Australian Journal of Basic and Applied Sciences
2019 September; 13(9): pages 99-104
DOI: 10.22587/ajbas.2019.13.9.9
Original paper
AENSI Publications
Journal home page: www.ajbasweb.com

Comparative study of the effects of X-ray and electron irradiations on the optical properties of the Solid State Nuclear Track Detector (CR-39)

KH.M. Abdel Raouf [1], Kh.M. Hella[2], and A. Rashad[3]

[1,2] Physics Department, Al- Qunfudhah University college, Umm Al-Qura University, Kingdom of Saudi Arabia
[1]Radiology Department Zagazig University Hospital Zagazig University Zagazig, Egypt
[2]Experimental Nuclear Physics Department, Nuclear research Center Atomic Energy Authority, Cairo Egypt B.O.13759
[3]Acceleration Department Nuclear research Center Atomic Energy Authority, Cairo Egypt B.O.13759

Corresponding authors: Kh.M. Hella
Physics Department, Al- Qunfudhah University College, Umm Al-Qura University, Kingdom of Saudi Arabia
Email: khalidhella@yahoo.com

Received date: 15 July 2019, Accepted date: 28 September 2019, Online date: 30 September 2019

Abstract

Recently, Solid State Nuclear Track Detector (CR-39) has a very important place at the top of the radiation detector for passive measurement, For this reason many investigation were done to improve the properties of this detector. In this investigation the energy gap of the SSNTD were calculated by measuring transmission at different wave length for ten samples, five of them were irradiated by electron at different energies while the other five samples were irradiated using X-ray at radiation part of the university hospital of Zagzig university, Zagzig, Egypt. Another one sample was used as standard sample. The transmission for all samples was measured at the National Research Center Al-Doqe, Cairo Egypt

Keywords: CR-39, energy gap

INTRODUCTION

In last Decades solid state nuclear track detector has the first priority of nuclear detectors in many fields; many types of detectors (organic and inorganic materials) were prepared to cover a wide range of nuclear measurements according to its properties It is well-known that Poly-allele-diglycol-carbonate (C-39) related to the chemical formula of $C_{12}H_{18}O_7$(its molecular structure is shown in Scheme 1) is one of the solid-state nuclear track detectors (SSNTD) that often uses in detecting charging nuclear particles.

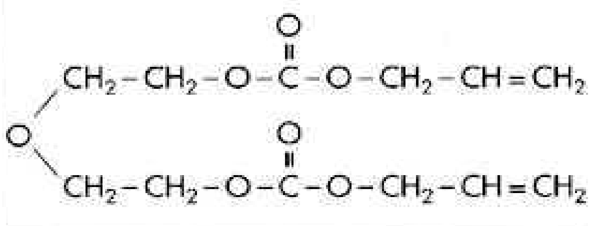

Fig.1 shows the basic chemical structure of CR-39 monomer.

The characteristic of CR-39 is visually transparent in the visible spectrum while most of it is completely opaque in the infrared and ultraviolet spectral regions (G. Marletta, 1990). It has been reported to the possibility of improving the properties of the polymeric materials through several treatments such as doping, irradiation, annealing *etc*., which make it a promising candidate for commercial applications (R.C. Ramola et al, 2009). Much of these effects, leads to modifying the materials polymeric structure *via* destroys the initial structure by way of the cross-linking which reflects an increase in the materials molecular weight and formation of a macroscopic network (H.S. Virk et al, 2001) *via* also a free-radical process of being formed, not able to be undone bond sharp divisions, etc. that outcome in the being broken into small of molecules and consistency of saturated and unsaturated groups (A.F. Saad et al, 2005). All these processes which lead to introduce the so-called defects inside

Citation: KH.M. Abdel Raouf, Kh.M. Hella, and A. Rashad Comparative study of the effects of X-ray and electron irradiations on the optical properties of the Solid State Nuclear Track Detector (CR-39). Australian Journal of Basic and Applied Sciences, 13(9): 99-104. DOI: 10.22587/ajbas.2019.13.9.9

the polymeric materials are responsible (M.A. El-Shahaw, 1997) for the changes occur in the visual, electrical, mechanical and chemical characteristics of the substance. These effects depend on the amount of energy deposited in the polymer. The polymer irradiations process became one of the most acceptable approaches to modify significantly the polymer physical properties.

