γ-Irradiation Effect on the Optical Constants,and the Electric Loss of PM-355

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ABSTRACT

The optical reflection, transmission, and UV/VIS- absorption spectra had been recorded in the wavelength(200-500nm) for PM-355 before and after irradiation with γ-ray irradiation by using ^{60}Co-dose within range of(30-160Mrad) at normal conditions. The absorption spectra of irradiated samples showed radiation induced absorption changes by photodegradation. There was an increment in absorption proportional with irradiation dose. The optical constants (α,K_{ex},n,ε_i,ε_r,E_g,) were calculated for all samples. The effect of irradiation on the optical constants of the PM-355 before and after irradiation had been investigated.

Keywords : Optical constants, Optical properties, PM-355,photodegradation.

تاثير اشعة كاما على الثوابت البصرية وعامل الفقد الكهربائي

الخلاصة

سجلت اطياف النعكاسية,النفاذية,والامتصاصية ضمن المدى (200-500nm) للمنطقة الفوق البنفسجية والمرئية لل (PM-355) قبل وبعد التشعيع باشعة كاما باستخدام المصدر المشع (^{60}Co) ضمن المدى(30-160)ميكا راد عند الظروف القياسية.
اظهرت اطياف الامتصاص للنماذج المشععة تغيرات في اطياف الامتصاص بتاثير عملية التفكك الضوئي.هناك زيادة في الامتصاصية بازدياد الجرعة. حسبت الثوابت البصريةلجميع النماذج (α,K,n,ε_i,ε_r,E_g),كما حسب عامل الفقد الكهربائي. ولقد فسرت نتائج تاثير اشعة كاما على الثوابت البصرية وعامل الفقد.

INTRODUCTION

Irradiation in polymers destroys the initial structure by way of cross linking, free radical formation, irreversible bond cleavages, etc., resulting in the fragmentation of molecules and formation of saturated and unsaturated groups. All these processes introduce so-called defects inside the material that are responsible for change in the Many researchers have succeeded in preparing polymer films deposited on various substrates such as glass or silicon wafer [2,3], in the interest of exploring the technological importance of film stability (e.g. toys and novelties, rigid packaging, refrigerator trays , boxes, cosmetic packs and costume jewele rs, lighting diffusers, audio cassette and CD

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cases) [4]. Several dyed polymers blends containing chlorine have been investigated for possible use in γ -ray dosimetry in and electron beam facilities [5]. Other researchers have worked to modify the styrene ring to reduce or enhance radiation induced discoloration. Such work is used to help in interpreting the behavior of polymeric scintillator exposed to gamma radiation [6]. While Kojima et al. have studied the response of alanine-polystyrene dosimeter at an absorbed dose of 5 kGy over the low temperature range 196-30◦C [7].

Solid polymer blends have been considerably studied in view of their wide potential application for novel systems and devices [8-10]. Suitable variation of preparing conditions like thickness, the electrical, electrochemical and optical properties of these materials could be selectively modified for particular properties in various applications [11-14]. It is well known that molecular structure and the physical properties of polymer could be modified by ionizing radiations [15,16]. Ionization of atoms and scission of molecules occur leading to the formation of charged species both ionic and free radicals. Raman scattering studies can provide information on the type of molecular species of the blends, while optical absorption studies are important to provide details of the electronic band structures, localized states and type of optical transitions, making these materials very attractive for chemical sensors in the detection of ionic species and for display panels[17-20].

Treating substances with any form of electromagnetic radiation or high energy electrons is known as IRRADIATION. Electromagnetic radiation is essential for modern life. It includes γ-rays, ultraviolet UV, visible light, infrared IR, and microwaves. Recent advances in technology have brought about an increasingly important role for gamma rays and electron beams. Gamma irradiation of living species induces breaks in the DNA double helix preventing replication and hence sterilization, damage to polymers is by a similar mechanism.

Absorption is defined as the ratio between absorbed light intensity (I_A) by material and the incidént intensity of light (I_o),as given in Eq(1)

$$A = I_A / I_o \qquad \ldots(1)$$

Transmittance (T) is given by reference to the intensity of the rays transmitting from the film (I) to the intensity of the rays incident on it (I_o) ($T=I/ I_o$), and can be calculated by [22]:

$$T = \exp [-2.303A \qquad \ldots(2)$$

And Reflectance can be obtained from absorption and transmission spectra in accordance with the law of conservation of energy by the relation [8]:

$$R + T + A = 1 \qquad \ldots(3)$$

Absorption coefficient (α) is defined as the ability of a material to absorb the light of a given wavelength,Eq.(4)

$$\alpha=2.303A/t \qquad \ldots(4)$$

Where A: is the absorption of the material and t is the sample thickness in cm.

