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Optical Properties of CR-39 Plastic Detectors Irradiated by He:Ne Laser

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Abstract: The CR-39 detector was irradiated by He:Ne laser at wavelength (532) nm . The laser energy doeses varied between 0 and 50 mW. The exposure time is (3) min. The optical parameters of these samples are inspectedby using two beams spectrophotometer in the spectral rangewavelength of 200 nm to 1100 nm. It was found that the average transmittance of the samples is about (80%) at wavelength(300) nm.

Optical measurement showed that the CR-39 detectorhas direct energy band gap.The fundamental absorption edge shifts towards the higherwavelength with the increasing of the laser energy. It is showed that the energy band gap decreases from 4.1 eV to 3.65eV when laser radiation energy is increased from0 to 50 mWwhile the absorption, extinction coefficient,refractive index (n)andoptical conductivity (σ) increases with the increasingof laser energy.

Keywords: CR-39 detector, He:Ne laser, optical properties

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Introduction

The study of optical properties of materials are very important to give information about the electronic transitions, defects, reduction of arrangement (disorder), the energy gap and other optical properties of the materials . [1]In general, the optical properties of thin films differ from the bulk materials and that is because of the microstructureof materials [2].

CR-39 detector is the chemical name allyl diglycol carbonate (ADC) which can be considered as a plastic polymer with transparent nature in the visible spectrum region[3].

CR-39 detector is characterized by a flexible, transparent, colorless and is resistant to many chemical solvents and mechanical stresses[4].The extraordinarycharacteristics

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of CR-39 detector. So, it is used in many applications, such as:nuclear path detector for revelation of charged particles,glass-reinforced fuel tank for fighter planesand optical uses in the lenses of eyeglasses[5].Lately,CR-39 plastic detector has been broadly utilized as nuclear path indicator for disclosure of charged particles. It has been additionally,utilized to monitor concentration of radon gas by recording particles radiated from the radon[6].

At the point when CR-39 is presented to charged particles, it makes a series ofhidden spoiling because of low straight vitality exchange (named inactive path) which can be made noticeable under microscope when scratched in a reasonable revealer under ideal circumstances.Radiation is one of the main parameters that changes the structural properties of polymers[5,6].

The low energies of the gamma rays, X-rays or laser radiation createmany changes in the form of molecular chains that make up the polymer.These changes have made an influence on the optical properties .Theyhave got variousapplications in many different scientific and technological fields[7].

The effect of laser radiation on the CR-39detector depends on the laser properties,such as:energy density ,Duplication rate, exposure time ,wavelength and thickness of detector[8].Many of the studies have been performedto show the influence of laser radiation on the chemical and physical characteristics of the CR-39 [9,10].

The optical penetration depth for CR-39has been studiedusing by XeCl and ArF laser with a wavelength of (248)nm and (193) nm respectively[11]. It was noted that the optical penetration depth decreases with the increasing of the radiation energy and diameter tracks decreases with the increasing of the dose of radiation exposure.

On the other hand, there is a large number of researches that have studied the effect of high doses of radiation on polymer CR-39. Theseresearchesarerelated withthe examination of the tracks and the optical absorption of the material[12].

In the current research, the influence of He-Nelaser with different energies of (5 ,25,50) mW on the optical characteristics of CR-39 will be studied.The change in the absorption coefficient and energy band gap of CR-39 detector was investigatedusing double beam of spectrophotometer.

Experiment

The samples were prepared from CR-39 sheet with area (4 cm^2). They were exposed at wavelength (532) nm of He:Ne laser radiation beam for (5, 25, 50) mW energies. The irradiated time was(3) minfurthermore, the separation between sample and laser source was (2)cm.Figure (1) illustrate the Schematic of laser irradiation system.

The optical properties studies were carried out by measuring the transmittance (T) in the wavelength of200 nm to 1100 nm by using spectrophotometer (Ultraviolet-Visible)(UV-1800) .

