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A study on the effects of Gamma radiation on the absorption spectra of polycarbonate thin films

Satar Jabbar Bader*, Riyadh. CH. Abul, Hussein F. Hussein

Department of Physics, College of Education for Pure Science, University of Basrah, Iraq.

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ABSTRACT

This study investigates the effect of gamma-rays on the optical properties of polycarbonate by analyzing its UV-Vis absorbance at various doses (0,2.5,6 and,12 kGy). Results show a significant increase in the UV region, attributed to radiation-induced chain scission, cross-linking, and formation of conjugated structures and color centers. At lower doses, a sharp rise in absorbance is linked to defect state creation and chromophore formation, causing material yellowing. Beyond 6 kGy, absorbance tends to plateau, indicating saturation of active modification sites. These findings are consistent with previous reports of photolytic degradation and increased optical density in irradiated polymers. The observed dose-dependent optical changes highlight the potential application of polycarbonate as a material for radiation dosimetry and detection.

1. Introduction

In recent decades, polymers have become increasingly integral to various aspects of daily life and industrial applications primarily due to their unique properties such as ease of fabrication and cost-effectiveness in mass production [1].These materials are ubiquitous across numerous sectors, including solar cell [2],communications[3], construction[4] ,electronics [5],optics[6], packaging, and medical devices[7]. Among these, polycarbonate (PC) stands out as an engineering thermoplastic that is recognized for its high toughness, good ductility, high glass transition temperature, excellent optical clarity, and dimensional stability. Polycarbonate is applied in critical fields, with uses in components for aircraft and automobiles, as well as safety glasses. However, during service, PC is subject to environmental factors including sunlight, temperature variations, moisture, and radiation exposure. Such conditions can instigate structural alterations in linear polymers, specifically Bisphenol A polycarbonate (BAPC), leading to a reduction in material properties, notably molecular weight. Originally developed during the "space race" in the late 1960s for astronaut helmets and visors, PC quickly found its place in safety eyewear due to its remarkable impact resistance. The production of the first single-vision ophthalmic lenses occurred in 1978, marking a significant milestone in its application. Over the subsequent decades, PC has been utilized in a myriad of applications owing to its distinctive characteristics, including exemplary toughness, high rigidity, good heat resistance, and resilience against organic compounds.

Extensive research has been conducted on the effects of varying gamma doses on PC polymers. Findings consistently indicate that the direct band gap (E_g^{opt}) of the material decreases as the gamma

*Corresponding author email: Sattar.Jabbar@uobasrah.edu.iq

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dose increases, highlighting the importance of understanding the behaviour of PC under different environmental and radiation exposures for safe and effective application in industrial uses. In the present work, the optical properties of PC were investigated using UV–visible spectroscopy to assess the applicability of gamma-ray dosimetry system materials for various applications.

2. Materials and method.

In this work, polycarbonate (commercially available as Makrofol E, Byer AG) was utilized. Thin films were produced through a casting technique, employing chloroform as the solvent. The concentration of Polycarbonate molecules in a solvent (10 mg/ml), the mixture was stirred at room temperature for 2h to yield a homogeneous solution. The solution deposited on a glass substrate by casting method at room temperature. The thickness of films was (2.5μm) measured by Micrometer model(COATING THICKNESS MEASUREMENT EQUIPMENT) from (OXFORD INSTRUMENTS) Structure of the (Polycarbonate polymer) is shown in Fig.1.

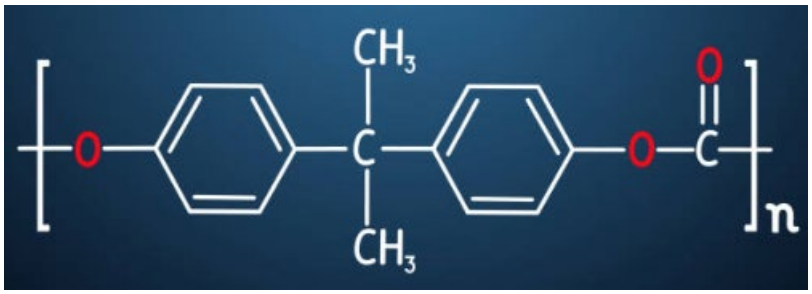

Fig .1. Structure of the Polycarbonate.