Several authors (G. Marletta, 1990; R.C. Ramola et al, 2009; M.F. Zaki, 2008; S. Singh et al, 2008; T. Phukan et al, 2003; H.S. Virk et al, 2001;) found that the visual characteristics of CR-39 irradiated with various doses of gamma rays, X-rays, and various particle fluencies. Also, it could be noticed that the visual band gap energy was lowering with elevate of gamma-absorbed dose as-well-as ions fluencies. Similar studies have been carried out by other authors. (A.F. Saad et al, 2005) pointed out that the qualitatively the lowering in the bandgap with elevating gamma dose with the most up to 400 kGy. (M.A. El-Shahawy, 1997) found that a small reduce not immediately caused by bandgap with elevate in gamma dose up to the most of 100 kGy. (H.El.Ghandoor et al, 1996) researched the influence of gamma irradiation on the refractive index of CR-39 polymer. (S. Singh et al, 2004) have quoted a lowering in bandgap with elevate in gamma dose without indicating if the bandgap was immediate or indirect. However, with respect to the effects of the irradiation process on the refractive index of CR-39 polymeric material the published data is rare in the reported literature.

The present work aims to compare the effects of low doses of X-ray and electron irradiations on the optical properties of the CR-39 polymeric material; namely the refractive index and the optical bandgap energy.

EXPERIMENTAL TECHNIQUE

Poly-Allyl-Diglycol-Carbonate, CR-39, sheets of thickness 0.5 cm The SSNTD's (CR-39) manufactured by TASTRAK factory (Track Analysis System Ltd., UK) with thickness 0.5 mm and density 1.31 g/cm3 were used in this study. The sheet was cut into pieces with an area of 1 × 1 cm^2 before uses. One of the pieces was left without irradiation as a base sample, and two groups each contain five samples have been irradiated in air at the linear accelerators of radiology department, Zagazig University Hospital, Zagazig University-Egypt; the required doses were obtained by adjusting the electron beam parameters and conveyer speed. The 1^{st}group was irradiated by an electrons with different energies of 4, 6, 8 12, 15 MeV while the 2^{nd}group was irradiated by the X-ray with energies of 50, 100, 150, 6000, 15000 kV.

The transmission and reflection spectra of the un-exposed and radiation-exposed samples were measured within the wavelength optical range 190-2500 nm; using a double-beam spectrophotometer, the measurement was carried out at room temperature at National Research Center-Egypt.

RESULTS AND DISCUSSIONS

.

Fig.2a, 2b shows the transmittance, *T* and reflectance, *R* spectra of the samples irradiated by electrons (Fig.2 a) and X-ray (Fig.2 b) at different energies doses.