The Refractive index (n), the index of refraction of a material is the ratio of the velocity of the light in vacuum to that of the specimen [23-24].

$$R= ((n-1)^2+k^2)/ ((n+1)^2+k^2) \qquad \ldots(5)$$

When $k\cong 0$

$$R= (n-1)^2/ (n+1)^2 \quad ....(6)$$
$$n= (1+R^{1/2})/ (1-R^{1/2}) \quad ....(7)$$

The extinction coefficient (k) was calculated using the following equation (Eq.8) [25].

$$K=\alpha\lambda/4\pi \quad ... (8)$$

Dielectric constant is defined as the response of the material toward the incident electromagnetic field. The dielectric constant of compound (ε) is divided into two parts real(ε_r), and imaginary (ε_i).The real and imaginary parts of dielectric constant ($\varepsilon_r$and ε_i) can be calculated by using Eq.8, Eq.10 and Eq.11. [23-5].

$$\varepsilon=\varepsilon_r - i\varepsilon_i \quad ..(9)$$
$$\varepsilon_r=n^2-k^2 \quad \text{(real part)} \quad ... (10)$$
$$\varepsilon_i=2nk \quad \text{(imaginary part)} \quad ...(11)$$

The electric loss tangent can be similarly defined[26,27]:

$$\mathrm{Tan}\delta=\varepsilon_i /\varepsilon_r \quad ... (12)$$

In this article, we report the optical characteristics of PM-355 samples, which undergo change upon irradiation with ɣ -rays.

Materials and Methods:

We used commercially available PM-355 sheet($1*2cm^2$),and of thickness(0.05cm).It was irradiated to ^{60}Co γ-ray irradiation within range of(30-160Mrad) at normal condition(temperature (25°C),and relative humidity(55%)). These films were evaluated spectrophotometrically by using UV/160 Shimadzu spectrophotometer, which operates in the wavelength range of 200nm to 1100nm before and after irradiation with ^{60}Co γ-ray source within range of(30-160Mrad).

Results and Discussion:

The study of optical absorption spectra is one of the most productive methods in developing and understanding the structure and energy gap of the polymers. Figures (1-3) show the absorption, reflectance, and transmittance spectra of (PM-355)before and after irradiation with γ-ray dose within range of(30-160Mrad).

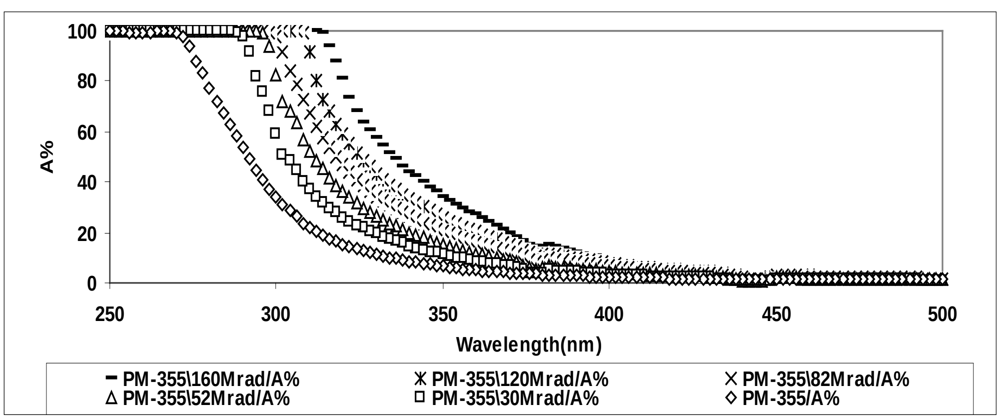

Figure.(1):Absorption spectra versus the wavelength for (PM-355) before and after irradiation with γ-ray dose within range of(30-160Mrad).