Polycarbonate polymer film was irradiated with ^{137}Cs gamma source made by J.L. Shepherd and Associates Company, California was placed in the Irradiation Unit of the Thermoluminescence Laboratory at the Department of Physics, College of Education for Pure Sciences, the University of Basrah in Basrah/ Iraq. The strength of the ^{137}Cs source was (1 curie) in 1985. The dose rate, which is adjusted to be provided by this source, is approximately (20 rad/min) in February 1985 reduced to (6.75 rad) during this work. The optical absorption spectra were recorded using a spectrophotometer mark (CE-7200). It is supplied from (CECIL), England. This is a measure for the interval wavelengths from (190-900)nm. During gamma-ray irradiation, 3mm thick Plexiglas was used with each sample to attain electronic equilibrium[8].

3. Results and discussion.

Figure 1 illustrates the UV–Vis absorption spectra of polycarbonate samples subjected to various gamma irradiation doses (0, 2.5, 6, and 12 kGy). The unirradiated sample (0 kGy) shows the associated with $\pi \rightarrow \pi^*$ and $n \rightarrow \pi^*$ electronic transitions in the aromatic carbonate structure of polycarbonate. The pronounced increase in absorbance for higher doses (6 kGy and 12 kGy) suggests the formation of conjugated structures and free-radical species due to chain scission and crosslinking, phenomena often observed in irradiated polymers[9]. The presence of secondary absorption peaks in the visible range (~600–700 nm) at higher doses may be linked to defect states and chromophore formation, which cause yellowing of the material [9] . However, the spectral shape remains generally consistent, indicating that while the concentration of absorbing species increases, the nature of the absorbing centers remains similar. These results align with previous studies reporting that gamma irradiation of polycarbonate leads to photolytic degradation and increased optical density due to both main-chain scission and oxidation processes[10].

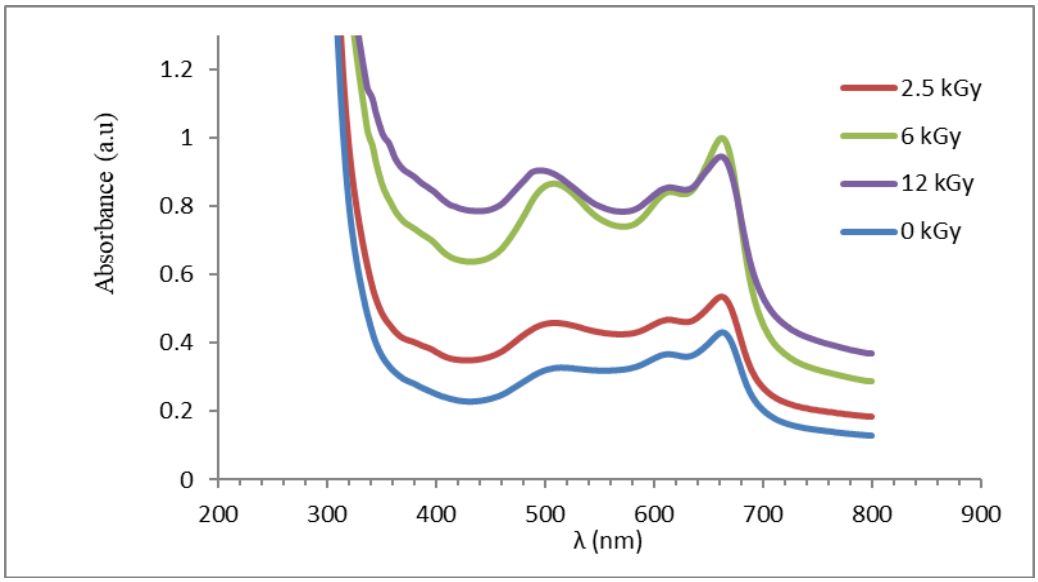

Fig. 1. Absorption spectra of poly carbonate for different doses

Fig 2. It is clearly observed that the value of the absorption edge decreases as the thickness increases. It is known that in the absorption process, a photon of known energy excites an electron from lower to a higher energy state, corresponding to an absorption edge.

