PMMA/ Anthracene Film as a Low Doses Dosimeter

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Abstract
A prepared PMMA/Anthracene film of thickness 70µm was irradiated under reduced pressure ~10^{-3} to ^{60}Coγ-ray dose of (0.1mrad-10krad) range. The optical properties of the irradiated films were evaluated spectrophotometrically. The absorption spectrum showed induced absorption changes in the 200-400nm range. At 359nm, where there is a decrease in radiation-induced absorption, the optical density as a function of absorbed dose is linear from 10mrad-10Krad.It can therefore, be used as radiation dosimeter for gamma ray in the range 10mrd-10krad.

أستخدام أفلام البولي ميثل ميثا أكريليت المطعمة بالأنثراسين كمقياس جرع واطئ

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الخلاصة

تم تحضير فلم ذو سمك 70 µm من البوليمربوليميثيل مثل كرانيت مطعم بالأنثراسين. شععت النماذج المحضرة بالفراغ (تحت ضغط ١٠^-٣ بار) لأشعة كاما المنبعثة من المصدر المشع Co-60 بجرع أشعاعية ضمن المدى (0.1mrad-10krad).

فحصت النماذج من خلال التحليل الطيفي لغرض أستخدامها كمقاييس للجرع الأشعاعية الواطئة. أظهرت أطياف الأمتصاصية للنماذج المشععة تغيرات في الأمتصاصية المحتثة بواسطة الأشعاع في مدى الطول الموجي (200-400nm). وجد تناقص في الأمتصاصية نتيجة لحدوث تلف سطحي وبشكل خاص في المدى 359 nm .

رسمت منحنيات المعايرة عند القمم وعند اطوال موجية مختارة في اطياف الأمتصاص. ولقد تم اختيار المناطق الخطية في منحنيات المعايرة وتحديد مدى مقياس الجرع من استجابة النماذج لأشعة كاما ضمن المدى (10mrad-10Krad).

Introduction

In the radiation processing of materials by gamma rays and electron beam, several kinds of plastic and dyed plastic dosimeter are widely used for routine dosimetry at high doses [1]. The quality assurance in radiation processing is primarily based on dosimetry, i.e. on the measurement of the absorbed energy per weight unit of the product [2].

PMMA is a clear, rigid polymer, very suitable for manufacturing routine dosimeters. Various selected additives; specially azo dyes can be incorporated in it, in solid solution, without affecting optical clarity. Other obvious advantages are for example that the resulting dosimeters are tough and very easy to handle the measure [3]. Since1960s, these dosimeters have gained almost worldwide acceptance [4]. In 1993, five different batches of dosimetry have been prepared and irradiated to^{60}Coγ-ray dose rates ranging from 0.14-6.5Gy/sec [5]. The use of Anthracene was introduced by Bell. It has became the widely used organic scintillation, the main reason for this being that it is the most organic phosphor available up to now [6]. PMMA/Anthracene composite showed photosensitivity, and consequently photo degradation and photo-oxidation higher than the other anthracene polymers (PC, PS) commercial polymers (plastic, fibers), frequently contain monomers (substance additives and impurities). Many of these compounds absorb strongly UV/VIS radiation and disturb the investigation of the polymers even if present only in traces. If the polymer contains electron donating (D), and electron accepting (A), monomeric compounds with opposite property will give rise to formation of DA complex. The corresponding charge transfer absorption band is due to partial shift of electrons from the donor to the acceptor, in most cases according to the following equation:

$$\mathbf{D+A \xrightarrow{h\nu} (D^{+} + A^{-})^{*}}$$

The resulting band is in visible region and thus causes a specific coloring of polymer solution film [7].

The major result of radiation is the degradation by chain scission in polymer, such as PMMA and its derivatives.

Degradation is, of course, evidenced by decrease in molecular weight, the weight average molecular weight being inversely proportional to the amount of the received radiation. In polymers with bulky side chains extensive degradation of the side chains occurs. When PMMA is irradiated by ionizing radiation, degradation products are removed and electron and hole trapping take place causing changes in optical absorbance [8].

Ionizing radiation induces chemical reactions in polymers, which results in changes in both molecular structure, and macroscopic properties. When oxygen is present, radiation-induced changes are often quite different (usually more severe) compared with irradiation under inert atmosphere. The common chemical mechanism of radiation-induced oxidative degradation of polymers involves the creation of organic free radicals within the material to generate peroxy radicals. The peroxy radicals lead to a variety of oxidation products, including hydroperoxides, carbonyl groups, and alcohols. The free radicals –mediated oxidation reactions also lead to the cleavage and cross-linking of the macromolecular chains, which results in changes in material properties[10].