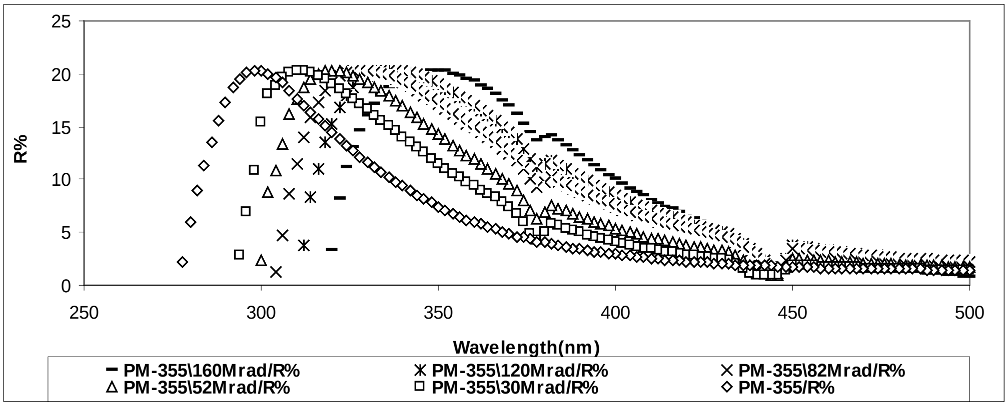

Figure.(2):Reflectance spectra versus the wavelength for (PM-355)before and after irradiation with γ-ray dose within range of(30-160Mrad).

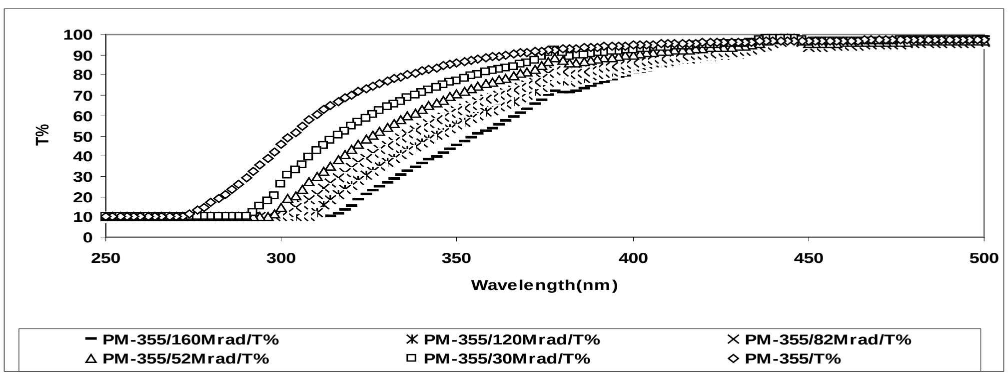

Figure.(3):The transmittance spectra of the (PM-355)before and after irradiation with γ-ray dose within range of(30-160Mrad).

It can be observed that the absorption peaks are of systematic increasing with absorbed doses, and shift toward the longer wavelengths. It was attributed to the ionizing radiation induces chemical reaction in polymers which result in changes in both molecular structure and macroscopic properties. Therefore, when PM-355samples were irradiated, degradation products are formed electron and hole take place causing changing in optical absorbance Figure.(1),which in a agreement with Khan, and Ahmad results[25].It was seen that the absorption spectra of PM-355 before and after irradiation with γ-ray dose within range of(30-160Mrad) were in the UV-region, that's mean that all samples are transparent. Also it was found that the transmittance decreased with radiation dose, which is in opposite to that absorption, that was attributed to the interfaces traps induced by γ-radiation Figure.(3).

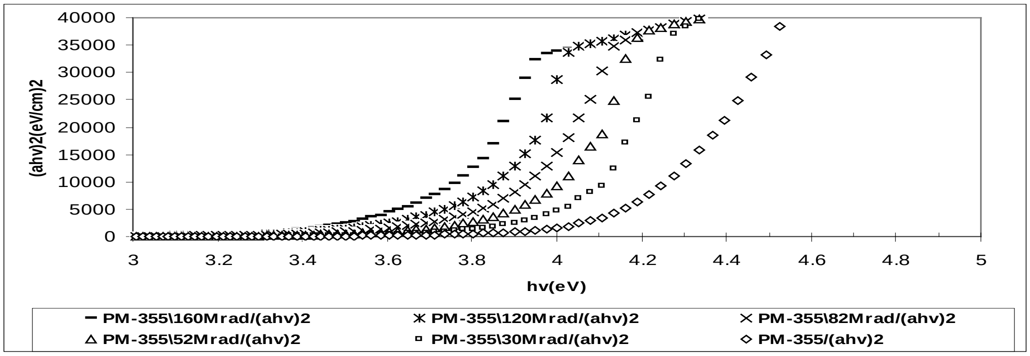

Figure.(4): Direct allowed transition $(\alpha h\upsilon)^2$ versus ((hυ) for PM-355 before and after irradiation γ-ray dose within range of(30-160Mrad)

