X-ray induced modification in CR-39 Plastic Detector

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Introduction

CR-39 plastic detectors have several advantages for measurement of the secondary target fragments. When CR-39 is used in the plateau region of the Bragg curve of proton radiotherapy beams, it has sensitivity only for proton-induced target fragments. Therefore CR-39 can be used to evaluate dose contribution in proton radiotherapy [1]. Interaction of electromagnetic radiations with CR-39 plastic detector causes structural changes in the detector. The extent of change depends on the factors like radiation type, exposure time, temperature, exposure condition, radiation type energy of incident radiation, irradiation condition, etching process etc. [2].

The FTIR spectroscopy technique is used to analyze the effects of X rays on CR-39 plastic detectorbefore and after irradiation with Cf -252 source. The main aim of the present work is to investigate the structural change in the electromagnetic induced CR-39 plastic detector as a function of time.

Experimental Details

Six samples of dimension 1cm x1cm were cut from CR 39 sheet of thickness 0.9 mm and of density 1.30 g/cm^3 manufactured by HARZLAS TD-1 (Nagase Landauer Ltd., Japan). The first two samples (first set) wereinitially treated with X-rays for 30 minutes and then exposed to alpha (α) radiation with a close contact to Cf-252 source for 60 minutes. The next two samples (second set) wereexposed to α radiation with a close contact to Cf-252 source for 60 minutes and then treated with X-rays for 30 minutes (post exposed)under the same conditions as in case of pre-exposed samples.The last two samples (third set) werealso initially treated with X-rays for 60 minutes and then exposed to α radiation with a close contact to Cf-252 source for 60 minutes under the same conditions(pre-exposed).These CR-39 plastic detectors were irradiated at normal to α particles using a weak Cf-252 source of active diameter 6mm at Physics Department BHU Varanasi India. The X-rays irradiation was carried out with a X- ray source (Fe-55) having activity 10 m Ci (370 M Bq.)and half-life period 999 days at High Energy Physics Lab, Physics Department BHU Varanasi India. The detectors were kept at a distance of 8 cm form X-ray source in a desiccator at room temperature. The flux rate of X-ray irradiation on CR-39 sheet for 30 minutes and 60 minutes was about 2.25 x 10^5 and 4.53 x 10^5photons per respectively.

The FTIR analysis was performed using Perkin Elmer Spectrum 65 FT-IR Spectrometer in the wave number range (400-4000) cm^{-1} having resolution 4 cm^{-1} at Physics Department BHU Varanasi India.

For the calculation of bulk etch rate and track etch rate, equations are discussed in detail by R.K.Jain et.al[3]. From the slope activation energy of bulk etch rate and track etch rate is calculated.

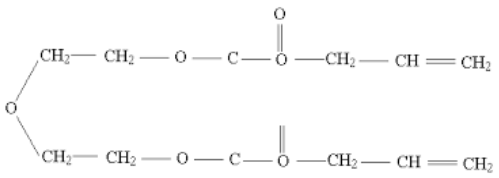

Fig.1: Structure of CR-39 Plastic Detector.

Result and Discussion

The FTIR spectral study of X-ray irradiated CR-39 plastic detectors have beenmade to study thestructural changes toanalyze the reaction

mechanism causing agreat change in the morphology of the polymerand are discussed as under:

The structure of CR-39 is shown in Fig.1. The FTIR spectra of pre and post X- ray irradiated CR-39 plastic detector are shown in Fig.2. The absorption peaks as observed from CR-39 spectrum are identified as: (a) 686 cm^{-1}: vibration of C–H deformation; (b) 1539 cm^{-1}:C–O stretching vibration; (c) 1908 cm^{-1} : C=C phenyl ring stretching vibration; (d) 2049 cm^{-1} ;C=O stretching vibration; (e) 2324 cm^{-1}, 2447 cm^{-1}, 2582 cm^{-1} :CH_3 stretching vibration; (h) 3161 cm^{-1} :C–H stretching vibration of aromatic compounds; (i) 3720 cm^{-1}:stretchingbandof OH group.

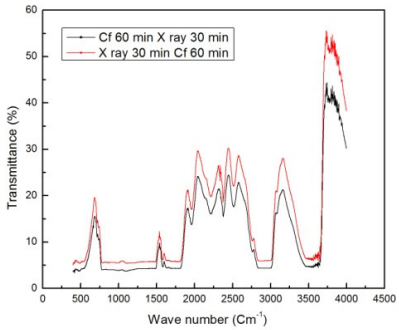

Fig.2: FTIR spectra of pre exposed (X-ray + Cf) and post exposed (Cf + X-ray) CR-39 plastic detectors.

Also the C-H stretching modes of vibration are most strong, involves carbon and hydrogen atoms, and are appeared at higher wavelength regime [6].From Fig..2 it can be observed that overall increase in the transmittance of pre irradiated CR-39 sample as compared to post irradiated CR-39 sample. The increase in the transmittance may be due to scissioning of the polymer chains, resulting in an increase of free radicals, unsaturation, etc.The spectrum corresponding to pre irradiated sample revealed that the material suffered severe degradation through bond breakage and a significant change in the structure of the polymer.Similar results were also observed by Singh et.al. [4], Meenakshiet. al. [5] and Kh. M. Abdel Raouf [6].

From Fig..3 it is clear that there is no particular change in the structure of CR-39 plastic detector except some changes in the peak intensities. Overall transmittance increases for 60 minutesirradiation.The minor changes in the intensities of (60 minutes) irradiated samples may be due to the breakage of few bonds in the ladder structure, but this may not change the overall structure of the polymer.

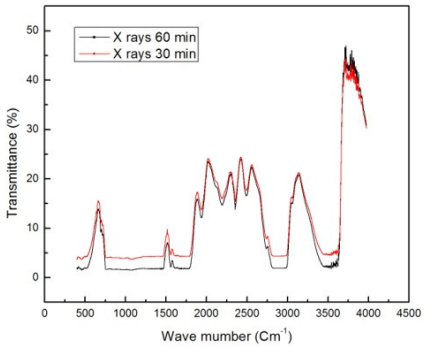

Fig. 3FTIR spectra of X-ray irradiated CR-39 plastic detector for (a) 30 min and (b) 60 min.

The activation energy for bulk etch rate and track etch rate for (X-ray + Cf) detector is calculated to be 0.61 ± 0.41 eV and 0.63 ± 0.53 eV while for (Cf + X-ray) detector it is 0.57 ± 0.39 eV and 0.58 ± 0.46 eV. The results so obtained agree that X- rays causes modification in the surface of the detector. Similar results were confirmed with gamma rays in our previous publications.

Acknowledgement:

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