

Spectrophotometric Study of γ -Irradiated PM-355*Nahida J.H.Al-Mashhadani***Nada F. Tawfiq****Mohammed T. Abdul Nabi***

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Abstract

The aim of the present work is concerned with the effect of γ -irradiation on PM-355 with absorbed dose of (30-160Mrad) range. This polymer is evaluated spectrophotometrically for use as high dose dosimeters. The absorption spectra of irradiated samples showed radiation induced absorption changes. There is an increment in absorption proportional with absorbed dose. This increment is attributed to interfaces traps which, are formed by irradiation. Calibration curve was drawn. The linear relation was found in calibration curve, and dosimeter range was determined from the linear part. The linearity in response curve suggested that PM-355 could be used as dosimeter within (30-160Mrad) rang. Energy gap shift was used as a second tool to determine the dosimeter range. It was found that PM-355 energy gap systematically decreasing with absorbed dose, and it could be used as a second tool to determine the dosimeter range.

Key words:PM-355,Spectrophotometric study-irradiated PM-355,High doses dosimeters

Introduction:

During the last decades, Solid State Nuclear Track Detectors (SSNTDs) have found applications in plasma experiments. The track detectors used in the fusion-oriented experiments encounter severe conditions (intense X-ray, gamma and neutron radiation, heat impact, shock waves and plasma fluxes).Therefore; such detectors should be tested under similar conditions. It was commonly believed that the SSNTDs have a very low sensitivity to electrons and electromagnetic radiation. The sensitivity of the Solid State Nuclear Track PM-355 detectors was tested against intensive gamma and electron radiation [1].

The reactions introduced by high-energy radiation can be specific as most chemical reactions, because the initial energy is rapidly degraded in matter, and much of chemical changes produced by radiation are consequence

of the action of electrons [2-4]. Further, the transient species produced by such electrons do not give final products immediately, but take part in various transfer process in such away that the molecules finally altered are not necessarily the only which are effected in the first instance. One of the commonest reactions is called cross-linking. It can occur in solution, although there are quantitative differences when both hydrogen atoms are formed from the same molecule, an instauration double bond can be formed instead of cross-linking. Instauration and cross-linking are often formed together. Another important reaction is degradation e.g., C-C scission. This is especially important with certain polymers, e.g poly (methylmethacrylate), cellulose acetate, and in fact many of the physical and chemical effects on such substance as polymers can be

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explained in terms of two reactions cross-linking and degradation. One of the most striking effects, especially with the less densely ionizing radiation like x- or γ -rays or fast electrons, is the almost universal accelerated by oxygen.

Polymers had been proposed for the measurement of doses in the megarad region [3]. The most widely used dosimetric quantity was the absorbed dose. Absorbed dose of any ionizing radiation is the energy imparted to matter by ionizing radiation [5]. Polymers appear quite promising for this purpose, especially because the dosimeter needs no preparation.

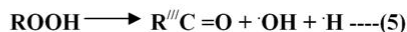
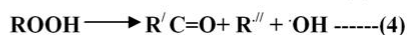
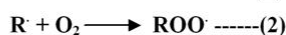
The effect of high-energy radiation on polymers becomes of increasing importance and presents a number of problems. The following processing may occur. Formation of hydrogen, lower hydrocarbons and other gases, degradation, polymerization cross-linking, and double bond formation, the properties of polymer are changed on such irradiation.

Ionizing radiation induces chemical reaction polymers, which result in changes in both molecular structure and macroscopic properties. When oxygen is present, radiation-induced changes are often quite different (usually more sever) compared with irradiation under inert atmosphere. The common chemical mechanism of radiation induced oxidation degradation of polymers involves the creation of organic free radicals within the polymer, which then undergo addition to molecular oxygen dissolved within the material to generate peroxy radicals.

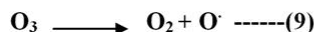
The peroxy radicals lead to a variety of oxidation products, including hydro peroxides, carbonyl groups, and alcohols. A common phenomenon in radiation induced oxidative degradation is the occurrence

of heterogeneous oxidation. This takes place when the rate at which oxygen is consumed within the polymer is more rapid than the rate at which can be supplied from the surrounding atmosphere by diffusing into the material when this happens exterior regions of the sample may become highly oxidized, while the oxygen-starved interior undergoes either a much lower degree of oxidation, or else an aerobic degradation. This process yields a material having mechanical properties, which vary significantly as a function of depth into the specimen [6].

