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Modified the optical and electrical properties of CR-39 by gamma ray irradiation

A.M. Abdul-Kader [a,b,*], *M.F. Zaki* [c], *Basma A. El-Badry* [d]

[a] *Helwan University, Faculty of Science, Physics Department, Ain Helwan, Cairo, Egypt*
[b] *Umm Al-Qura University, University College, Physics Department, Al-Qunfoza, Kingdom of Saudi Arabia*
[c] *Experimental Nuclear Physics Department, Nuclear Research Center, Atomic Energy Authority, P.O. 13759 Abu Zaabal, Cairo, Egypt*
[d] *Physics Department, University College for Women, Ain Shams University, Cairo, Egypt*

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ABSTRACT

The radiation technique is a useful technology technique to induce suitable modifications of the polymeric materials. In the present work, poly allyl diglycol carbonate (CR-39) solid state nuclear track detector samples were irradiated using different doses (150–950 kGy) of gamma ray irradiations. The effect of gamma ray irradiations on the optical and electrical, properties of CR-39 was investigated. The obtained results showed a decrease in the optical energy gap with increasing the gamma dose. Increase in the numbers of carbon atoms (N) in a formed cluster with increasing the irradiation dose was observed. Meanwhile, an increase in the Ac conductivity was obtained with increasing the gamma dose. Also, the variation in the dielectric constant and loss with irradiation dose was studied at the room temperature. The results indicate that the gamma ray irradiations in the dose range 150–950 kGy enhance the optical and electrical properties of the CR-39 polymer samples.

1. Introduction

Poly allyl diglycol carbonate (CR-39) is a class of polymeric solid state nuclear track detector which has many applications in various radiation detections. CR-39 has index of refraction lower than that of crown glass and has also high abrasion. This makes it an advantageous material for eyeglasses and sunglasses (Abdul-Kader, El-Badry, Zaki, Hegazy, & Hashem, 2010). The modification of the polymers is an attractive way to tailor the response of different industrial devices in a wide range of applications. The radiation processing is a useful technology to induce suitable modifications of materials. The interest in radiation treatment of polymers has increased, prompted by the radiations induced modifications of the properties of various polymeric

* *Corresponding author*. Helwan University, Faculty of science, Physics Department, Ain Hellwan, Cairo, Egypt. Fax: +20 225552468.
E-mail address: atawab2001@yahoo.com (A.M. Abdul-Kader).
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materials. The physical and chemical modifications induced in polymers under radiation are triggered by the energy loss by the radiation within the target (Marletta, 1990). In recent years, the optical and electrical properties of polymers have attracted much attention in view of their applications in many optical and electrical devices (Reddy, Zhu, Mai, & Chen, 2006; Radwan, Abdul-Kader, El-Hag Ali, 2008). However polymer at present have many deficiencies, so new methods are required to improve the physical and chemical properties of polymers. Several methods are used to improve the properties of polymers like ion bombardment and electron beam and gamma ray irradiations, UV-light, plasma, … etc. Gamma-ray irradiation of polymers is one method among the physical modification methods, which recently received a lot of attention from the electronic engineering point of view. This is due to their linear energy transfer radiation is lower than that of the ions. Defects induced by irradiation inside the polymeric materials are responsible for changes in the optical (Kumar, Sonkawade, Chakarvarti, Singh, & Dhaliwal, 2012; Siddhartha, Kapil Dev, Raghuvanshi, Krishna, & Wahab, 2012; Rück, 2000; Šiljegović et al., 2011), electrical (Radwan, Abdul-Kader, et al, 2008; Abdel Moez, Aly, & Elshaer, 2012; Qureshi et al., 2009; Radwan, Fawzy, & El-Hag Ali, 2008; Verma, Dhar, Rath, Sarkar, & Dabrowski, 2012), mechanical (Pelagade et al. 2012; Anandha babu, Ramasamy, Vijayan, Kanjilal, Asokan, 2008; Seguchi, Kudoh, Sugimoto, & Hama, 1999) and chemical properties (Abdul-Kader, El-Gendy, & Al-Rashdy, 2012) of the polymer. The breakage of chemical bonds during the irradiation eventually leads to the release of hydrogen atoms as hydrogen molecule (Abdul-Kader, Turos, Grambole, et al., 2005) and the formation of double bonds –C=C– (Mott, 1969). Crosslinking and chain scission also occur. Exposure of the samples during and after the irradiation to the air leads to their oxidation (Abdul-Kader, Turos, Grambole, et al., 2005; Costa, Luda, & Trossarelli, 1997; Costa et al., 1998; Abdul-Kader, Turos, et al., 2005; Premnath, Harris, Jasty, & Merrill, 1996). The hydrogen release and the oxygen uptake cause changes in the physical and chemical properties of the polymeric material (Abdul-Kader, Turos, et al., 2005). The optical absorption method can provide information about the band structure and energy gap in crystalline and non-crystalline materials (Mishra et al., 2000).