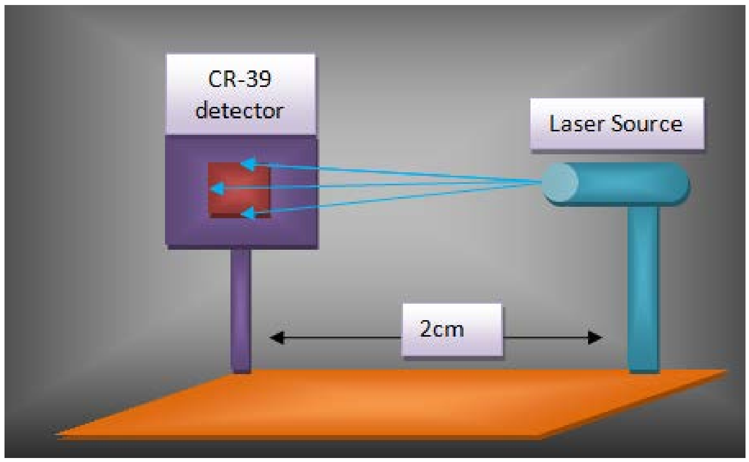


Fig. (1): Schematic of laser irradiation system

Results and discussion

The optical parameters of CR-39 detectors were investigated by measuring the transmittance (T) in the wavelength (λ) rangeof (200 -1100) nm. The optical transmittance spectra of all samples were recorded.

Figure (2) shows variation of the transmittance as a function of wavelength with energies of laser (5, 25,50)mW. It was found that the average transmittance of the samples are about (80%) at wavelength (300 nm).

The optical spectra of all samples shows deviation in the fundamental absorption edge towards smaller photon energy with raising of laser energy.The measurement of the optical constants procedure can give additional knowledge about nature of the energy band gap for crystal structure of materials.

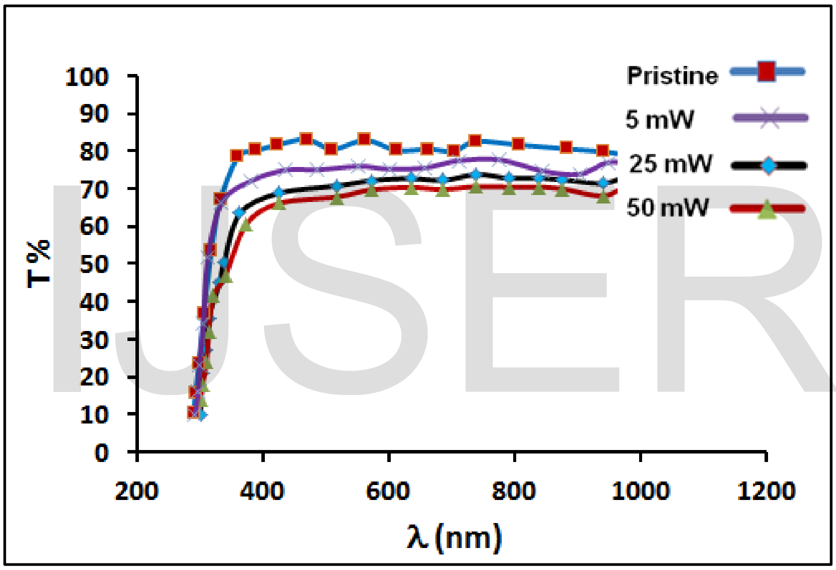


Fig. (2):Transmittance versus wavelength for CR-39 detector with different laser energies

The absorbance (A) represents the logarithm of the reciprocal of transmittance (T)[13]:

$$A = \log \frac{1}{T}$$

The fundamental absorption edge for CR-39 detectors is about (340)nm .Also, the fundamental absorption edge do not pointedly indicate the non-crystalline or amorphous nature of the samples. The absorbance decreased with the increasingof the wavelength (λ) and increased with the increasing of the laser dose as given in thefigure (3).

