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STUDIES OF ISOTHERMAL ANNEALING OF FISSION FRAGMENT AND ALPHA PARTICLE TRACKS IN CR-39 POLYMER DETECTORS

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ABSTRACT

Two groups of CR-39 detectors samples are axposed to two types of charged particle radiation. The first group are severe damaged with fission fragment tracks from ^{252}Cf source. The second accepted alpha particles resulting from the interaction of highly energetic ^{19}F-ions and a copper disk with thickness 1cm, which are of less damage tracks than fission fragments. The isothermal annealing of tracks in the temperature range from 175 to 300 °C in step 25 °C for annealing time of 10,15,20,25 and 30 minutes has been investigated. The changes introduced in the track density and track diameter for two types of irradiation in the detector have been observed and compared between them. The results indicate that the track density and the size of the tracks are considerably changed due to annealing.

Keywords: Annealing Process, CR-39, Alpha particles, Track diameter, Track density.

INTRODUCTION

The annealing of radiation damage in different categories of solid state nuclear track detectors (SSNTDs) has been studied by several researchers [1-11]. The annealing of the damage trails at elevated temperatures presumably occurs via the diffusion of atomic defects through the crystal lattice or the movement of molecular fragments within a polymer. Interstitial atoms can then recombine with lattice vacancies, and broken molecular chains may re-join and various species recombine. In plastic, some repair of broken molecular chains may occur.

Fleisher considered that the most useful type of information as to the thermal stability of charged particle tracks in various dielectric materials comes from the heating of duplicate sample sets at various combinations of time (t) and temperature (T). Results of this form may then be used to construct an Arrhenius plot log (t) against (1/T). Those time and temperature combinations, which have resulted in total fading, can be separated from those, which have only produced partial track fading, by a single straight line. This indicates a relationship on the form,

$$t = B \exp \left(E_a / kT \right) \tag{1}$$

where E_a is the activation energy of annealing; B is a constant of proportionality; k is the Boltzmann constant; T and t are the annealing temperature and annealing time respectively[12].

For any degree of track fading, the Arrhenius plot may be constructed to show a series of time and temperature combinations, which achieve this degree of fading. This series of data points will define a straight line. It has been found that each depicting degree of fading produce a " fan like " distribution. The lower the degree of fading then the smaller is the gradient of the line, indicating a lower activation energy.

Fleisher concluded that as the range of activation energies produced was similar to those values obtained from atomic diffusion studies then the annealing of charged particle tracks consisted of a diffusional motion of displaced atom back into stoichiometric positions[13].

EXPERIMENTAL PROCEDURES

To study the complete annealing of alpha particles and fission fragment tracks in CR-39, a number of experiments were carried out. A set of CR-39 plastic foils were irradiated, in vacuum, by a collimated beam of fission fragments from a ^{252}Cf source incident perpendicularly to the detector surface, the second set was irradiated with alpha-particles produced from the nuclear reaction between ^{19}F-beam and a copper disc target in the Arbuzov set-up [14].

In Arbuzov experiment, the copper disk in the Arbuzov set-up was bombarded with about 9.73×10^{8} ^{19}F-ions of 3.4 GeV/N specific energy at normal incidence at the Synchrophasotron, Dubna. Light particles are emitted from a copper disc target at the samples making with its axis an angle of 25° to the 65 GeV ^{19}F-beam. The Arbuzov experiment is mainly to investigate with solid state nuclear track detector the relativistic heavy fragments emitted at wide angles in relativistic nuclear reactions. A special set-up is designed for this purpose [15].

All samples, irradiated from ^{252}Cf and that irradiated from Arbuzov set-up, were isothermally annealed at 175, 200, 225, 250, 275, 300 °C respectively. Both sets of annealed samples of CR-39 along with unannealed reference standard were then etched with 6.25N NaOH. The temperature was well controlled within less than 1 °C around 70 °C. Track density and track diameter are measured with an optical microscope.

RESULTS AND DISCUSSION

The ratios of the survival to the original track densities as a function of the annealing time at various temperatures were plotted.

Figure (1) shows the ratios of the survival to the original track densities as a function of the annealing time at various temperatures [for alpha-tracks]. The complete annealing of the alpha tracks takes place after 15 minutes annealing at 300 °C. Figure (2) shows the ratios of the survival to the original track densities as a function of the annealing time at various temperatures [for fission-fragment tracks]. The complete annealing of the fission-fragments tracks takes place after 30 minutes annealing at 300 °C.

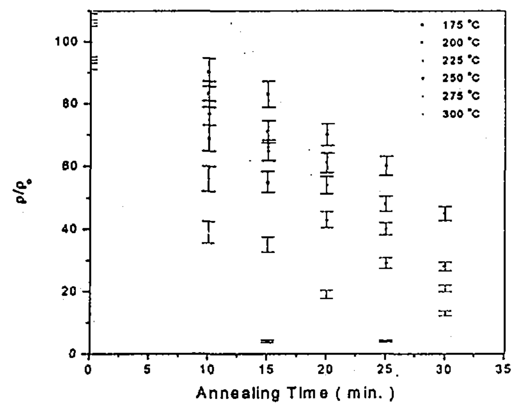

Fig. (1): The variation ratio of the track density of annealed samples to unannealed reference standard with annealing time at annealing temperatures 175 °C, 200 °C, 225 °C, 250 °C, 275 °C and 300 °C for alpha tracks in CR-39 track detector.