The results presented in this work focus on the effect of gamma ray irradiation of CR-39 for use in suitable opto-electronic applications. The principal objective of this work is to improve the optical and electrical properties of CR-39 through gamma ray irradiation induced structural modifications of the polymer surface.

2. Experimental details

2.1. *Material*

CR-39 polymer is one of the trade names of the family poly allyl diglycol carbonate. The chemical composition of CR-39 is $(C_{12}H_{18}O_7)_n$, where H content is 6.6% wt, C content is 52.6% wt and O content is 40.8% wt. CR-39, sheet used in this study were manufactured by Pershore Mouldings (PM), Ltd, England. It is of thickness 1.5 mm and dimension 20 cm × 20 cm. This sheet was cut into 1cm × 1 cm sized samples.

2.2. *Irradiation facility*

The CR-39 polymeric samples were placed in polyethylene sachets and the irradiation was carried out with ^{60}Co Gamma source with energies in the order of 1.173 and 1.332 MeV, at a dose rate of 3.5 kGy/h at NCRRT, Atomic Energy Authority, Cairo, Egypt. The samples were irradiated at different absorbed doses ranging from 150 to 950 kGy at the same condition.

2.3. *Characterization techniques*

2.3.1. *Optical measurements*

The optical absorption spectra of the pristine and all the irradiated samples were subjected to spectral studies in the Ultraviolet and Visible regions. These studies were carried out by using UV-Visible 8500 Double-Beam Spectrophotometer TECHCOMP in the wavelength range of 190–1100 nm having resolution of 0.1 nm. All the spectra were recorded by mounting the samples in the Integrating Sphere Assembly attached with the Spectrophotometer, keeping air as the reference.

2.3.2. *Electrical measurements*

The electrical properties of the pristine and gamma irradiated polymer samples were carried out at room temperature by using an LCR Bridge Model Z Hioki-3531, Japan. This bridge is good earthed, and all connected cables are good shielded, and connected to the earth. The two surfaces of each polymer samples were coated with silver paint and checked for good conduction and then kept in between the two cell electrodes for making measurements. The bridge can be used to measure different parameters: resistance, dielectric loss ($D = \tan \delta$) and capacitance in the frequency range of 42 Hz to 5 MHz at room temperature. The AC conductivity was calculated using the relation d/RA (Ω^{-1} m^{-1}) (Singh, Sharma, Shrinet, Rakshit, & Avasthi, 2004). The measured values of capacitance then have been converted into the dielectric constant (ε) by using the formula ($Cd/\varepsilon_o A$) (Singh & Prasher, 2006), where d is the thickness of polymer sample, A is the area of electrode plates and ε_o is the permittivity of free space.

3. Results and discussion

3.1. *UV–VIS spectral analysis*

Fig. 1 shows the UV-visible spectra recorded for gamma irradiated CR-39 samples at different doses by using the UV-visible spectrophotometer. One notes that with increasing gamma doses, the UV/Vis spectra of the polymers show red shift that indicates a decrease in the band gap (Singh and Prasher, 2004). This shift in absorbance is thought to be caused by the formation of conjugated bonds i.e. possible formation of carbon clusters and/or defects. The visual observation of the irradiated samples indicates change in the colour while the pristine sample is colourless.