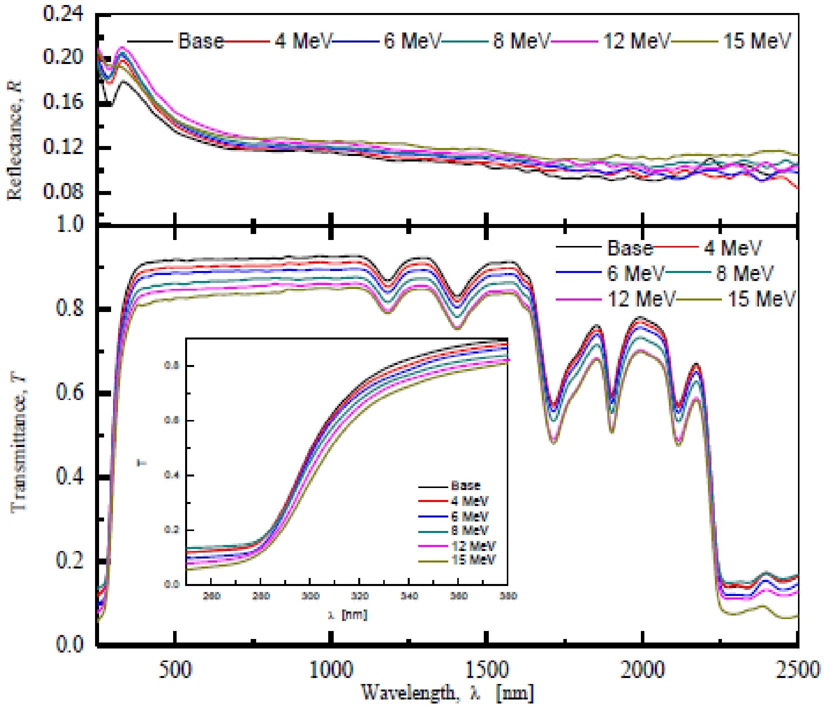

Fig.2a shows the transmittance and reflectance spectra of the samples irradiated by electrons

Citation: KH.M. Abdel Raouf, Kh.M. Hella, and A. Rashad Comparative study of the effects of X-ray and electron irradiations on the optical properties of the Solid State Nuclear Track Detector (CR-39). Australian Journal of Basic and Applied Sciences, 13(9): 99-104. DOI: 10.22587/ajbas.2019.13.9.9

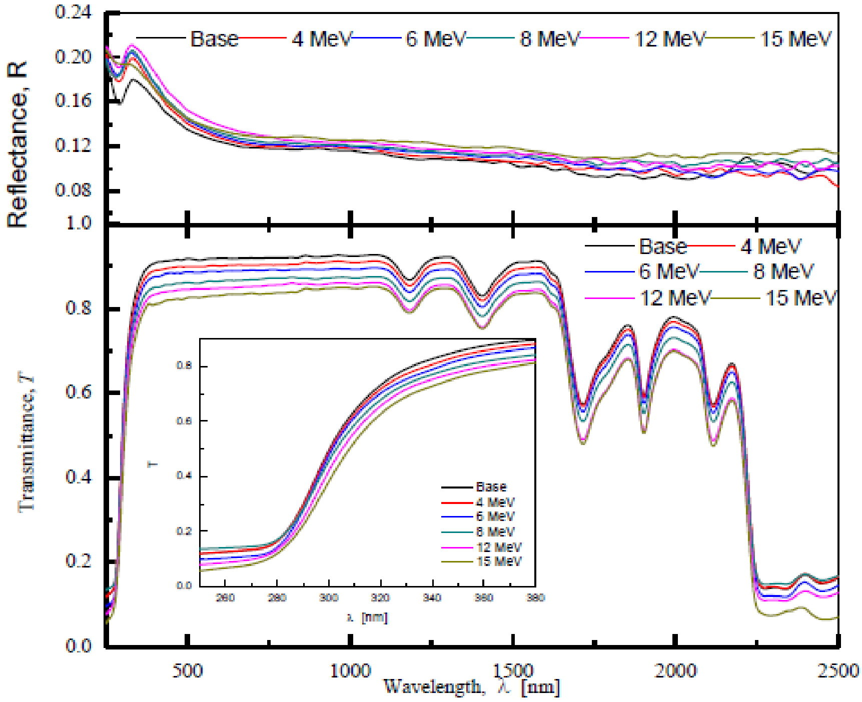

Fig.2b The transmittance and reflectance spectra of the samples irradiated by X-Ray