Experimental Procedure:

PMMA was dissolved in methylene chloride in 7%wt/vol concentration and handily checked until achieving best homogeneity. Solution of 0.25% wt/vol of anthracene concentration was prepared. The concentration of doping to matrix (wt/wt) was $4X10^{-3.}$ The solution transferred to clean glass petri dish of 5cm in diameter placed on plate form leveled with aid of sprit level. It was closed and left overnight to dry.

The prepared film was irradiated to^{60}Co gamma source to the dose of (0.1mrad-10Krad) range. The chamber was evacuated to~10^{-3} by using artificial vacuum system. The films were irradiated as 1cm X 2cm strips of thickness 70µm. The spectra of films were determined using a UV/VIS/IR spectrophotometer, which operating in the wavelength range of 200-1100nm.

Results and Discussion:

The variations include shift towards higher wavelength. The absorption spectrum of 70µm thick irradiated anthracene-dopted PMMA within dose (0.1mrad-10krad) shows radiation induced absorption changes in the (200-400nm) range.

At 359nm, there are systematic changes (decreasing in optical absorbance according to the absorbed dose of (0.1mrad-10krad) range (Fig.1).

Cowel and Pitts had suggested that the photo-oxidation of anthracene occur by a singlet oxygen mechanism [11]:

$$\mathbf{A_0 + h\nu \longrightarrow {}^1A^*} \quad \mathbf{(4\text{-}5)}$$

$$\mathbf{{}^1A^* \longrightarrow A_0 + energy} \quad \mathbf{(4\text{-}6)}$$

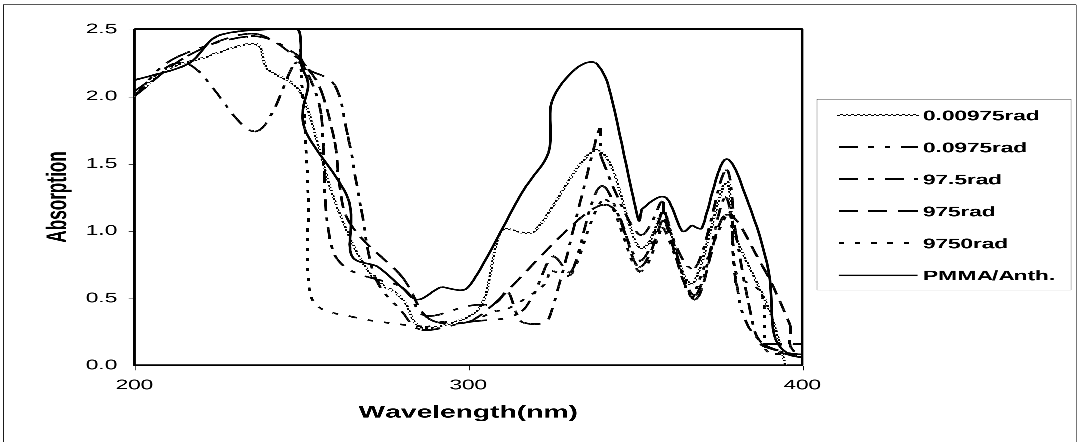
$$\mathbf{{}^1A^* \longrightarrow {}^3A^*}$$

$$\mathbf{{}^3A^* + {}^3O_2 \longrightarrow A_0 + {}^1O_2} \quad \mathbf{(4\text{-}7)}$$

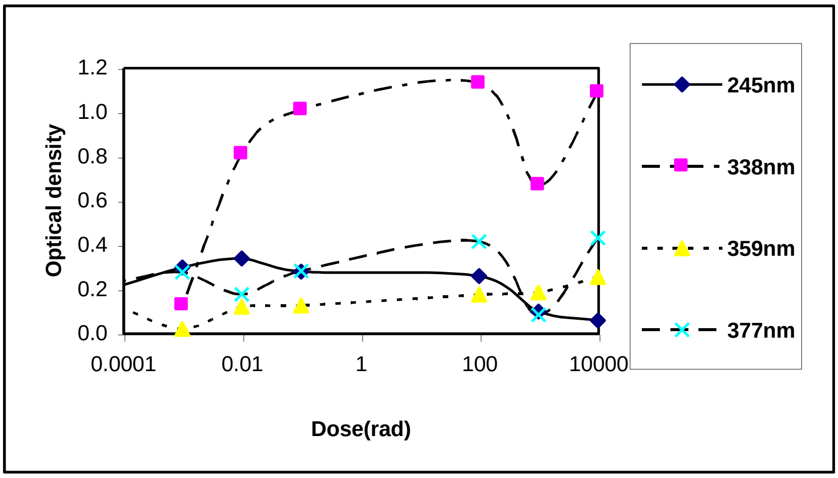
$$\mathbf{A_0 + {}^1O_2 \longrightarrow AO_2} \quad \mathbf{(4\text{-}8)}$$