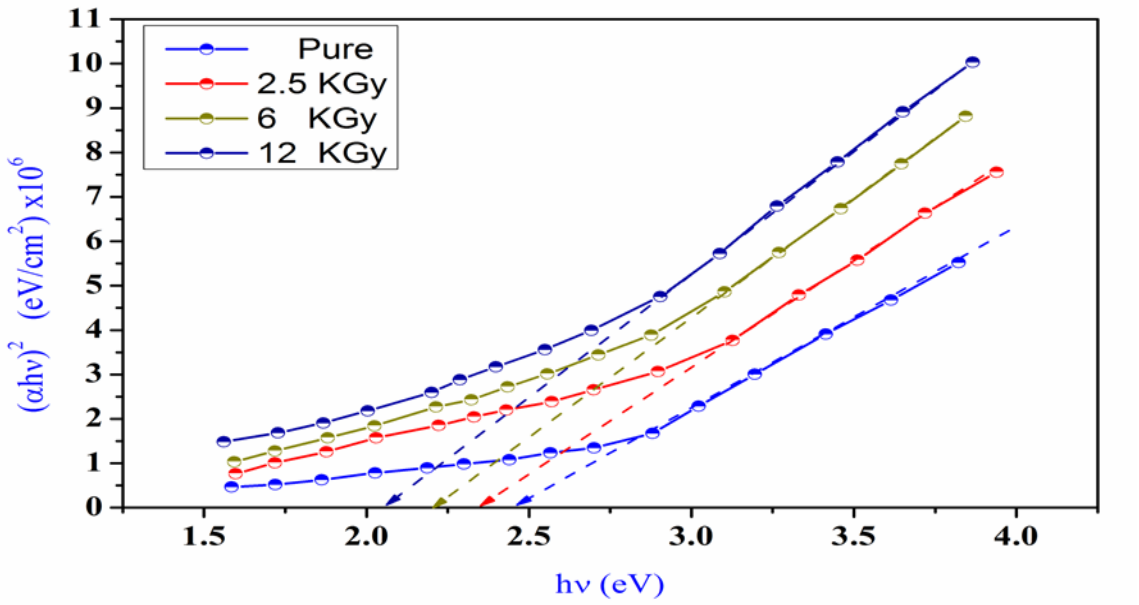

Fig. 2. The fundamental optical gaps of PC thin films before and after gamma irradiation.

It should be pointed out that the absorption coefficient of amorphous semiconductors, in the high-absorption region the energy gap E_g^{opt} can be obtained from the Touch formula[10].

The graph in Figure 3 shows the variation of normalized absorbance of polycarbonate at a wavelength of 654 nm as a function of the applied gamma-ray dose.