It has been observed that theun-irradiated CR-39sample is highly transparent reach a value of transparency of 90%. It was found that, once the samples were irradiated by such as electrons or X-ray the transmittance values decreases gradually while the reflectance increases with the increases the radiation dose. Furthermore, the transmittance spectra of the samples can be divided to three different regions; the 1st region characterizes the fundamental absorption edge in the wavelength optical range 250-400 nm; at which the materials are strong absorption the incident light. The 2ndregion in the wavelength range 400-2160; where the transmission spectra contain five absorption bands observed at 1180, 1400, 1720, 1900 and 2110 nm, respectively. These absorption bands are due to the C-H stretching. The 3rd region observed in the wavelength range 2110-2500 nm; where strong absorption has occurred, indicates that the CR-39 are almost opaque in near-infrared spectral region (beyond 2110 nm). This result characterizes the most cited behavior of the transmission spectra of the CR-39 polymeric material. Furthermore, for both types of radiations, a slight redshift in the fundamental absorption edge has been also observed with the increases of the radiation dose (See Fig.3a, b)

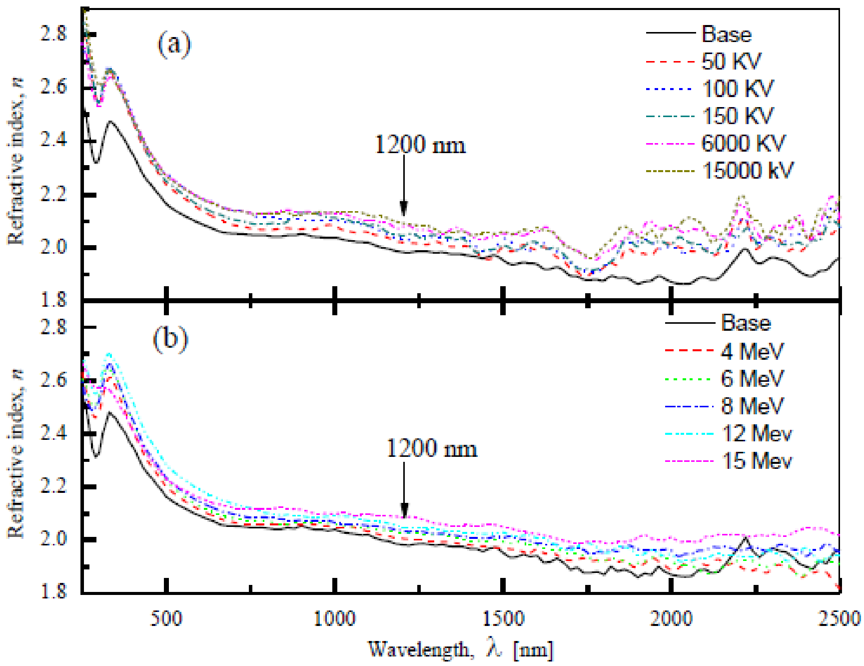

Fig.3a, b Refractive indexfor samples irradiated by X-ray and eletrons

Citation: KH.M. Abdel Raouf, Kh.M. Hella, and A. Rashad Comparative study of the effects of X-ray and electron irradiations on the optical properties of the Solid State Nuclear Track Detector (CR-39). Australian Journal of Basic and Applied Sciences, 13(9): 99-104. DOI: 10.22587/ajbas.2019.13.9.9

The real and imaginary parts of the complex refractive index, *n* and *k*, have been calculated as a function of the radiation doses from the recorded transmittance and reflectance spectra *via* the relations:

$$n = \left\{ \sqrt{\frac{4R}{(R-1)^2} - k^2} - \frac{(R+1)}{(R-1)} \right\} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(1)$$

Where *n* is the real part of the refractive index and *k* is the imaginary part of the refractive index and frequently called the extinction coefficient $(= \alpha\lambda/4\pi; \text{where}, \alpha \text{ isabsorption coefficent})$.The absorption coefficient α can be also calculated from the well-known relation

$$\alpha = (\frac{1}{t}) \ln\left(\frac{1}{T}\right) cm^{-1} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.\ldots.(2)$$

Where *t* is the sample thickness.

