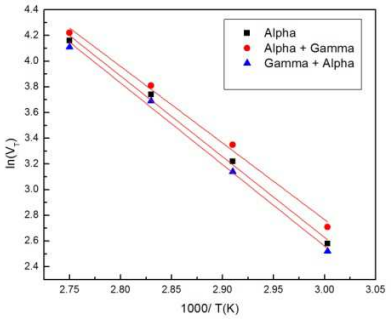

Fig.2: Variation of track etch rate (µm\h) with temperature for alpha, alpha+gamma, and gamma+alpha irradiated CR-39 detectors.

From the table 1, it is clear that etching parameters are reduced when CR-39 is pre irradiated with gamma rays while etching parameters increases when post irradiated with gamma rays. Here gamma rays modify the surface of CR-39 in pre exposed process and CR-39 become more transparent to visible light. Hence it is better to expose CR-39 first to gamma rays at a certain dose and then to irradiate to nuclear particles.

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References

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