Effect of X-ray irradiation on the activation energy and etching parameters of Makrofol-N plastic detector

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Introduction

Makrofol-N is a Solid State Nuclear Track Detector (SSNTD) which is used in the detection of heavy ions as well as fission fragments. It is well known that Linear Energy Transfer radiation like gamma rays, UV-radiation, X-ray radiation, infrared radiation etc do not register tracks in SSNTDs. Interaction of X-ray radiations with Makrofol-N plastic detector causes structural changes in the detector. The changes in the detector depend on the factors like radiation type, exposure time, temperature, exposure condition, energy of incident radiation, irradiation condition, etching process etc.

In the present paper, the values of various etching parameters, namely, bulk etch rate (V_G), track etch rate (V_T), critical angle (θ_C), sensitivity (S) of the plastic for registration of fission fragments, etching efficiency (η) and activation energies for bulk (E_G) and track etching (E_T) are reported.

Experimental Details

Makrofol-N plastic detector ($C_{16}H_{14}O_3$, density = 1.23 gm/cm^3) manufactured by Bayer Co., Germany having a thickness of 300 µm and 2 cm^2 in area were irradiated at normal to fission fragments (FF) us ing 252Cf source having activity 15x10^3 fission fragments per second at NPD, BARC, Trombay, Mumbai, India. X-ray irradiation was carried out with Fe-55 source having activity 10 mCi (300M Bq) at Physics department, BHU, Varanasi. Six samples were prepared, the first two samples (first set) were initially trated with X-ray for 30 minutes (pre exposed) and then exposed to fission fragments (FF) with a close contact to 252Cf source for five minutes. The next two samples (second set) were exposed to fission fragments (FF) for five minutes and then treated with X-ray for 30 minutes (post exposed) under the same condition as in case of pre exposed samples. The last two samples (third set) were also were exposed to fission fragments (FF) for five minutes and then treated with X-ray for 60 minutes at the same condition. One set also irradiated with only fission fragments at same condition. In first three sets we have the effect of both types of radiation i.e. (X-ray + gamma ray). For the calculation of bulk etch rate and track etch rate at different temperatures, equations are discussed in detail by R.K. Jain et.al.

Result and Discussions

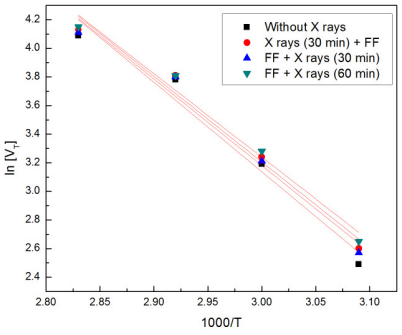

Fig 1 : Variation of bulk etch rate (µm\h) with temperature for without X ray, X ray (30 min) + FF, FF + X ray (30 min) and FF + X ray (60 min) irradiated Makrofol –N detectors.

The bulk etch rate (V_G), track etch rate (V_T), critical angle (θ_C), sensitivity (S) of the plastic for registration of fission fragments, etching efficiency (η) and activation energies for bulk (E_G) and track etching (E_T) are given in table 1. From the table it is clear that bulk etch rate and track etch rate both increases with

temperature for pre and post irradiation of X rays. The sensitivity and etching efficiency decreases with rise in temperature and trend continues for pre and post irradiation of X rays. The critical angle θ_C also show similar trend.

Table 1: Values of etching parameters, V_G, V_T, S, η and θ_C for Makrofol-N

Irradiation Type	**Temp °C**	**Bulk Etch Rate (µm/h)**	**Track Etch Rate (µm/h)**	**S = V_T/V_G**	**η = (1-V_G/V_T) %**	**θ_C= $Sin^{-1}(V_G/V_T)$**
Without X-ray	50	1.25	12.0	9.60	89.58	5.98
	60	2.53	24.2	9.56	89.54	6.05
	70	6.49	43.8	6.75	85.18	8.52
	80	9.25	60.0	6.49	84.58	8.87
X-ray (30 min) + Fission Fragments	50	1.32	13.5	10.23	90.27	5.61
	60	2.98	25.6	8.59	88.35	6.68
	70	6.83	45.0	6.59	84.82	8.73
	80	9.60	62.2	6.47	84.56	8.87
Fission Fragments + X-ray (30 min) +	50	1.29	13.0	10.08	90.08	5.69
	60	2.67	24.9	9.32	89.28	6.15
	70	6.56	44.5	6.78	85.26	8.48
	80	9.45	60.8	6.43	84.46	8.94
Fission Fragments + X-ray (30 min) +	50	1.38	14.1	10.21	90.21	5.62
	60	3.10	26.0	8.39	88.08	6.85
	70	6.99	45.6	6.52	84.67	8.82
	80	9.95	63.6	6.39	84.60	9.00

Figure 1 and Figure 2 shows variation of bulk etch rate and track etch rate for without X ray, X ray (30 min) + FF, FF + X ray (30 min) and FF + X ray (60 min) irradiated Makrofol-N 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 without X ray, X ray (30 min) + FF, FF + X ray (30 min) and FF + X ray (60 min) irradiated Makrofol-N is **(0.62 ± 0.4) eV, (0.67 ± 0.51) eV, (0.69 ± 0.23)** and **(0.66 ± 0.39) eV** resp. The activation energy for track etching for without X ray, X ray (30 min) + FF, FF + X ray (30 min) and FF + X ray (60 min) irradiated Makrofol-N is **(0.54 ± 0.76) eV, (0.52 ± 0.26) eV , (0.52 ± 0.26) eV** and **(0.50± 0.34) eV** resp.

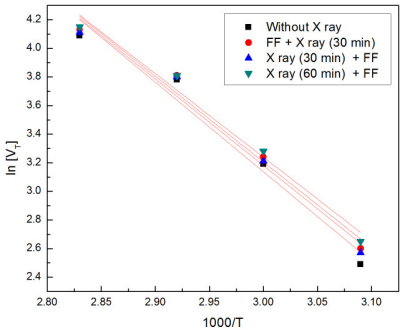

Fig 2 : Variation of track etch rate (µm\h) with temperature for without X ray, X ray (30 min) + FF, FF + X ray (30 min) and FF + X ray (60 min) irradiated Makrofol -N detectors.

From the table 1, it is clear that etching parameters increases when Makrofol-N is irradiated with X-rays. Here X rays modify the surface of Makrofol-N in post exposed (60 min) process and Makrofol-N become more transparent to visible light. Also activation energy (E_G and E_V) decreases with post exposure of X-rays (60 min). Least effect observed with post exposure of X-rays with 30 min exposure. Hence it is better to expose Makrofol -N first to X-rays at a certain dose (more than 60 min) and then to irradiate to nuclear particles.

Acknowledgement

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References

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