# Effect of infrared laser on bulk etch rate and track etch rate in Makrofol-E polycarbonate plastic detectors

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## Introduction

It is observed that track registration characteristics of polycarbonate plastic detectors are affected by electromagnetic radiations. This process inside the polymer leads to breaking of original bonds, generation of excited and ionized species, chain scission, radical formation and bond rearrangements etc. These effects result change in the bulk and track etch rates of the detector [1].

Laser produces significant effects on SSNTDs. Infrared (IR) laser induces thermal effects [2] while ultraviolet (UV) laser [3] results in photodecomposition. Makrofol-E is widely used solid state nuclear track detector (SSNTD). In this paper we present effects of IR laser ($\lambda$=1064) on bulk and track etch rates of Makrofol-E detector as well as study effect on activation energy of bulk and track etch rate.

## Experimental Procedure

Makrofol-E having a thickness 600µm and area 1cm$^2$ were cut in fifteen pieces. Fifteen detectors were divided into three sets, each of five samples. The first set (unexposed to laser beam), used as a reference set, was irradiated in close contact with a fission source ($^{252}$Cf). The second set (post exposed) was first exposed to fission source in close contact to the same $^{252}$Cf source and the treated in air with laser at energy intensity 6 J/cm$^2$ to 10 J/cm$^2$. For the third set (pre-exposed), the process was reversed (laser + fission) under the same conditions. After irradiation plastic detectors were etched in 6.25 NaOH solution at temperature ranging from 323 K to 343 K. The accuracy in the maintenance of temperature was ±1 K. Then Makrofol-E detectors were washed in distilled water and dried in open air. The thickness of removed layer resulting due to etching was measured by using an Olympus microscope (BH-2) fitted with an objective of 100 x (oil immersion). For the calculation of bulk etch rate, track etch rate and activation energy of bulk and track etch rate, detailed explanation is given in our previous publication[3].

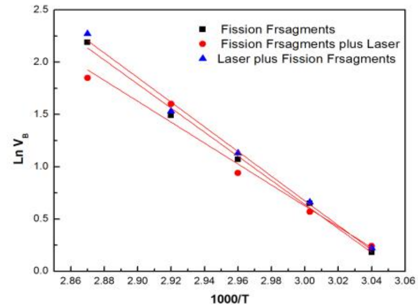


**Fig.1** The dependence of Ln $V_B$ versus reciprocal temperature for un-exposed, post-exposed and pre – exposed Makrofol-E detector.

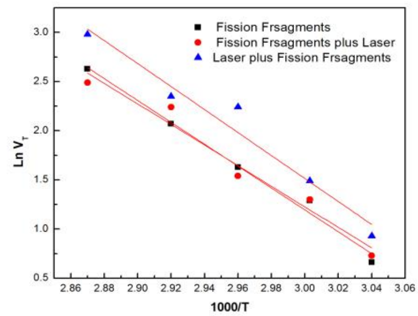


**Fig.2** The dependence of Ln $V_T$ versus reciprocal temperature for un-exposed, post-exposed and pre – exposed Makrofol-E detector.

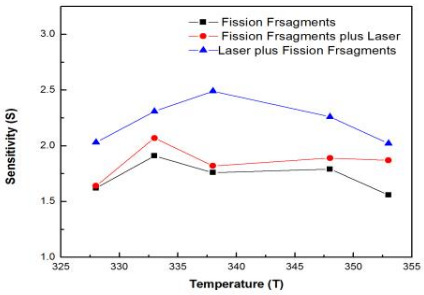


**Fig.3** Variation of Sensitivity S for un-exposed, post-exposed and pre–exposed Makrofol-E detector.

## Results and Discussion

Fig 1 and Fig.2 shows linear dependence of Ln $V_B$ and Ln $V_T$ versus reciprocal temperature, for un-exposed, pre-exposed and post-exposed Makrofol-E detector. For each set, the activation energies for bulk etch rate ($E_B$) and track etch rate ($E_T$) were calculated from the slopes of these linear plots and shown in **Table1**.

**Table 1**: Activation energy of Makrofol-E detector

| Irradiation Type | $E_B$ (eV) | $E_T$ (eV) |
|---|---|---|
| Fission Fragments | 0.85±0.44 | 0.73±0.59 |
| Fission Fragments plus laser | 0.76±0.90 | 0.80±1.12 |
| Laser plus Fission Fragments | 0.90±0.48 | 0.90±1.13 |

From the table, it is observed that the activation energy of bulk etch rate for exposed detector is different to un-exposed detector. The values of activation energy of bulk etch rate is found to be different for un-exposed detector to the exposed (pre and post) detector. We can say that activation energy of bulk etch rate ($E_B$) is a characteristics of bulk material of the detector. An increasing trend in the activation energy of track etch rate from un-exposed detector (0.73 eV) to pre-exposed (0.80 eV) and then post-exposed detector (0.90 eV) is observed. This increase in activation energy may be due to hardening of detector material resulting from the cross-linkage due to exposure of the laser radiations in the polymer detector. This hardening of detector material can be useful in the detection of high energy particle without increasing the thickness of the detector. Hence we can say that downward etch rate along the track is larger than the bulk etch rate. G Saffarini et.al [1] found similar result using CR-39 detector but the values of activation energies of bulk etch rate and track etch rate are slightly different. The difference may be due to the detector material in CR-39. Fig 3 shows the effect of infrared laser on the sensitivity of Makrofol-E detector. The sensitivity of post-exposed detectors is relatively higher than that of un-exposed and pre-exposed detectors. The sensitivity is found to be highest for post-exposed detectors at temperature 338 K. This temperature may be considered as the temperature for the optimum sensitivity of post-exposed detectors. The decrease in the sensitivity of the detectors after 338 K may be due to increase in hardening of the detector material. This decrease in sensitivity for post-exposed detector after 338 K is associated with larger increase in $V_B$ as compared to $V_T$. Also from Fig 3, it may be observed that sensitivity of un-exposed and pre-exposed detectors also decreases after temperature 338 K. The observed decrease in sensitivity may be due to combined thermal effect of infrared laser and etchant solution, for temperature higher than 338 K. Hence thermal energy of etching solution plays a vital role in laser characteristics on the etching properties of Makrofol-E detector. This opens a new path for applying Makrofol-E detector for the detection of particles according to their energy. Hence for the detection of high energy particles (cosmic rays), laser irradiation may be preferred before the use of detector while for low energy particles one should use detector exposed to laser radiation after exposure to ion source and etch at temperature 338 K.

## References

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