The extrapolations of the lines of $(\alpha h\upsilon)^2$ versus (hυ) for which $(\alpha h\upsilon)^2 = 0$, give the direct optical band gap Figure.(4).It was found that the energy gap decreasing linearly with the irradiation dose ,which was attributed to increasing in localized state with irradiation dose Figure.(5).

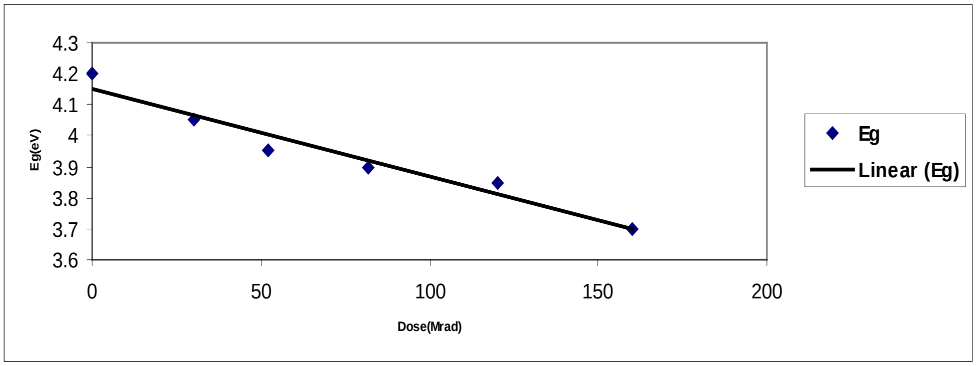

Figure.(5):The energy gap variation versus the irradiation dose for PM-355 before and after irradiation γ-ray dose within range of(30-160Mrad).

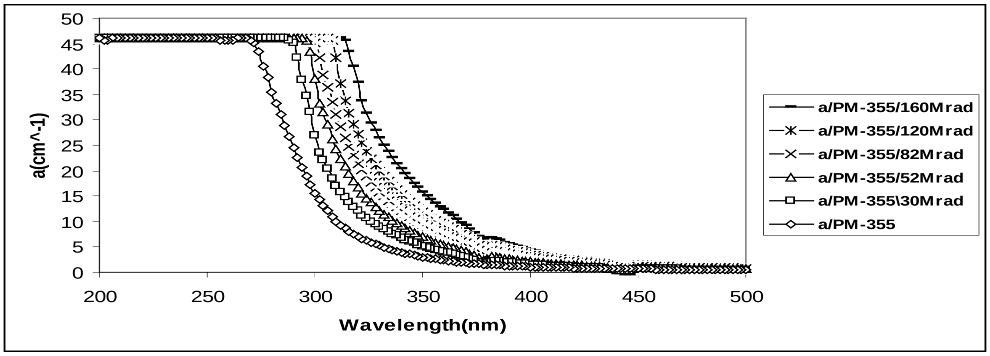

Figure.(6):The absorption coefficient versus the wavelength for the PM-355 before and after irradiation with γ-ray dose within range of(30-160Mrad).

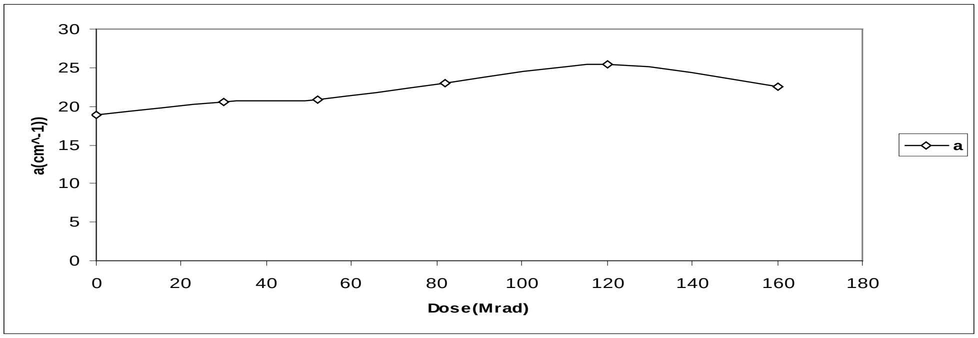

Figure.(7): The variation of α versus irradiation dose the PM-355 before and after irradiation with γ-ray dose within range of(30-160Mrad).