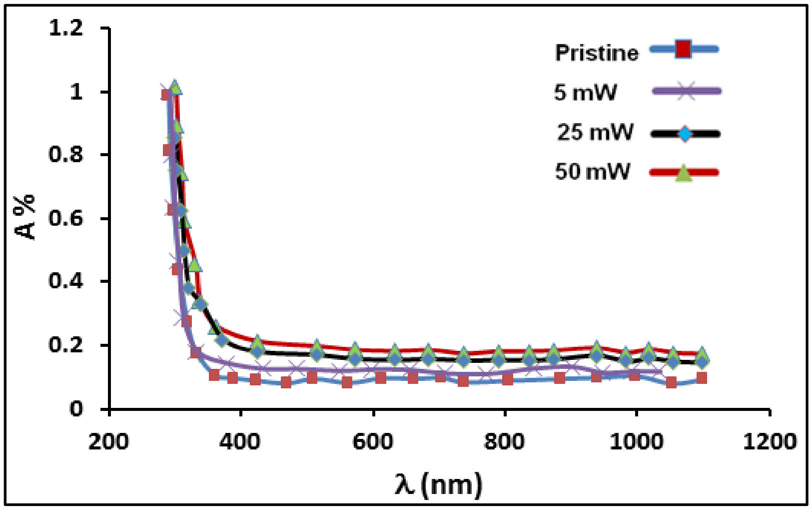
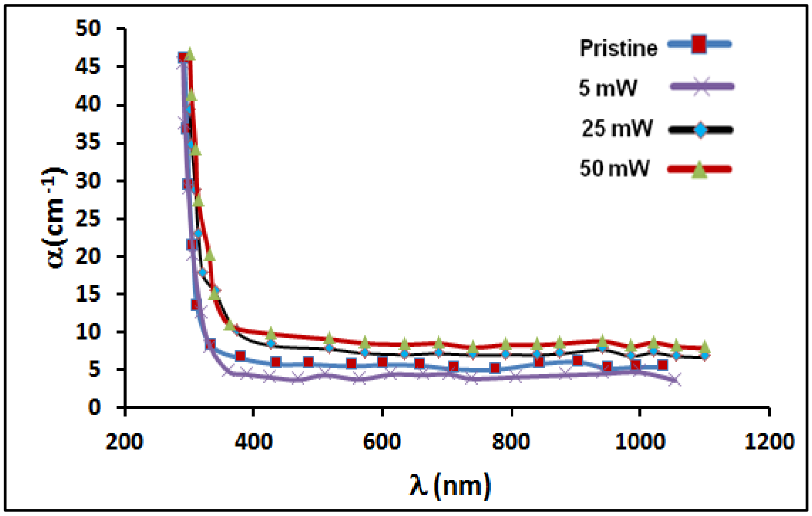


Fig. (3):Absorbance versus wavelength for CR-39 detector with different laser energies

According to absorption spectra,there must be a decay of molecules which may wind up with the chain scission in the materials.Accountingthe chain scission, the sample has gotten to be plasticized.The optical energy gap for all samples were calculated in terms of the absorption coefficient (α), when the light falls by initial intensity (I_o) on the sample with thickness (t) .Therefore; the change in the intensity is a result of passingthe light distance in the sample.Absorption coefficient (α) can be expressed in the following equation[14] :

$$\alpha = 2.303\frac{A}{t}$$

The value of the absorption coefficient changes with the wavelength (where this change depends on the properties of



semiconductor material as well as on energy photons (hν)).

Fig. (4):The absorption coefficient versus wavelength for CR-39 detector with different laser energies

Figure (4) illustrates the variation of absorption coefficient (α) versus wavelength (λ). The absorption coefficient is found to be increased after the laser irradiation of the samples. These values of the absorption coefficient show that the electronic transition of semiconductor is of a direct transition.

It is possible to calculate the energy value by plotting the relationship between the photon energy (hν) as a function of $(\alpha h\nu)^2$ and the extrapolation (E_g) of the portion at [$(\alpha h\nu)^2 = 0$], as appeared in figure (5).The rapport between $(\alpha h\nu)^2$and ($h\nu$) was examined to evaluate the type of the optical transition.

Extrapolating the straight lines of these relation ($h\nu$) axis produces anoptical energy band gap (E_g):[15,16]:

$$\alpha = \frac{A_o\left(h\nu - E_g\right)^{r/2}}{h\nu}$$

Where:(r)is a constant, depending on the nature of the electronic transitions which is equal to (1) for a direct energy band gap .

(ν)and (h) are the frequency and Planck constant respectively.

$A_0$is a fixed.

Figure (5)illustrates the variation of the value of $(\alpha h\nu)^2$as a function(hν) . It was4.1eV for pristine CR-39 detector and shows by 4.0eV,3.8 eVand 3.65eV after irradiation by He:Ne laser beam depending on laser energy. These values of energy band gap are, nearly, in agreement with values reported by [17].