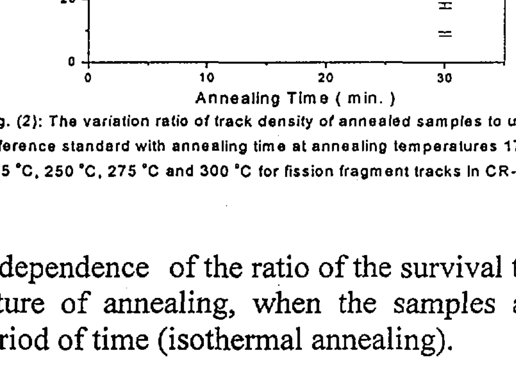

Fig. (2): The variation ratio of track density of annealed samples to unannealed reference standard with annealing time at annealing temperatures 175 °C, 200 °C, 225 °C, 250 °C, 275 °C and 300 °C for fission fragment tracks in CR-39 track detector.

Figure (3) shows the dependence of the ratio of the survival tracks to the original track density, on the temperature of annealing, when the samples are annealed at different temperatures for a fixed period of time (isothermal annealing).

Figure (4) shows the dependence of the ratio of the survival tracks to the original track density, on the time of annealing, when the samples are annealed at different time for a fixed temperature.

When irradiated track detectors are held at high temperatures for a given time, it is found that either the latent damage trails are totally removed from the detector, so that they cannot be revealed by subsequent etching, or their development by etching is impaired.

Higher annealing temperatures often result in the degradation of the polymer. The material is then considerably softened resulting in an increase in the bulk etch rate which would result in a decrease in the etching efficiency. This could be a possible explanation for the decrease in track density in these temperature ranges. The polymer chain spacing are probably rearranged thus changing the detection thresholds. This may account for the change in track density in these temperature ranges.

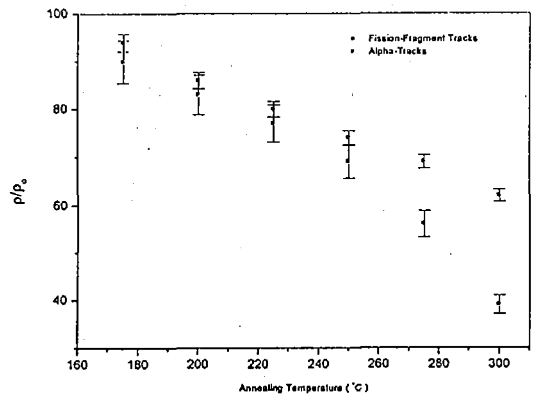

Fig. (3): The variation of track density of annealed samples of CR-39 along with unannealed standard at annealing time 10 minutes.

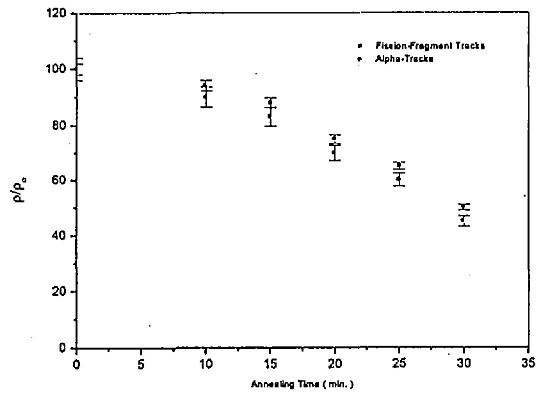

Fig. (4): The variation of track density of annealed samples of CR-39 along with unannealed reference standard at annealing temperature 175 °C.

Figure (5) shows the change of the track diameter of fission fragment and alpha tracks with annealing temperature at fixed period of time in CR-39 track detector.

Figure (6) shows the change of the track diameter of fission fragment and alpha tracks with annealing time at fixed temperature in CR-39 track detector.

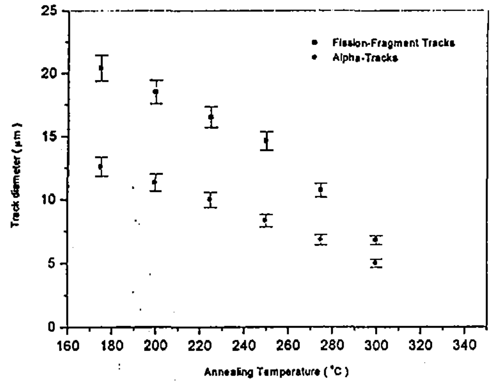

Fig. (5): The variation of track diameter of fission fragment and alpha tracks with annealing temperature at annealing time 30 minutes in CR-39 track detector.

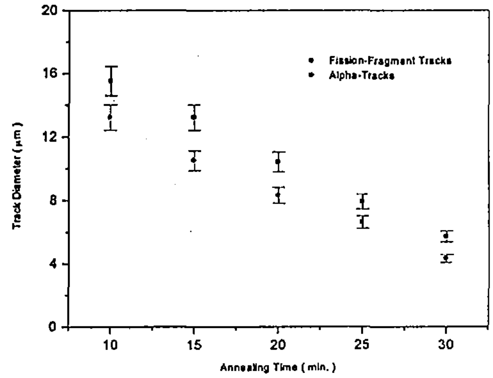

Fig. (6): The variation of track diameter of fission fragment and alpha tracks with annealing time at annealing temperature 300 °C in CR-39 track detector.

It is clear that the degradation of the polymer occurs by increasing the annealing temperature and annealing time and the fading in the track diameter is observed in fission fragment and alpha tracks. In alpha tracks the reduction in the track diameter is higher than the reduction in case of fission fragment tracks because the damage in case of fission fragments is more severe than the damage due to alpha particles.

CONCLUSION

CR-39 nuclear track detector heavily damaged, with ionizing particles, noticeably response to annealing at 200 °C. Raising the temperature may lead to drastic changes in the detector material as a whole. The bulk etch rate rapidly increases at temperature beyond 300 °C. This increment, in turn, negatively affects the detector efficiency. For accurate track measurements such effects should be taken into consideration.

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