The absorption coefficient of the samples involved was calculated using equation(4). Figure.(6) shows the absorption coefficient of the PM-355 before and after irradiation with γ-ray dose within range of(30-160Mrad) . It was clear from the Figure.(7) that absorption coefficient was increasing with irradiation dose .It was attributed to the photo degradation induced absorption changes, which were caused by increasing the localized state by radiation.

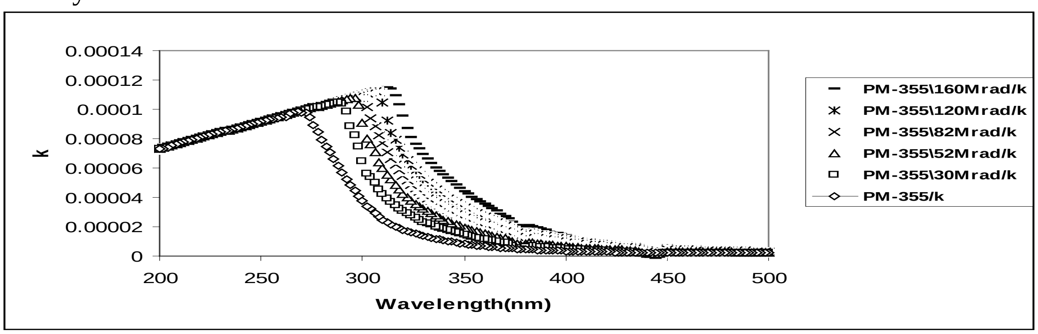

Figure.(8):The extinction coefficient versus wavelength for the PM-355 before and after irradiation γ-ray dose within range of(30-160Mrad).

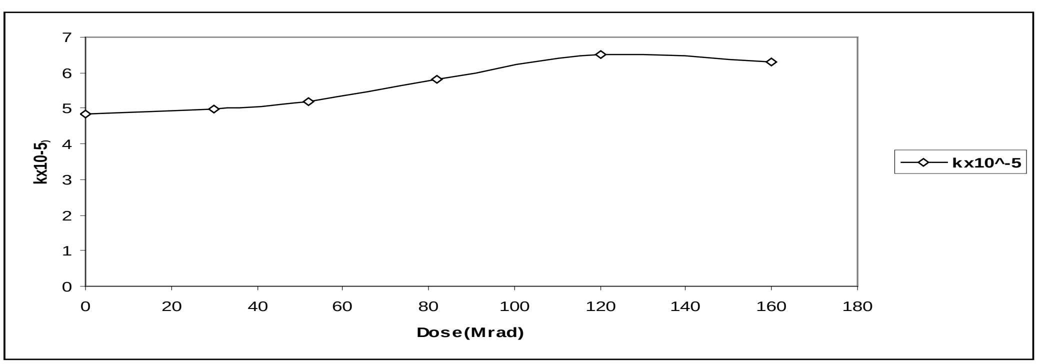

Figure.(9): The variation of K versus irradiation dose the PM-355 before and after irradiation with γ-ray dose within range of(30-160Mrad)..

The behavior of extinction coefficient (K) is nearly similar to the corresponding absorption coefficient as shown in Figure.(7),which in a good agreement with Tariq,Y Alwan[27].
The increasing in extinction coefficient with irradiation dose was due to increasing in absorption coefficient for the previous reasons, its peaks displaced towered long wavelength, that was attributed to decreasing in energy gap with irradiation dose, ,the absorption coefficient for PM-355 before and after irradiation with γ-ray dose within range of(30-160Mrad) were calcaculated at(λ_c =1240/Eg$_{)}$, and absorption coefficient increased with wavelength ,so it was decreased with irradiation dose (λ_c longer). Figures.(8-9).

