

QUANTITATIVE EVALUATION OF EFFECT OF DOPANTS/ ADDITIVES ON ANNEALING INDUCED TRACK REPAIR IN CR-39 DETECTORS USING A NOVEL APPROACH.

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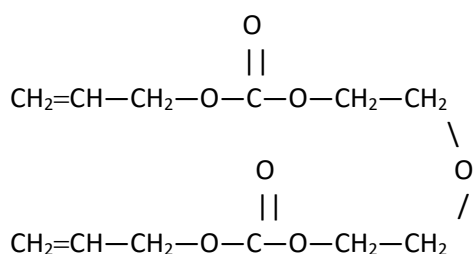
Abstract :

Keeping in view that temperature plays a significant role in track registration properties of Solid State Nuclear Track Detectors and also results in repair of tracks over time with regard to charged particle irradiation of insulating solids, thereby, track annealing finding a centre stage in Nuclear Track Research in view of numerous applications of Solid State Track Recorders in diverse areas of Science and engineering, the present study has focused on quantitative evaluation of repair of damage/ tracks in CR-39 detectors with various additives in the framework of a novel and analytical approach of study of annealing kinetics wherein, a parameter, most appropriate to relate to formation/ repair of tracks in comparison with other parameters, has been used and measured to express quantitatively the annealing induced repair of damage in the detector samples used in the study.

Keywords : CR-39 (without additive), CR-39 (DOP), CR-39 (DIOP), CR-39 (DNP), Track Etch Rate (V_T), Bulk Etch Rate (V_B), Track Diameter (D)

Introduction:

CR-39, a highly versatile track detector in view of its excellent response with regard to track registration, high sensitivity, etching and optical properties, since the beginning of its use as dielectric track recorder in 1978 [2], has been most extensively employed in diverse applications of Solid State Nuclear Track Detectors in various areas [7], [8]... [17]. The highly cross-linked thermoset CR-39 polymer results from the polymerization of a liquid monomer diethylene glycol bis (allyl carbonate) [5], [6].



Diethylene glycol bis (allyl carbonate)

During polymerization, as the polymeric chains grow by attaching monomer units, the polymeric network that forms has closed zones with unused monomer

molecules which are trapped inside. Therefore, a residual unsaturation in the form of unused monomer molecules caged inside the polymeric network continues to exist in the polymer resulting in structural inhomogeneity and non-uniformity in response. CR-39 detectors are, therefore, produced by employing specific cure-cycle regimes with suitable temperature-time combinations to ensure more uniform polymerization.

Additives/ dopants may also be added to CR-39 during polymerization with aim to improve the response of CR-39 track detectors [3], [4]. There have been variable observations on how dopants influence the sensitivity of CR-39 track detectors and also its etching and optical properties [6]. It is well known that temperature has a definite impact on track recording in SSNTDs. Tracks get repaired on thermal treatment/ annealing. Also, track formation by passage of charged particles, and track repair on annealing, are more likely reciprocal processes on the same route, therefore, annealing studies are of fundamental importance in Nuclear Track Research.

Present Work:

In the present work, CR-39 detectors with various dopants/ additives have been subjected to annealing after exposure and the response in terms of repair of damage has been expressed quantitatively for which a novel approach of study of kinetics of annealing has been adopted. In fact, addition of Dopant/ Plasticiser influences the response of CR-39 detectors. Dopants are chemical compounds of low molecular weight which penetrate the polymer matrix and connect with polymer chains with polar bonds.

In any irradiated sample of Solid State Nuclear Track Detector subjected to Chemical Etching for revealing the tracks, the damage along the track makes etching take place faster along the track than in the bulk, so the track etch rate (V_T) is more than the bulk etch rate (V_B) by a value that solely and entirely relates to damage and can be expressed as, [18], [19]

$$V_T = V_B + f \quad (1)$$

f relates only to damage

$$\text{Etch Rate Ratio } V = \frac{V_T}{V_B} = 1 + \frac{f}{V_B} \quad (2)$$

$$\text{Also, Track Diameter [1], } D = 2 V_B t \sqrt{\frac{V-1}{V+1}} \quad (3)$$

If ΔV_B is the change in bulk etch rate (V_B) and Δf the change in f consequent to annealing, track diameter after annealing D_1 can be expressed as [18] [19].

$$D_1 = D \left(1 + \frac{x}{100} \right) \sqrt{\frac{(V+1)(100-y)}{V(100-y)+2x+y+100}} \quad (4)$$

where Percentage Change in Bulk Etch Rate [18]

$$x = \frac{\Delta V_B}{V_B} \times 100$$

and Percentage Change in f term [18]

$$y = \frac{\Delta f}{f} \times 100$$

$f = V_T - V_B$, the difference of Track and Bulk Etch Rates, as a result of faster etching along the track which in turn arises due to damage along the track, is the only parameter in comparison to all others viz. V_T , V_B and D that relates only and entirely to formation of tracks or the damage. Other parameters depend on bulk properties of the detectors also. Annealing causes repair of damage/ track. Annealing induced repair of damage can be quantitatively assessed most accurately in terms of change in f i.e., in terms of y , which refers to percentage change in f consequent to annealing.

Experimental Details :

Detectors CR-39 (without additive), CR-39 (DOP), CR-39 (DIOP), CR-39 (DNP) have been obtained from Pershore Mouldings (Worcestershire, England).

TABLE
CURE CYCLE DETAILS

CR-39 (without additive) CR-39 (DOP) CR-39 (DIOP) CR-39 (DNP)	Cure cycle starts at 34°C and then rises to 90°C in a programmed manner over 32 hours followed by cooling to 40°C before removal. DOP (dioctyl phthalate), DIOP (di iso-octyl phthalate), DNP (dinonyl phthalate) are additives with concentration 1% by weight.
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Detector samples were exposed to 5.45 MeV α particles from ^{241}Am source in normal incidence in vacuum, 10^{-2} torr, in an exposure unit in the High Energy Physics laboratory, Department of Physics, Kurukshetra University, Kurukshetra. Post irradiation annealing of exposed samples was done at 95°C for various times – 5, 10, 15 hours. The samples were etched in 6.25N NaOH at 60°C for 20 hours.

Results and Conclusion :**TABLE****EXTENT OF ANNEALING (y) IN DIFFERENT CR-39 DETECTORS FOR POST IRRADIATION ANNEALING AT 95°C FOR VARIOUS TIMES**

Detector Type	Annealing time (hours)	y
CR-39 (without Additive)	5	6.86
	10	13.71
	15	18.04
CR-39 (DOP)	5	1.85
	10	3.70
	15	7.47
CR-39 (DIOP)	5	0.69
	10	6.92
	15	11.75
CR-39 (DNP)	5	1.41
	10	5.21
	15	8.10

It is evident in the results, that, for annealing for 5 hours at 95°C, track repair expressed quantitatively as ' y ' is 6.86% for CR-39 (without additive), 1.85% for CR-39 (DOP), 0.69% for CR-39 (DIOP) and 1.41% for CR-39 (DNP). Results for other annealing times i.e. 10hours, 15 hours also convey the same inference. Also the cure cycle adopted for all the four detectors is same. It can be, obviously inferred that track repair induced by annealing is less for CR-39 detectors with dopant which implies that the tracks are more stable in CR-39 detectors with dopants giving us option to decide the suitability of use of CR-39 detectors with additives not only with regard to etching and optical properties but also with regard to stability of track/damage. The approach adopted above is unique in precise measurement of annealing induced track repair in terms of a parameter (y) which has altogether no dependence on the bulk property of detector and it relates only to damage.

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