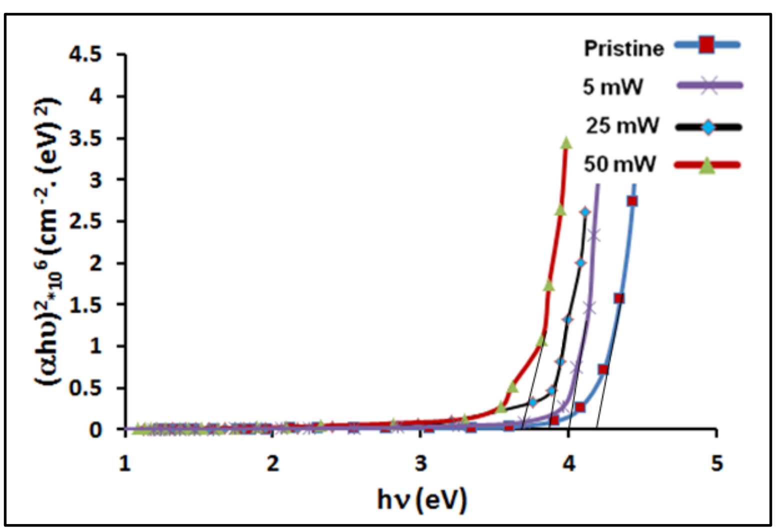


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Fig. (5):Variation of $(\alpha h\nu)^2$ versus $(h\nu)$ for CR-39 detector with different laser energies

The values of E_g for different laser doses are presented in table (1). This result affirms that the irradiation with He-Ne laser produces defects in the polymers structure, which increases the electronic perturbation . this electronic perturbation stimulates the production of an allowed state in the optical energy gap or the distortion of the valence band [18].Absorption, likewise, increases with the increasing of the laser intensity.

The diagram in figure (6) illustrates the alteration in optical energy gap with the increasing of the laser exposure density. It, also, shows a linear decrease of the optical energy.

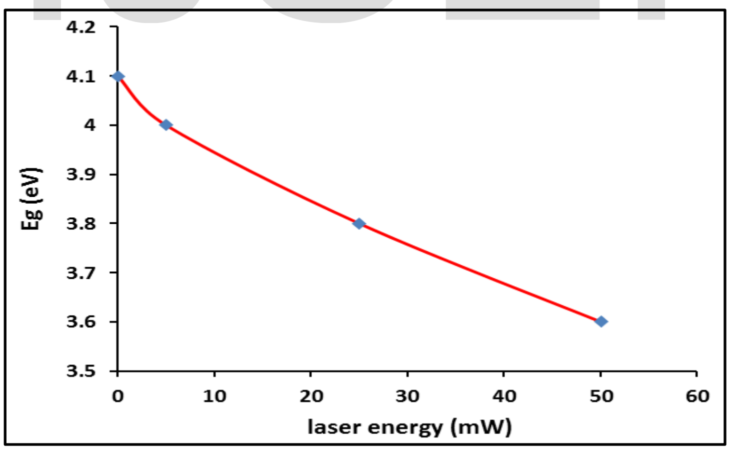

Fig.(6): The Effect of the laser energy on the optical energy gap of CR-39 plastic detector.

The extinction coefficient (k) has been calculated by the following equation [19]:

$$k = \frac{\alpha\lambda}{4\pi}$$

The value of extinction coefficient (k) increases with the increasing of the laser density, as shown in figure (7).

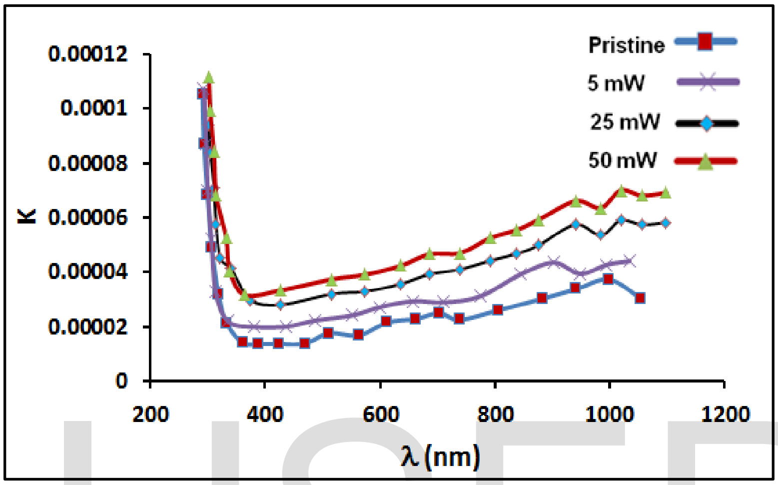

Fig. (7):The extinction coefficient versus wavelength for CR-39 detector with different laser energies

The refractive index (n) can be measured using by the following equation [20]:

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

where (R) is the reflectance.