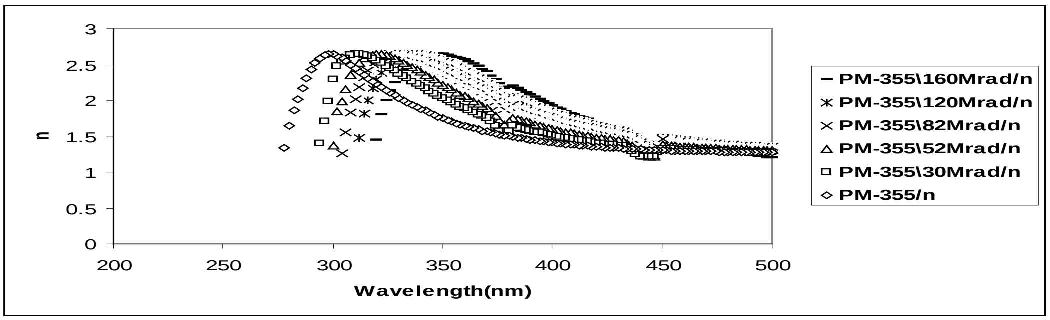

Figure.(10):The refractive index versus wavelength for the PM-355 before and after irradiation with γ-ray dose within range of(30-160Mrad).

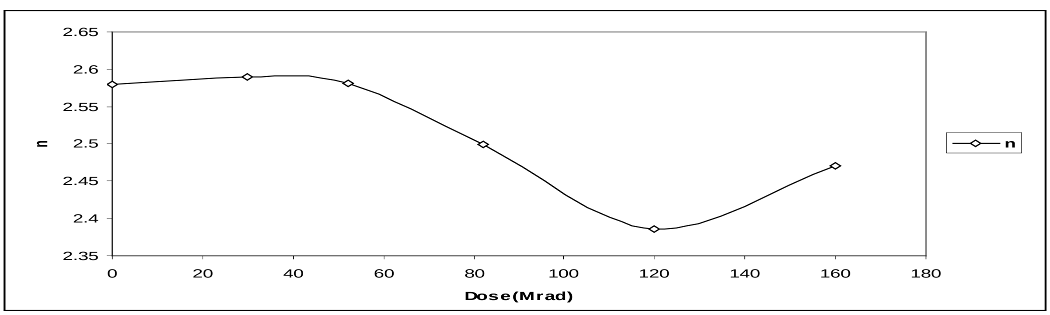

Figure.(11):The variation of refractive index versus irradiation dose the PM-355 before and after irradiation with γ-ray dose within range of(30-160Mrad).

Studying the refractive index will complete the fundamental study of the optical properties ,and optical behavior of the material. Figure.(10) shows the variation of the refractive index with wavelength for PM-355 before and after irradiation with γ-ray dose within range of(30-160Mrad).This figure shifts toward the long wavelengths with increasing the irradiation dose,which is nearly similar to the corresponding refraction spectra (refractive index depends on reflectivity(eq.(7)).This behavior of the wavelength shift is due to decreasing in energy gap with irradiation dose,which causes increasing in localized states and increasing in refractive index Figures.(11-12) in a good agreement with(25,27.

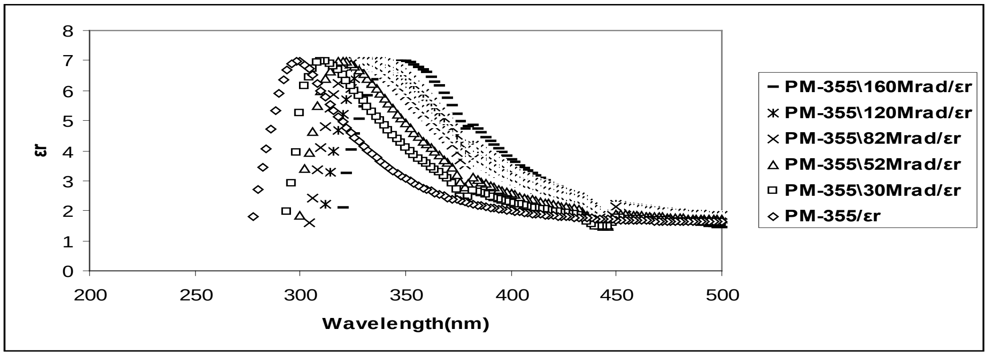

Figure.(12): The variation of real part of the dielectric constant versus the wavelength for the PM-355 before and after irradiation with γ-ray dose within range of(30-160Mrad).