Fig.4a, b shows the spectral variation of the refractive index, *n*(Fig.4a) and the extinction coefficient, *k* (Fig.4b).The figures depict; that for such of the investigated samples, the refractive index, *n*(Fig.4a) decreases with the increases of the wavelength and also with increasing the radiation doses. The dispersion of the refractive index values observed beyond the wavelength 2110 nm can be attributed to the presence the absorption in this region. The estimated values of the refractive index as a function of the X-ray or electrons irradiation doses taken at 1200 nm; after the fundamental absorption edge and before the observed absorption bands are listed in Table 1. It has been observed that for both types of radiation the refractive index of CR-39 increases with the increase the radiation doses. On the other hand the extinction coefficient, *k* (Fig.4b) in the fundamental absorption edge (250-400 *nm*) showed decreases with the increase in the wavelength (see inset of Fig.4b), thereafter takes minimum values at the highest transmittance region (400-1200 *nm*). The characteristic bands observed in the extinction coefficient curves are related directly to the bands occurred in the transmittance spectra (See Figs.1 a, b). It has been observed that for both types of radiation the refractive index of CR-39 increases with the increase the radiation doses.

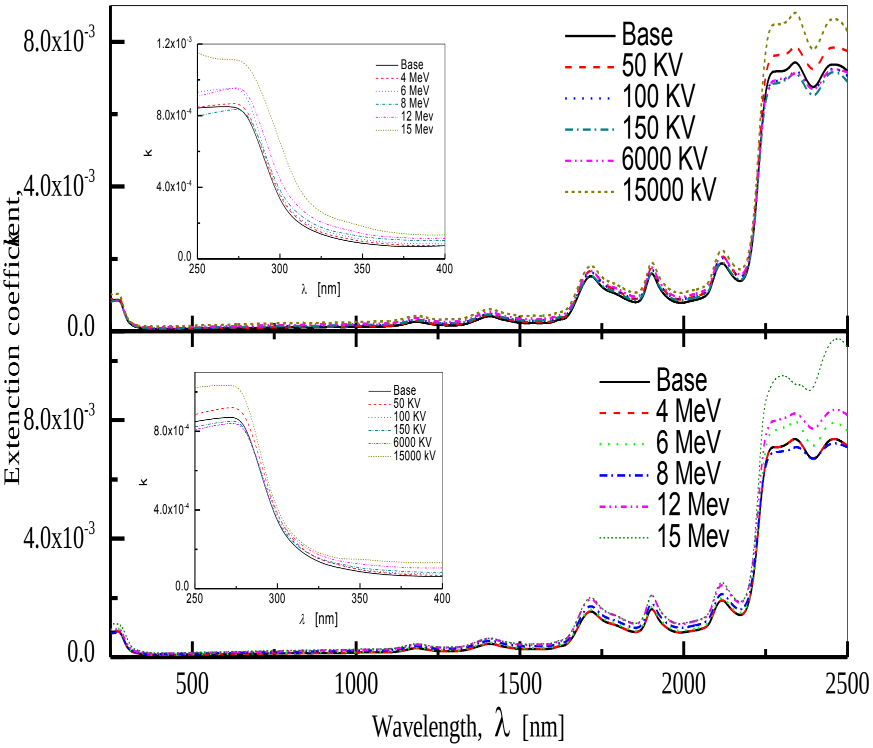

Fig.4a, b Extenction coefficient for samples irradiated by X-ray and eletrons

Fig.5 a, b shows the optical absorption coefficient, $\alpha$of the, investigated CR-39 samples at the fundamental absorption edge as a function of the X-ray and electron radiation doses. The figure depicts that the absorption coefficient increases with increasing the photon energy and for both types of radiations the absorption coefficient increase with the increase of the working dose.

