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Improvement in Optical Properties of Nuclear Track Detector

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Abstract: The purpose of this work was obtaining information about the interaction of γ- ray with CR-39 track detector by using the UV-Vis spectrometry and FTIR which can be used in concerning sensor for gamma irradiation. CR-39 samples irradiated by radioactive source Co-60 at different doses are (0, 100, 200, 300, 400, and 500 kGy). The UV-Vis spectroscopy show transitions electronic in the visible region from ground state to excited state, by increasing gamma doses, and the absorbance spectrum for all samples take the same behavior with slightly shift. This shift due to decrease in the optical band gap energy E_g. The FTIR spectra show for all samples there are increases in the intensity of the characteristic peaks with increasing gamma ray, at 3234, 2367 and 1817 cm^{-1}, this increase may be related to more oxidation process that, in turn was produced on the polymer chains by increase gamma doses, and the number of peaks at 1817, 2367, 2645 and 3234 cm^{-1} is belong to carbonate group C=O stretching vibration, O=C=O asymmetric by stretching, C-H Stretching, H_2O free stretching vibration, respectively. By increase gamma ray did not observed changes in the CR-39 groups but observed change in the intensities of peaks, then CR-39 detector can be used properly in the field of radiation dosimetery.

Keywords: CR-39 Polymer, UV/Vis, FTIR, Radiation Dosimetry, Gamma Ray Irradiation

1. Introduction

Solid state nuclear track detector CR-39 has a chemical formula ($C_{12}H_{18}O_7$) and it advantages by perfect structural stability and it has high resistance to most of the solvent, chemicals and different environmental factors. CR-39 is clear in the visible range and almost entirely no transparent in the electromagnetic range [1]. It has the track registration property because of high detection efficiency, high sensitivity, and short etching time. This polymer is also an excellent material for a number of industrial, medical and optical applications [2]. CR-39 plastic detector is one of the most commonly used for radiation detection, because its high sensitivity to protons and alpha particles. These particles do not caused tracks but can make weighty and sometimes intense effect on the properties of track [3-4]. The primary configuration of solid-state nuclear track detectors (SSNTD) such as CR-39 polymer destroys by the interaction of radiation with it, as well as heavy chemical variations take place in polymers under the effect of ionizing radiations (X-rays, gamma rays, fast and slow neutrons, fast electrons, alpha particles, protons, and other products of nuclear reactions) [5]. Form point of view the process of destruction makes by severance, cross-linking and release of molecules, atoms, and molecular fragments, this due to changes in some properties of SSNTD polymer like conductivity, density, optical absorption, molecular-weight distribution etc [3]. Polymer substances have decay by random fracture of the original chain with the amount of fractures being relative to the radiation dose which is surly related to the effect of x-rays or gamma rays on polymer. The bond fracture may provide rise to free radicals ionic species, water molecules, gaseous products, etc [6]. When CR-39 polymer was irradiated by gamma ray or x-ray, Co_2 molecules are formed and the formation of Co_2 was attributed to bond breaking in

CR-39 polymer by the effect of radiation doses. This Co_2 is trapped inside, this can result the successive crazing and cracking of the plastic due to collected local stress. The production of Co_2 is a function of gamma ray dose [6-7]. The study of the physico-chemical properties like optical and chemical properties of the polymer after the effect of radiation on CR-39 polymer are very important because these parameters are modified after exposed of polymer to radiation dose and also these changes may enhance the polymer applications in many fields [8]. The target of the present work is to produce the response of CR-39 polymer to different gamma doses from (0 – 500 kGy), and study the optical and chemical properties of CR-39 polymer under these gamma doses.

2. Experimental Details

2.1. Material

Is this work, the poly ally diglycol carbonate detectors named CR-39, were cut from sheet manufactured by TASRAK Analysis System, Ltd., UK: TASTRACK. The CR-39 has a chemical formula of $C_{12}H_{18}O_7$. The samples have thickness 1 mm and dimension 2 cm × 2 cm. The molecular structure of the monomer CR-39 polymer track detector show in in figure 1.

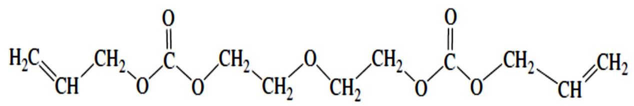


Figure 1. *The structure of CR-39 monomer.*

2.2. Irradiation

CR-39 samples were irradiated with different doses are (0, 100, 200, 300, 400, 500 kGy) of gamma ray by using radioactive point source of Co-60 has half-life 5.27yrs, and energies 1.174, 1.332 Mev.

2.3. UV/Vis Absorption

The change in optical absorption of pristine and irradiated CR-39 detector with gamma ray were obtained by UV/V is Spectra which was carried out by UV/Visible Double Beam spectrometer JASCO V-630 in the range of wavelength 200-1100 nm at an interval of 1 nm, at ambient condition.