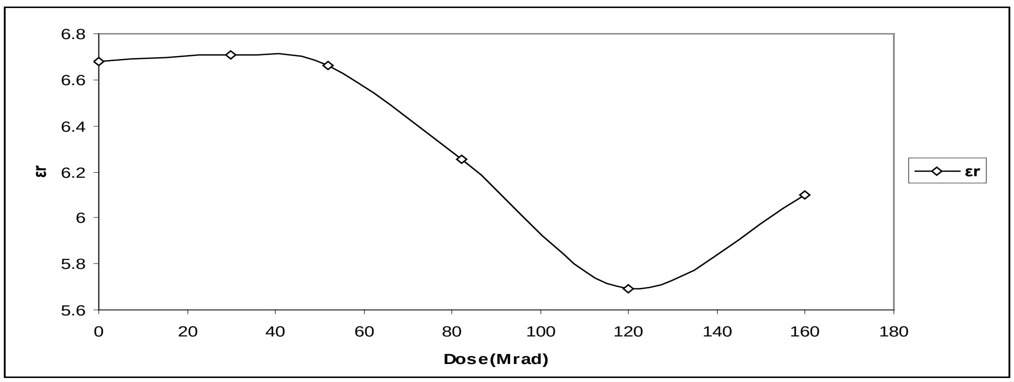

Figure.(13): The variation of real part of the dielectric constant versus exposure doses of the PM-355 before and after irradiation with γ-ray dose within range of(30-160Mrad).

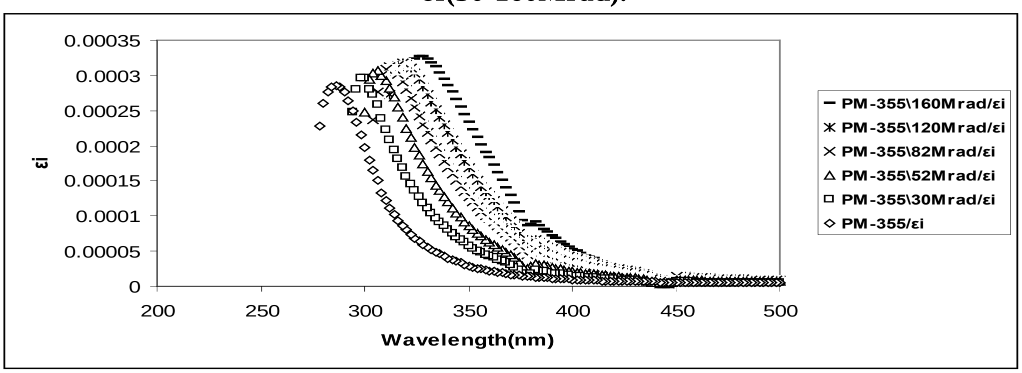

Figure.(14): The variation of imaginary part of the dielectric constant versus wavelength for the PM-355 before and after irradiation with γ-ray dose within range of(30-160Mrad).

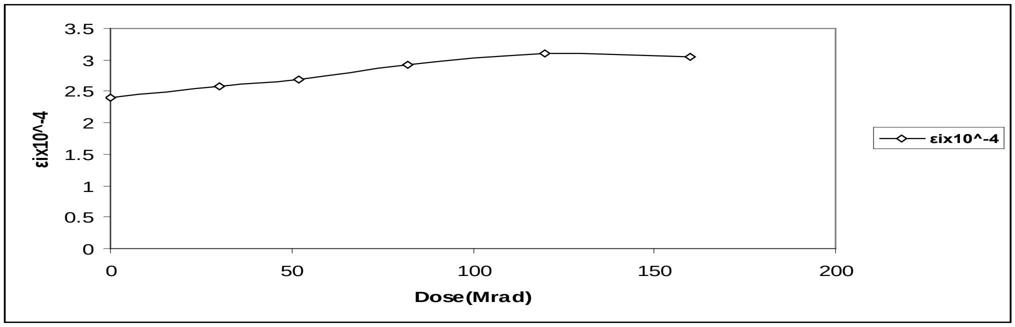

Figure.(15):The variation of real part of the dielectric constant versus irradiation dose the PM-355 before and after irradiation with γ-ray dose within range of(30-160Mrad).

Figures.(12,14) show the variation of the real and imaginary parts of the dielectric constant respectively for the PM-355 before and after irradiation with γ-ray dose within range of(30-160Mrad).The behavior of ε_r is similar to that of refractive index because of the smaller value of K^2 compared to n^2 Figures.(15-16) ,while ε_i. depends mainly on K 's values, which is related with the variation of the absorption coefficient Figures.(13,15) .