Citation: KH.M. Abdel Raouf, Kh.M. Hella, and A. Rashad Comparative study of the effects of X-ray and electron irradiations on the optical properties of the Solid State Nuclear Track Detector (CR-39). Australian Journal of Basic and Applied Sciences, 13(9): 99-104. DOI: 10.22587/ajbas.2019.13.9.9

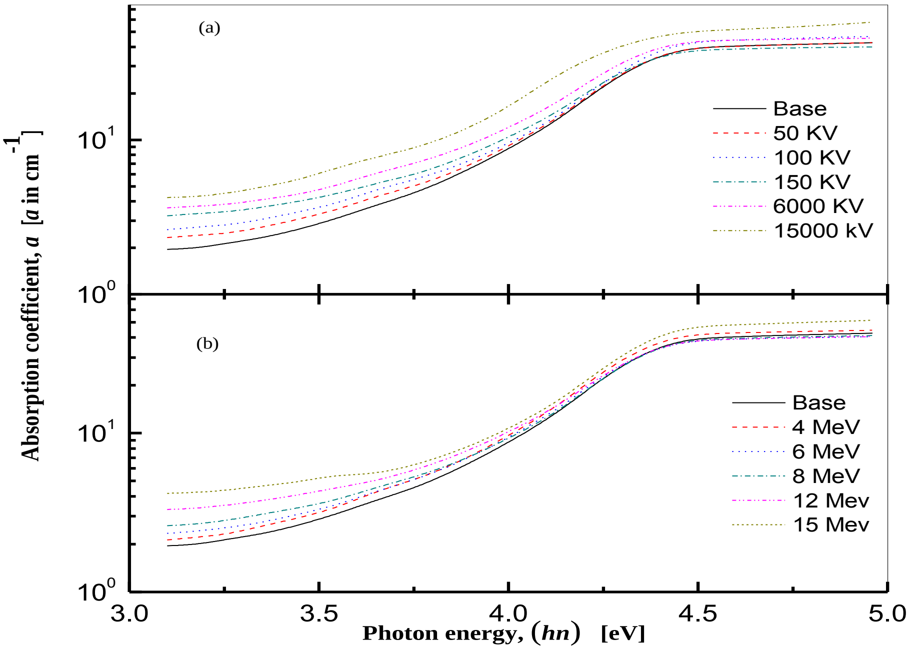

Fig.5 a, b The optical absorption coefficient, CR-39 at the fundamental absorption edge as a function of the X-ray and electron

The analysis of the absorption coefficient according to this relation:

$$(\alpha h\nu) = \beta(h\nu - E_g)^m \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where $h\nu$ is the photon energy, $(h\nu = 1240/\lambda)$ and β is a constant. The exponent *m* determines the type of the optical transition, which takes the values of $1/2$, 2 for direct and indirect optical transitions, respectively. The plots of $(\alpha h\nu)^{1/2}$*vs.* photon energy, $h\nu$ as shown in Fig.6 a, b enables us to determine the value of the optical bandgap as a function of radiation doses; by extrapolation the linear parts to zero energy. It has been observed that the values of the energy gap slightly decrease with the increase of the radiation doses, where X-ray radiation has slightly higher effects than the electron radiation.