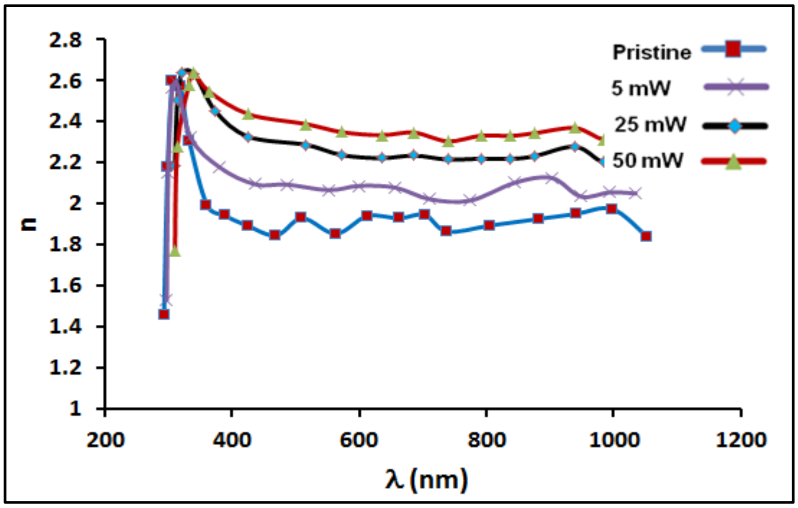

Fig. (8):The refractive index versus wavelength for CR-39 detector with different laser energies

Referring to the optical transmittance studies, the refractive index increased with the increasing of the laser energy dose. It is seen that the value of refractive index lies in the range (2.0-2.6), as given in the figure (8).

The real part of the dielectric constant(ε_r) as well as the imaginary part of the dielectric constant (ε_i), could be procured by stratify the following relationship: [21]

$$\varepsilon_r=n^2-k^2$$
$$\varepsilon_i=2nk$$

Variation of dielectric constants (ε_r) and (ε_i) with wavelength for different laser energies is shown in figures (9) and (10) respectively. From these figures, it can be shown that the values of dielectric constants initially increases with the increasing of wavelength and reaches a maximum value and then decreases and increases with the increasing of wavelength laser energies.

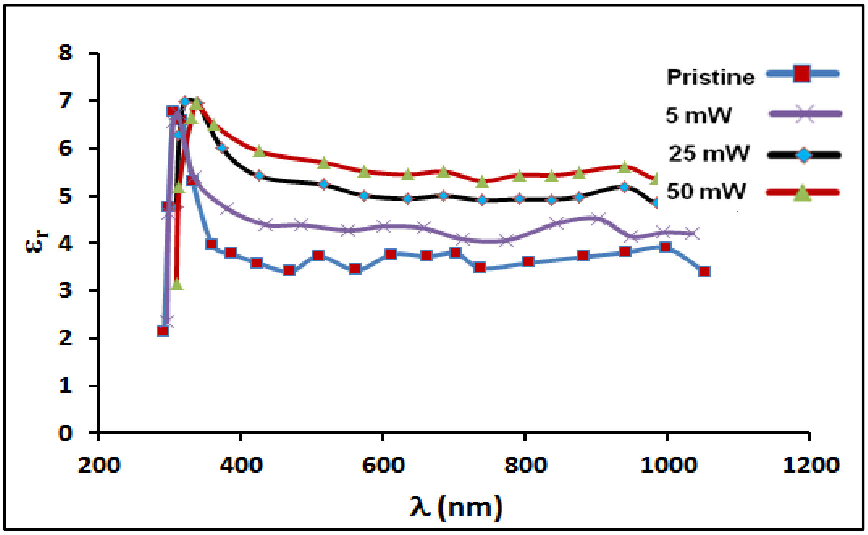

Fig. (9):Real dielectric constant(ε_r) versus wavelength for CR-39 detector with different laser energies