$$\mathbf{{}^1O_2 \longrightarrow {}^3O_2 + energy}$$

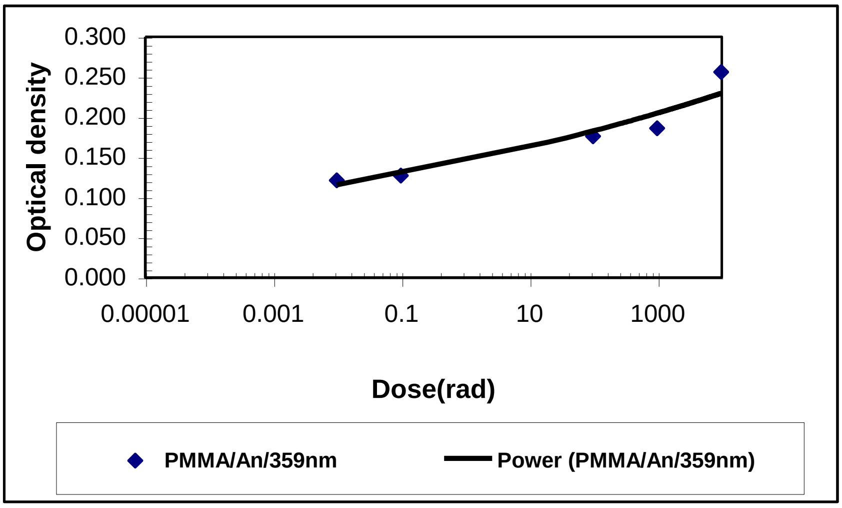
where $\mathbf{A_0}$ **,** $\mathbf{{}^1A^*}$ **,** $\mathbf{{}^3A^*}$ refer to anthracene in its ground, exited singlet and triplet states, respectively. $\mathbf{AO_2}$ is the endoperoxide and $\mathbf{{}^1O_2}$ **is** the singlet oxygen [86]. Polycyclic aromatic hydrocarbons (e.g.anthracene, pyrene naphthalene….ect.) are assumed to generate a singlet oxygen by energy transfer to ground state oxygen molecules, and polycyclic aromatic hydrocarbons are well known as compounds that can take part in energy transfer reactions [9,10]. The molecules in the triplet state of these compounds can absorb additional quanta (triplet-triplet absorption) reaching the higher excited triplet state. This higher triplet state has a large excess energy, which can be transferred to the C=C or C=O bonds to produce free radicals [10]. It was proved anthracene-PMMA composite showed photosensitivity, and consequently photo degradation and photo-oxidatiation higher than the other anthracene/polymer composites. Decreasing in the absorption was also found according to the absorbed dose of (0.00975-9750rad) in (Fig.1), for cases in which photo degradation caused surface damage, cracks formation [7]. This is acommon phenomenon in radiation induced oxidative degradiation (hetrogeneous oxidation). This takes place when the rate at which oxygen is consumed within the polymer is more rapid than the rate at which it can be supplied from the surrounding atomosphere by diffusinginto the material. When this happens, exterior regions of the sample may become highly oxidized, while the oxygen-starved interior undergoes either a much lower range degree of oxidation, or else anaerobic degradiation. This process yields amaterial having mechanical properties, which vary signiticantly as a function of depth into specimen [10].Calibration curves were drawn at 245, 338, 359, and 377nm (Fig.2). At 359nm, where there is a decrease in radiation-induced absorption, the optical density as a function of absorbed dose shows a linear dependence in the 10mrad-10Krad range (Fig.3).



(Fig.1): UV/VIS Absorption spectra as a function of the wavelengths in PMMA/Athracene samples.



(Fig.2): Optical density of a PMMA/Athracene film as a function of gamma dose at different wavelength.



(Fig.3): Optical density of a PMMA/Athracene film as a function of gamma dose at 359nm wavelength.

Conclusion

70µm thick PMMA/Anthracene can be used as a radiation dosimeter of 10mrad-10krad. At 359nm, the optical density is more linearly changes with the absorbed dose. This dose range is important for using as an environmental and personal dosimeter.

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