2.4. Fourier Transforms Infrared Spectroscopy (FTIR) Spectroscopy

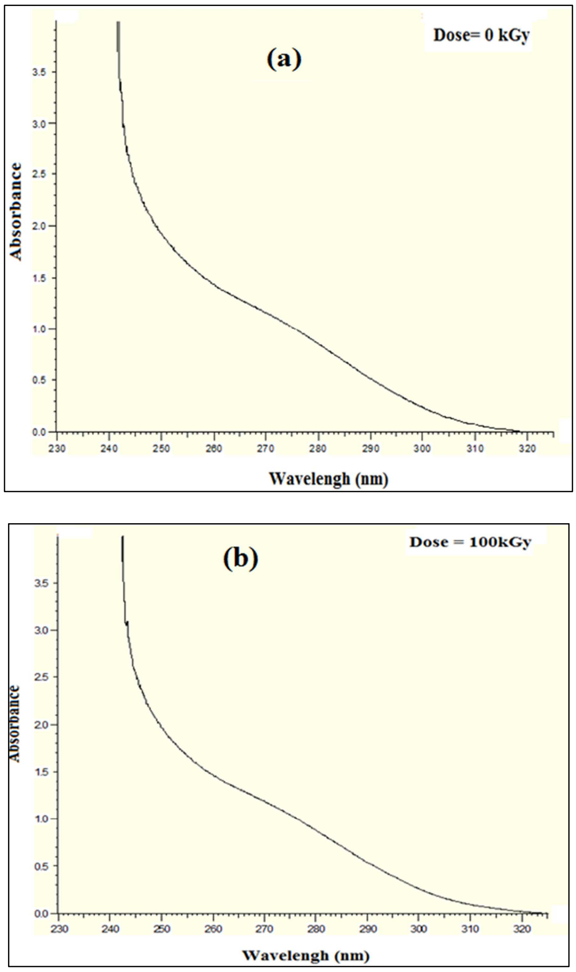
The functional groups in molecules of CR-39 can be identified by FTIR Spectroscopy. The spectra for all CR-39 samples were obtained by Nicolet 6700 spectrometer, thermo Scientific, in the wavenumber range from 400-4000 $cm^{-1}$and resolution of 4 cm^{-1}. The spectra was recorded to obtain the variation in the functional groups of CR-39 between the pristine sample and the irradiated with gamma rays.

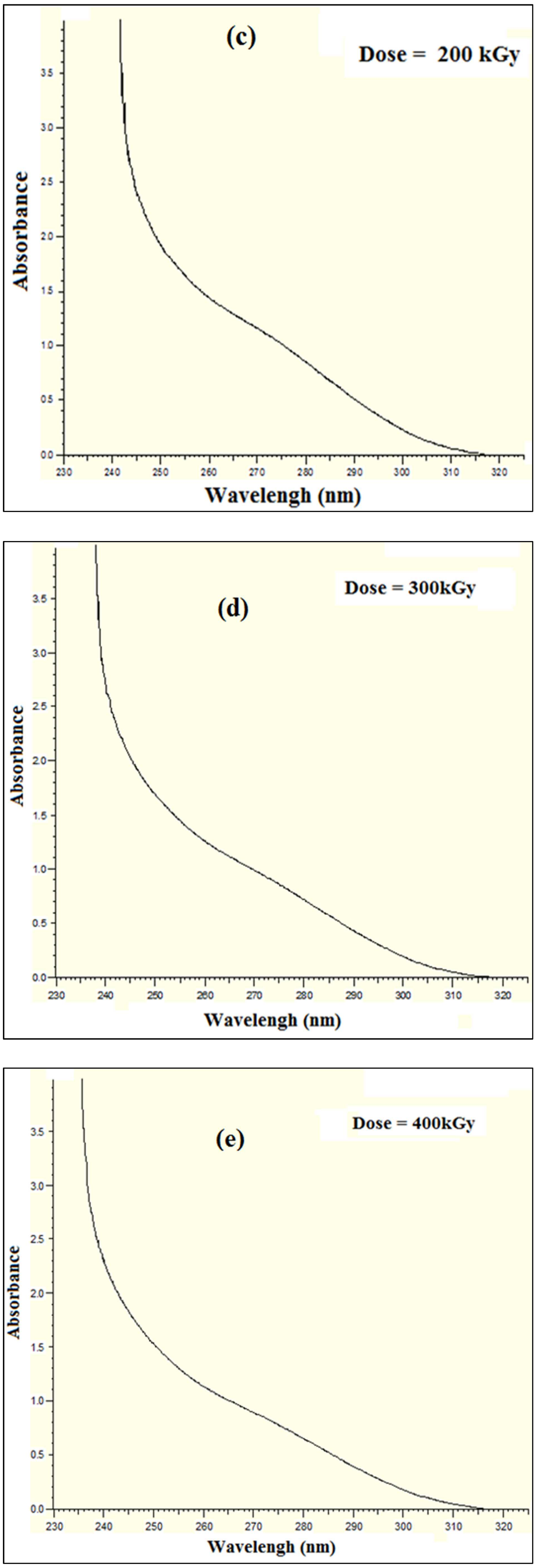
3. Results and Discussion

The poly-ally chain connected by di-ethylene glycol di-carbonate link form structure for CR-39 polymer. This structure containing three main functional groups: ally group, carbonyl group and ether group, which are responsible for the improvements in physicochemical properties after radiation exposure, so the presence of allyl group in the CR-39 structure makes it more sensitive for any type of radiation [2-9].