As reported by researchers, the chain oxidation reactions are thought to be as follows[7]:



Chain reactions and hydroperoxides (ROOH) are produced continuously. But the hydroperoxides decompose gradually to form(RC=O or R''' C=O) as expressed by Eq. (4), and (5). Therefore, as the result of chain oxidation reactions, the carbonyl groups represent the extent of the chain oxidation reaction. The gamma irradiated samples undergo strongly heterogeneous oxidation due to oxygen diffusion effects. As can be seen, the surface regions, where oxidation takes place, experience very different mechanical property changes compared with the interior. Ionizing radiation results in the dissociation of the oxygen molecule into two atoms Eq. (6). This likely involves oz-species, followed by atomic oxygen with O₂ in three-body collision Eq. (7) involving any other gaseous species, (M), gives Ozone[7]:

γ 

In the γ -sources, throughout the sample exposure time, the gas-phase reactions leading to ozone formation proceed in the atmosphere immediately surrounding the sample. Both O_2 and $\text{O} \cdot$ would be expected to oxidatively attack the polymeric material, so that either or both species could be postulated as being responsible for gamma-induced surface oxidative effects[6].

Beer-Lamberts' law is fundamental for quantities absorption spectroscopic in the UV/VIS and constitutes a special case of the general law of absorption of radiation equation (10) in homogenous matter [8, 9]:

$$I = I_0 e^{-\alpha t} \text{----} (10)$$

Equation (10) implies that the decrease in light intensity only depends upon the intensity at depth (t) and on a constant (α) characteristic of the substance (absorption coefficient) [8,9].

The absorbency is the logarithm of the ratio between the intensities of the light beam before entering (I_0) and after leaving the mater (I), $\log_{10}[I_0/I]$, abbreviated E (for Extinction) or A.

The fundamental absorption refers to band-to-band or the transitions in which an electron transfers from the valance band to the conduction band with of absorption photon energy approximately equal to energy of forbidden gap.

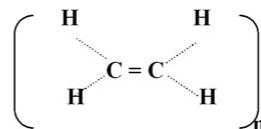
For materials of high absorption properties within the UV frequencies, Tauc and Menth developed a power law, which identified such optical property by[10]:

$$(\alpha h\nu)^{1/r} \propto (h\nu - E_g) \text{-----} (11)$$

where α is the absorption coefficient (cm^{-1}), ν is the frequency (sec^{-1}) and (E_g) is the optical energy gap. (r) constant for fixed electronic transition and varies between 1/2, 3/2, 2, and 3. The values of (r) are 1/2 for direct absorption, 3/2 for forbidden direct transition, 2, and 3 for indirect transition. By plotting $(\alpha h\nu)^{1/r}$ versus $h\nu$ for fixed r value, the extrapolation of the linear part could be used to define E_g [10].

Materials and Methods:

The rectangular PM-355 films of (2x3) dimensions and 500 μm thickness were used. At the first time of its production was called polymethylene. The polyethylene is of structure [11]:



The PM-355 films were irradiated to gamma rays from a ^{60}Co gamma source for the absorbed dose (30-160Mrad) at room temperature. The optical density UV/VIS spectroscopic measurements were carried out by using UV/160 Shimadzu spectrophotometer, which operates in the wavelength range of 200nm to 1100nm. The instrument is computerized and it contains a CRT screen and a keyboard for operator input. This spectrophotometer has a full scale absorbance up to (4.5). The light sources are halogen lamp and socket-deterium lamp. The detector is

Si-photodiode. UV/VIS absorption spectroscopy were made for prepared samples before and after irradiation with gamma source ^{60}Co within (30-160Mrad) dose range. The spectra were used to carry out these measurements:

- The relation ship between the absorption spectra with absorbed dose of (30-160Mrad) range (Fig.1).
- The response curve was drawn between response ($\Delta A/t$) as a fuction to the doses of (30-160Mrad) range, where (ΔA)is the optical density difrence between the optical density before and after irradiation at selected wavelength(313nm) , and (t) is sample thickness(Fig.2) .
- Energy gap was obtained by plotting $(\alpha h\nu)^{1/r}$ versus $h\nu$ with r

values equal to 1/2,3/2, 2,and 3. The linear portion was best fitted with $r=1/2$, which indicates a transition of direct type. Energy gap shift in irradiated samples was plotted as a function to the doses(Fig.3), and (Fig.4).

Results and Discussion:

Samples of PM-355 irradiated with ultraviolet and γ -ray are almost identical. This indicates that the same types of free radicals are formed during both kinds of irradiation [12-13]. Therefore, when PM-355 was irradiated with γ -ray, degradation products are formed and electron and hole trapping take place causing changes in the optical absorbance (Fig. 1),which in agreement with Khan, and Ahmad results[14]. Upon irradiation, the systems undergo a fairly change in the near ultraviolet spectrum [15].