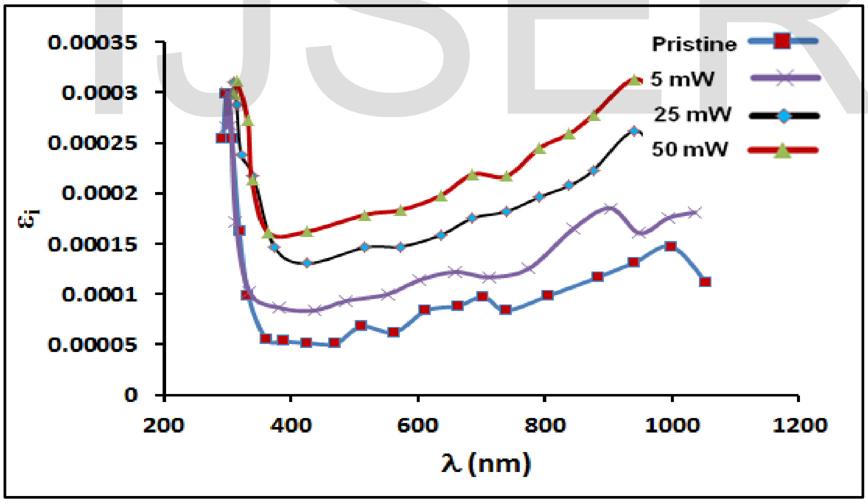

Fig. (10):Imaginary dielectric constant(ε_i) versuswavelength for CR-39 detector with different laser energies

The optical conductivity (σ)is given as[22]:

$$\sigma = \frac{\alpha n c}{4\pi} \quad (\mathrm{Sec})^{-1}$$

Where (n) and (c) are the refractive index and the velocity of light, respectively.

Figure (11) shows the variation of the optical conductivity(σ) as a function of the photon energy(hν) for CR-39 detector with differentlaser energies .The value of optical conductivity depends on refractive index and absorption coefficient.

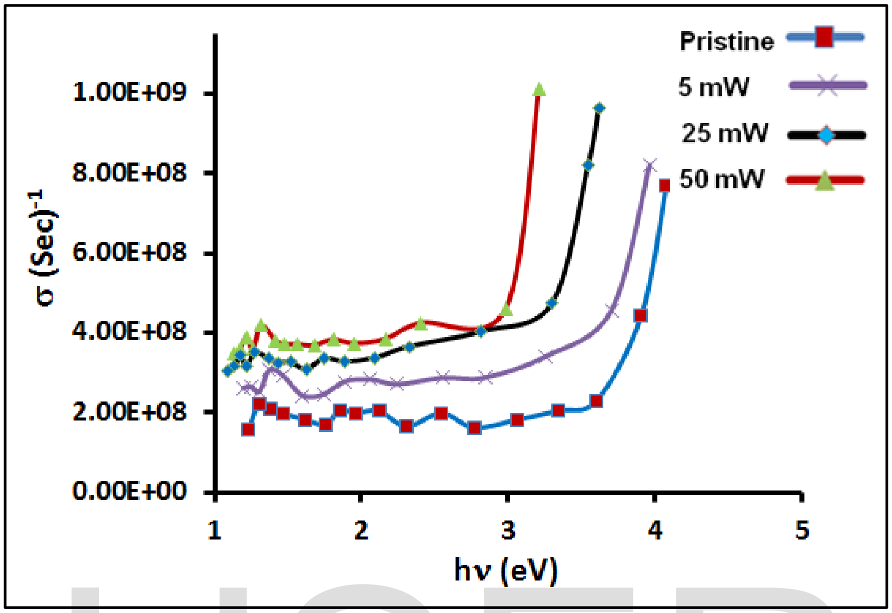

Fig. (11): Variation of the optical conductivity (σ)withphoton energy(hν) for CR-39 detectorat variouslaser energies

Table (1) Optical constants for CR-39 detector before and after Irradiation.

Laser Energy (mW)	A %	T %	α (cm^{-1})	E_g (eV)	k	n	ε_r	ε_i	σ (sec)$^{-1}$
0.0	0.16	80	5	4.1	0.000018	2	4	0.00005	2x10^8
5.0	0.18	73	6	4.0	0.00002	2.3	5.1	0.0001	3.3x10^8
	0.20	70	10	3.8	0.0000	2.5	6	0.00014	

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25.0					25				$4.0x10^{8}$
50.0	0.23	68	12	3.65	0.0000 65	2.6	6.3	0.00016	$4.1x10^{8}$

Conclusions

The influence of He-Ne laser doses on the optical properties of the CR- 39 plastic detector was measured. The optical constants of CR-39 detector were investigated in the ultraviolet-visible region at range (200-1100) nm of wavelength.

The variation in the values of the optical band gap energy E_g were measured using optical absorption spectra.Also , there wasa shifting of the wavelength to lower values with the increasing of thelaser energies.