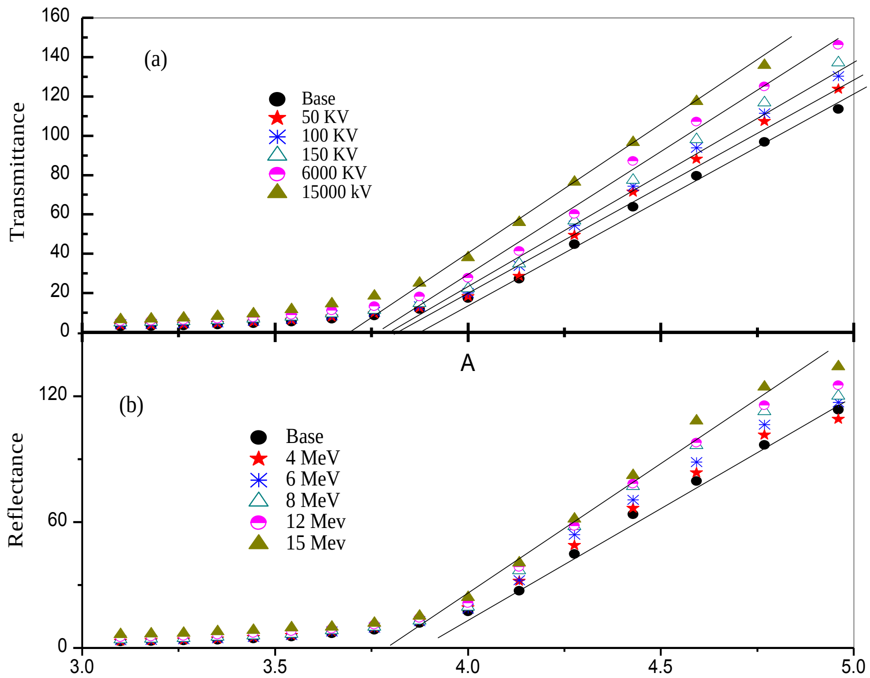

Fig.6 a, b used to determine the value of the optical band gap as a function of radiation doses

Citation: KH.M. Abdel Raouf, Kh.M. Hella, and A. Rashad Comparative study of the effects of X-ray and electron irradiations on the optical properties of the Solid State Nuclear Track Detector (CR-39). Australian Journal of Basic and Applied Sciences, 13(9): 99-104. DOI: 10.22587/ajbas.2019.13.9.9

ACKNOWLEDGMENT

This work was supported by the Deanship of Scientific Research, under Grant no. 43405054. Great thank for the Physics Department, Al- Qunfudhah University College, Umm Al-Qura University and the National Research Center Al-Doqe, Cairo Egypt

REFERENCE

A.F. Saad, S.T. Atwa, R. Yokota, M. Fujii, Radiation-induced modifications on spectroscopic and thermal properties of CR-39 and SR-90 nuclear track detectors. Radiat. Meas. Volume 40 (2–6), 780-784 (2005).

G. Marletta, Chemical reactions and physical property modifications induced by keV ion beams in polymers. Nucl. Inst. Meth. Phys. Res. B46, (1–4), 295-305 (1990).

H. El-Ghandoor, S.A. El-Fiki and S.Y. El-Zaiat, Interferometric investigation of the effect of gamma radiation on the refractive index of CR-39 polymer Opt. and Laser Tech 28(8) 585, (1996).

H.S. Virk and AK Srivastava. , Modification of optical, chemical and structural response of CR-39 by 50 MeV lithium ion irradiation. *Radiat Meas.*; **34**, (65-67), (2001).

M.A. El-Shahawy, Spectral changes of CR-39 induced by irradiation and heat treatment. Journal of Polymer Degradation and Stability 57, (157-161) (1997).

M.F. Zaki. Gamma-induced modification on optical band gap of CR-39 SSNTD. *J. Phys. D: Appl. Phys*. **41**, (175404-175408), (2008).

R.C. Ramola, S. Chandra, A. Negi, J.M.S. Rana, S. Annapoorni, R.G.Sonkawade, P.K. Kulriya and A. Srivastava. Study of optical band gap, carbonaceous clusters and structuring in CR-39 and PET polymers irradiated by 100 MeV O7+ ions Physica B404(1), 26, (2009).

S. Singh and S Prasher.The optical, chemical and spectral response of gamma-irradiated Lexan polymeric track recorder. *Radiat. Meas.*; **40**, (50-54), (2005).

S. Singh, and S .Prasher The etching and structural studies of gamma irradiated induced effects in CR-39 plastic track recorder. Nucl Inst. Meth. Phys. Res. B222 (3-4), (518-524) (2004).

T. Phukan, D. Kanjilal, T.D. Goswami and HL Das. Study of optical properties of swift heavy ion irradiated PADC polymer. *Radiat. Meas.*; **36**, 611, (2003).