3.1. UV/Vis Studies

The transitions electronic in the visible region for the absorption spectra from the ground state to the excited state have been studied by UV-Visible technique. Figure 2. shows the variation in the absorbance of pristine and irradiated CR-39 detector samples with the wavelength at different doses: a) 0kGy, b)100 kGy, c)200 kGy, d)300kGy, e)400 kGy, f) 500kGy, and it is shown that the absorbance spectrum for all samples take the same behavior with slightly shift by increasing gamma doses. This shift denoted to the decrease in the optical band gap energy E_g [10], this behavior is correlated with the formation of carbon [11]. This result confirms that the influence of gamma ray on CR-39 polymer detectors are affected in the UV-Visible region, which is consistent with the pervious results [12-13].





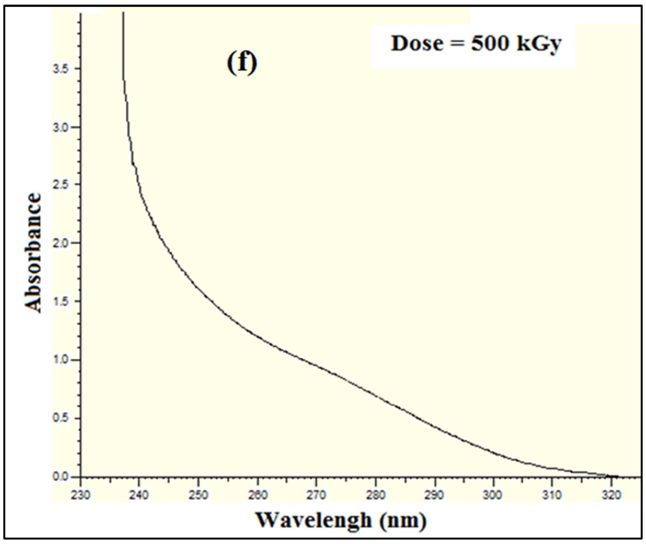


Figure 2. *UV-visible spectra of the variation in the absorbance at a) 0 kGy, b) 100 kGy, c) 200 kGy, d) 300kGy, e)400 kGy, f) 500kGy, with the wavelength.*

3.2. FTIR Spectroscopy

Figure 3 shows the spectra of FTIR for pristine and irradiated CR-39 sample detector with doses 0,100, 200, 300, 400, 500 kGy. It is clear that the FTIR spectra for all samples are characterized by number of peaks at 1817, 2367, 2645 and 3234 cm^{-1} is belong to carbonate group C=O stretching vibration, O=C=O asymmetric stretching, C-H Stretching, H_2O free stretching vibration, respectively [14]. After irradiation, there is no shift in the peak position or formation of new bonds, there are increases in the intensity of the characteristic peaks with increasing gamma ray, at 3234, 2367 and 1817 cm^{-1}. This increase may be related to more oxidation process that, in turn was produced on the polymer chains by increase gamma doses [15]. In general, did not observed change in the CR-39 groups under gamma irradiation, but observed changes in the intensities of peaks.

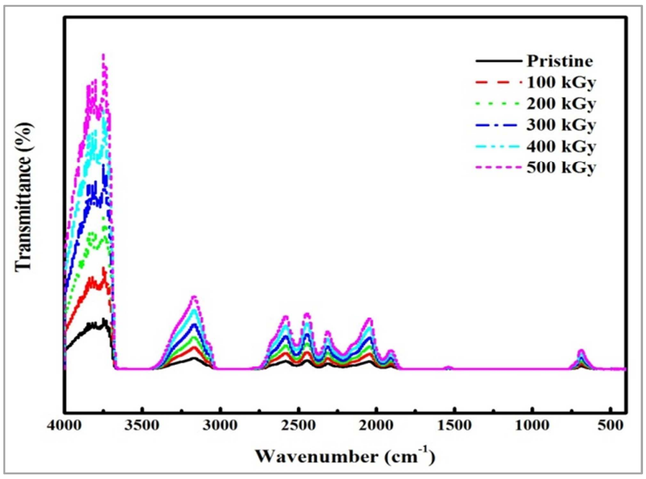


Figure 3. *Spectra of FTIR for pristine and irradiated CR-39 polymerwith different doses of gamma rays.*

4. Conclusion

The UV-Vis spectroscopy show transitions electronic in the visible region from ground state to excited state, by increasing gamma doses the absorbance spectrum for all samples take the same behavior with slightly shift. This shift due to decrease in the optical band gap energy E_g. Thus irradiation makes the polymer more conductive, by increase gamma ray did not observed changes in the CR-39 groups but observed change in the intensities of peaks.

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