It is concluded that the values of the band gap is decreased from 4.1 eV to 3.65 eV and absorption coefficient (α) is somewhat raised as a result of laser irradiation energy.

Finally, the change in the values of optical parameters (such as the refractive index , extinction coefficient, dielectric constantsand optical conductivity)was noticed that the increasing iscollateral with the increasing of the laser energy.

References

[1]K. Chopra "Thin Film Phenomena " McGraw-Hill , New York , (1969).

[2]C. Kittel '' Introduction to Solid State Physics '' , Fifth Edition , John Wiley & Sons , New York , London , Sydney , Toronto , (1976).

[3]R.M. Cassou, E.V. Benton, Nucl. Track Detect. 2, 173 (1978).

[4] Abdul-Kader, A.M., El-Badry, B.A., Zaki, M.F., Hegazy, T.M. & Hashem, H.M. Ion beam modification of surface properties of CR-39. *Philosophical Magazine* 90:p. 2543-2555(2010).

[5]Ahluwalia VK, Mishra Anuradha. Polymer science, a text book.India: ANE Books; (2008).

[6]Do¨ rschel, B., Fu¨lle, D., Hartmann, H., Hermsdorf, D.,Kadner, K. and Radlach, Ch. Measurement of track parameters and etch rates in proton-irradiated CR-39 detectors and simulation of neutron dosemeter responses.Radiat. Prot. Dosim., 69(4), 267–274 (1997).

[7] Jyotsna A. Sapkal , P.C. Kalsi, Chhavi Agarwal, M. Thanamani, S. Murali. Radiation Physics and Chemistry 78,p. 81–84 (2009).

[8]Nidal Dwaikat, Toshiyuki Iida, Fuminobu Sato, Yushi Kato, Ippei Ishikawa, Wataru Kada, Atsuya Kishi, Makoto Sakai, Yohei Ihara.,. Nuclear Instruments and Methods in Physics Research A 572, p.826–830 (2007).

[9]Gruhn, T.A., Li, W.K., Benton, E.V., Cassou, R.M. & Johnson, C.S. 1980. Etching mechanism and behavior of polycarbonates in hydroxide solution: Lexan and CR-39. In Solid State Nuclear Track Detectors, edited by Francois, H., Kurtz, N. & Massue, J.P. Proceeding of the 10th International Conference, Lyon, 2-6 July, New York: Elsevier Ltd.

[10]Hamilton, E.I. & Clifton, R.J. 1981. CR-39, a new α-particle sensitive polymeric detector applied to investigation of environmental radioactivity. Journal of Applied Radiation and Isotopes 32: p.313-324.Hepburn, C. & Windle, A.H. (1980).

[11] P. Parvin, B. Jaleh, N.A. Sheikh, Radiat. Meas. 40,775 (2005).

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

[13] D. Schrode, "„Semiconductor Material and device characterization", Wiley, (2006).

[14] Ben.G.Streetman ,, Solid State Electronic Devices ,, (Prentice-Hell of lndia. Private L. limited New Delhi), (1991).

[15] A. J. Grant , T. D. Moustakas , T. Penney& K. Weiser , (Amorphous and Liquid Semiconductor) , Ed. by J. Stuke , W. Brenig (Taylor , Francis & London) , p.325 (1973).

[16] M. Dongol , ((Egypt. J. Sol.)) , Vol.23 , No.2 , P.297 , (2000).

[17]Z. NURSHA'DAH, S.M. ISKANDAR, A.R. AZHAR, M.J. SUHAIMI, R. NUR LINA & M.K. HALIMAH"UV-VIS Spectral Evaluation of CR-39 Detector Exposed with Diagnostic Dosage"43(6), p.953–958,(2014).

[18] A. Abd-El Mongy, Egypt. J. Solids , p.29, 261 (2006).

[19]E.D. Palik (editor), "Handbook of Optical Constants of Solids", Academic Press, Elsevier, (1985).

[20] P.S. Kireev, "„Semiconductor Physics", Translated from Russian by M. Samokhvalov, MIR publishers, Moscow, (1978).

[21] David. L. Greenaway and Gunther Harbeke, ''Optical Properties and Band Structure of Semiconductors'', Pergamon Press, Oxford (1970).

[22]Mishra, R.L., Mishra, S.K. and Prakash, S.G." Optical and Gas Sensing Characteristics of Tin Oxide nano-crystalline Thin Film" J. Ovonic Res.. 5(4): p.77-85,(2009).