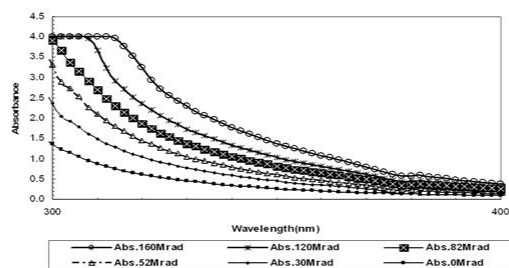


Fig.1: The absorption spectra of (PM-355) changes with absorbed dose (30-160Mrad).

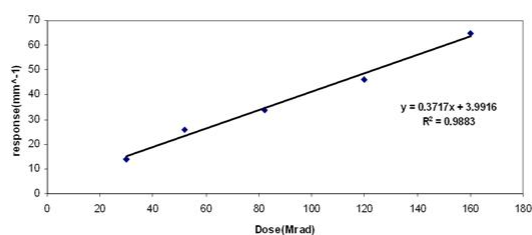


Fig.2: The response of PM-355 according to absorbed dose

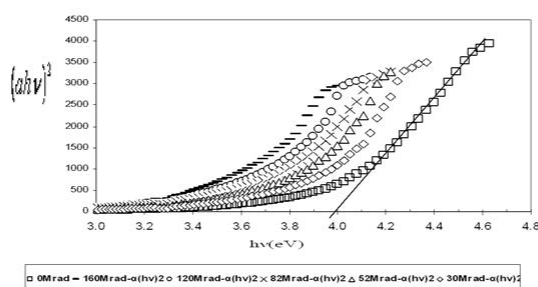


Fig.3: Energy gap shift with the absorbed dose.

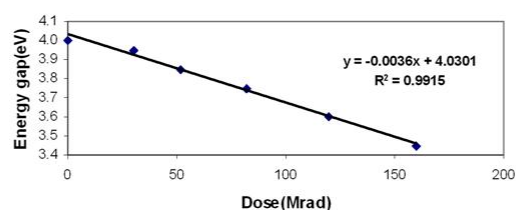


Fig.4: The relationship between the energy gap shift and the absorbed dose.

There was systematic increasing in optical absorbance with doses (30-160Mrad) range. (Fig.2) shows the relationship between the response and absorbed dose, which confirmed the results above. It was found decreasing in the response with absorbed doses (30-160Mrad) range. It was attributed to the irradiation, which induced absorption changes in these plastics. The radiation-induced changes were generally proportional to the absorbed dose. The linearity of response curves suggests that PM-355 can be useful as a routine dosimeter for absorbed dose range (30-160Mrad). The response of plastic dosimeters is dependent on several environmental factors, and sample thickness [14]. After irradiation with absorbed dose of (30-160Mrad) range, there are changes induced by radiation. The decreasing in energy gap can be attributed to interface traps, which are induced by irradiation [16].

Conclusion:

1. Photodegradation increases the absorption of degraded samples. The systematic increment in PM-355 absorption suggests that it can be used as a dosimeter within (30-160Mrad) range.
2. The energy gap decreases by irradiation, because of interfaces traps induced by irradiation. The systematic decreasing in PM-355 in energy gap with absorbed dose suggests that it can be used as a dosimeter within (30-160Mrad) range.

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الدراسة الطيفية PM-355 المشع باشعة كاما

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الكلمات المفتاحية: PM-355 المشع باشعة كاما الدراسة الطيفية PM-355، مقياس الجرعة العالية
الخلاصة:

ان الهدف من هذا البحث يتعلق بدراسة تأثير تشعيع PM-355 باشعة كاما وبالجرع الاشعاعية التي تقع ضمن المدى (30-160Mrad). تم تحليل اليوليمر طيفيا باستخدامه كمقياس للجرع العالية. اظهرت اطياف الامتصاص للنماذج المشععة تغييرا في الامتصاصية المحتث بالاشعاع. هناك زيادة في الامتصاصية بازياد الجرعة الممتصة. اعزيت الزيادة الى المصائد البينية المتكونة بتاثير الاشعاع. رسمت منحنيات المعايرة. وجد علاقة خطية في منحنيات المعايرة. ان خطية منحنيات الاستجابة حددت امكانية استخدام PM-355 مقياس الجرع ضمن المدى-30 (160Mrad). استخدم الزحف في فجوة الطاقة كوسيلة ثانية لتحديد مدى مقياس الجرع. وجد تناقص نظامي في فجوة الطاقة ل PM- 355 مع الجرعة الممتصة. ويمكن استخدامها كوسيلة ثانية لتحديد مدى مقياس الجرع.