

FTIR spectra of UV induced CR-39 Plastic Detector

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Introduction

CR-39 plastic detectors are extensively used for detection of gamma rays and cosmic ray detection, in neutron dosimetry, heavy ions, radon monitoring, micro-mapping of radioactive elements in rocks, particle identification eyeglass lenses and nuclear physics. [1] The unique features of CR-39 plastic detector include complete transparency to visible light, colorless and complete opaque to infrared and ultraviolet radiations. The CR-39 monomer contains three functional group; Allyl group ($-\text{CH}_2=\text{CH}-\text{CH}_2-$), ether group ($-\text{CH}_2-\text{O}-\text{CH}_2-$) and carbonyl group ($\text{C}=\text{O}$). These functional groups are responsible for the modification in physiochemical properties upon exposure to any kind of radiations.

The induced modifications of the CR-39 detector by ionizing radiation (cross linking or main chain scissions) could be investigated by spectroscopic techniques like FTIR. Spectrofluorometry can detect the induced modification in fluorescent materials by measuring the emission spectra resulting from excitation with a suitable wavelength.

The FTIR spectroscopy technique is used to analyze the effects of UV rays on CR-39 plastic detector before 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

Five 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 samples (a) was treated with uv rays having wavelength 160 nm for 2 hours. Second sample (b) was first treated with uv rays for 2 hours and then exposed to alpha radiations for 1 hour. Third

sample (c) was first exposed to alpha radiations for 1 hour and then treated with uv rays having wavelength 120 nm. Fourth sample (d) was first exposed to alpha radiations for 2 hour and then treated with uv rays having wavelength 140 nm. The last sample i.e.fifth (e) was first exposed to alpha radiations for 1 hour and then treated with uv rays having wavelength 160 nm. These CR-39 plastic detectors were irradiated at normal to alpha particle using a weak Cf-252 source of active diameter 6 mm at Physics Department BHU Varanasi India. The UV irradiation was carried out with a VUV monochromator Model 234/302 McPherson (wavelength range 115 nm to 370 nm) at High Energy Physics Lab, Physics Department BHU Varanasi India. The power of deuterium lamp was 30 watt and diffraction grating used has 1200 lines per mm.

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

Bulk etch rate and track etch rate are calculated from the equations discussed in detail in our publication R.K.Jain et.al [3].

Result and Discussion

The FTIR spectral study of uv irradiated CR-39 plastic detectors have been made to study the structural changes to analyze the reaction mechanism causing a great change in the morphology of the polymer. The relative modifications in the intensities of different bonds can be understood from the relative functional groups present in CR-39 polycarbonate detector. The overall analysis of FTIR spectra reveals the increase in higher percentage (%) of transmittance (decrease in absorbance). The increase / decrease in transmittance (absorbance) is due to formation of free radicals, chain scission and cross linkage.

The FTIR spectra of uv irradiated CR-39 plastic detector are shown in Fig.2. For reference sample 1 (uv @ 160 nm) is taken and transmittance observed is minimum. Pre and post irradiation of uv radiations at wavelength 120 nm is shown sample 2 and 3. Post irradiation of sample with uv radiations leads to modification of plastic leading an increase in transmittance as compared to pre irradiation. This may be due to cross linkage and chain degradation. The trend is similar for other samples. Maximum transmittance is observed for sample 4 (α 2hr + uv 140 nm) as more and more alpha particles damages the plastic surface.

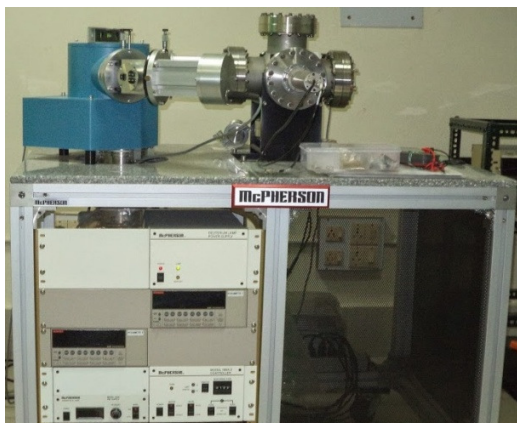


Fig.1: VUV Monochromator Model (234/302) McPherson (115 nm-370 nm).

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} : CH₃ stretching vibration; (h) 3161 cm^{-1} : C-H stretching vibration of aromatic compounds; (i) 3720 cm^{-1} : stretching band of OH group.

Also the C-H stretching modes of vibration are stronger, involve carbon and hydrogen atoms, and are appeared at wavelength regime 1000 cm^{-1} .

From Fig.2 it can be observed that the spectrum corresponding to post uv irradiation samples 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]. Similar results were confirmed

with gamma rays in our previous publications and Tayal et al.[6].

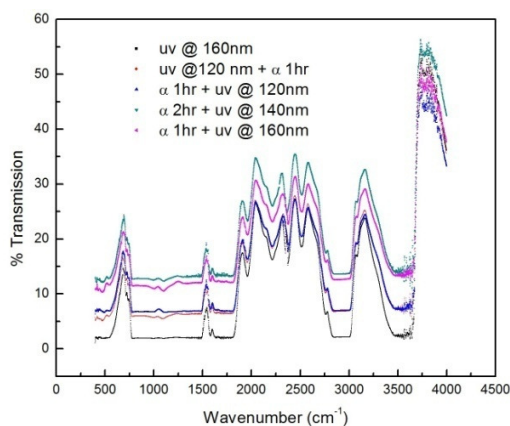


Fig.2: FTIR spectra of (a). uv @ 160 nm, (b). uv @ 120 nm + α 1 hr, (c). α 1 hr + uv @ 120 nm, (d). α 2 hr + uv @ 140 nm and (e). α 1 hr + uv @ 160 nm.

The activation energy for bulk etch rate and track etch rate for sample (a) uv @ 160 nm is calculated to be 0.63 ± 0.45 eV and 0.68 ± 0.50 eV while for sample (b) uv @ 120 nm + α 1 hr, it is 0.60 ± 0.35 eV and 0.64 ± 0.55 eV and for sample (c) α 1 hr + uv @ 120 nm it is calculated to be 0.65 ± 0.15 eV and 0.70 ± 0.28 eV. For sample (d) α 2 hr + uv @ 140 nm, the calculated values are 0.67 ± 0.19 eV and 0.71 ± 0.44 eV. For sample (e) α 1hr + uv @ 160 nm, the values comes out to be 0.66 ± 0.81 eV and 0.70 ± 0.25 eV. The results so obtained agree that uv rays causes modification in the surface of the detector. Similar results were confirmed with gamma rays in our previous publications [5].

Acknowledgement:

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