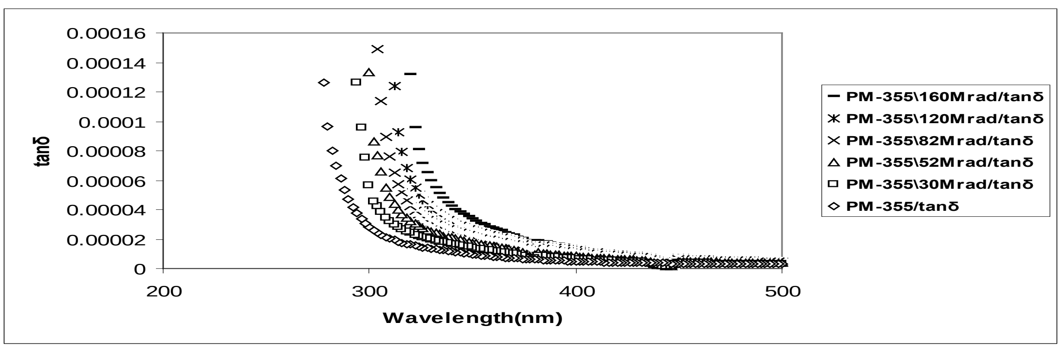

Figure.(16): The variation of electric loss tangent versus wavelength for the PM-355 before and after irradiation with γ-ray dose within range of(30-160Mrad).

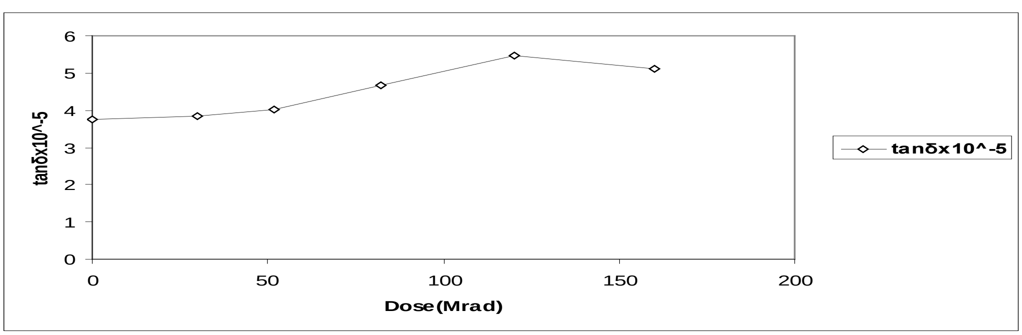

Figure.(17):The electric loss tangent versus irradiation dose the PM-355 before and after irradiation with γ-ray dose within range of(30-160Mrad).

From Figure.(16),it was seen that the electric loss tangent decrease with wavelength , and shifted towards the longer wavelengths .There was increment in electric loss tangent with exposure dose [17].Its behavior follows (α,k,ε_{i}).

Table (2): Represents the parameters of optical properties of polymer system involved.

Polymer. system	E_g(ev)	λ_{cut}(nm)	n	$K\times10^{-5}$	ε_r	$\varepsilon_i\times10^{-4}$	α (cm^{-1})
PM-355	4.2	295.238095	2.58	4.835	6.68	2.4	18.9
PM-355/30Mrad	4.05	306.17284	2.59	4.989	6.71	2.58	20.49
PM-355/52Mrad	3.95	313.924051	2.581	5.2	6.66	2.68	20.814
PM-355/82Mrad	3.9	317.948718	2.5	5.829	6.254	2.915	23.04
PM-355/120Mrad	3.85	322.077922	2.386	6.51	5.693	3.1	25.42
PM-355/160Mrad	3.7	335.135135	2.47	6.31	6.1	3.04	22.54

Conclusions:

- PM-355samples were irradiated, degradation products are formed electron and hole take place causing changing in optical absorbance.
- The systemic changes in optical density suggested that PM-355 can be used as a ɣ-Dosimeter.
- The energy gap decreasing linearly with the irradiation dose ,which was attributed to increasing in localized state with irradiation dose.
- There are an increment in optical constants(α,k,ε_i) with radiation dose within range(30-120).
- The electric loss tangent decrease with wavelength , and shifted towards the longer wavelengths .There was increment in electric loss tangent with exposure dose .Its behavior follows (α,k,ε_{i}).

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