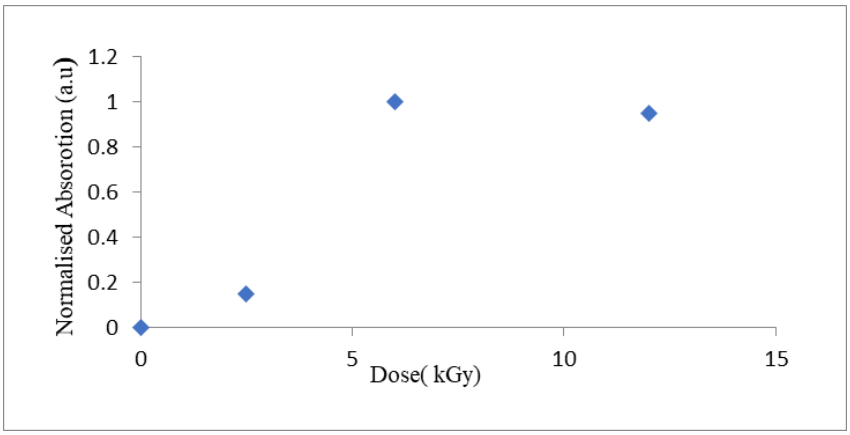

Fig 3. Variation of absorbance with Gamma-dose at 664 nm

The results indicate a clear dose-dependent response, where the absorbance increases significantly with increasing gamma dose up to approximately 6 kGy, after which it remains nearly constant or shows only slight variations. This behavior can be attributed to radiation-induced modifications in the polymer structure, such as chain scission, cross-linking, and the formation of color centers, which enhance light absorption at specific wavelengths[11]. The initial sharp increase in absorbance suggests that structural defects and chromophore formation dominate at lower doses. At higher doses, a saturation effect likely occurs as most available active sites are already modified, leading to a plateau in absorbance values[12]. The stability of the absorption spectrum was further investigated at an irradiation dose equivalent to 6 kGy, with measurements taken over four weeks. the results retained their overall profile throughout the monitoring duration, as illustrated in Fig. 4.[13]

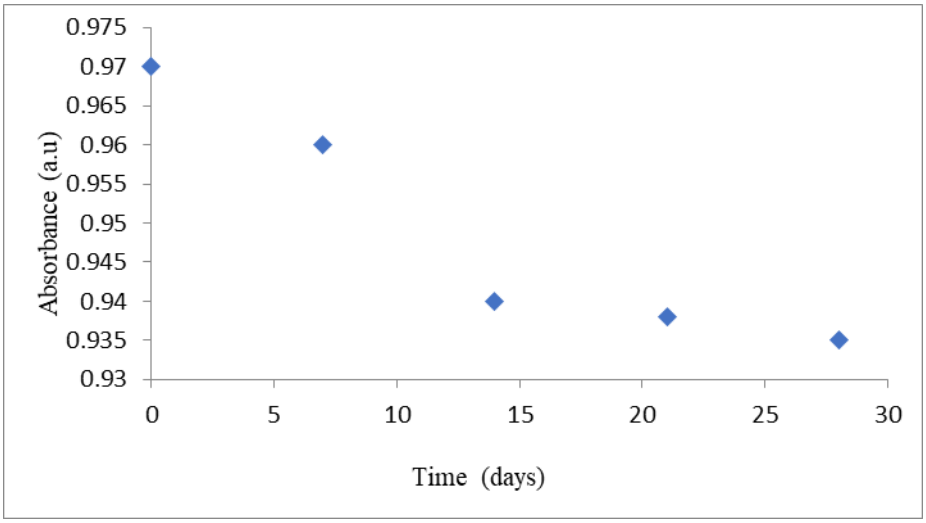

Fig. 4. Polycarbonate absorbance response under room temperature as a function of time at 664 nm. Gamma Irradiation 6 kGy.

Such radiation-induced optical changes in polycarbonate have been documented in several studies, underscoring its potential application in dosimetry and radiation detectors[14].

4. Conclusion.

The study concludes that gamma-ray irradiation significantly affects the optical properties of polycarbonate, particularly by increasing UV absorbance due to radiation-induced chain scission, cross-linking, and the formation of conjugated structures and color centers. At lower doses, a rapid increase in absorbance is observed, while beyond 6 kGy, the absorbance tends to plateau, indicating saturation of modification sites. These dose-dependent optical changes suggest that polycarbonate has promising potential for applications in radiation dosimetry and detection.

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دراسة حول تأثيرات إشعاع غاما على أطياف الامتصاص للأششية الرقيقة من البولي كربونات

ستار جبار بدر*، رياض جاسب ابوالهيل، حسين فالح حسين

قسم الفيزياء , كلية التربية للعلوم الصرفة , جامعة البصرة

معلومات البحث

الاستلام 31 تشرين أول 2025
المراجعة 24 شباط 2026
القبول 24 شباط 2026
النشر 30 حزيران 2026

الكلمات المفتاحية

1- مقنن اشعاعي، 2- تشعيع البولي كاربونيت بأشعة كاما 3- أطياف الامتصاص.

الملخص

تبحث هذه الدراسة في تأثير أشعة جاما على الخصائص البصرية للبوليكاربونيت، من خلال تحليل امتصاصها للأشعة فوق البنفسجية والمرئية عند جرعات مختلفة (0، 2.5، 6 و12 كيلو جراي). تُظهر النتائج زيادة كبيرة في منطقة الأشعة فوق البنفسجية، تُعزى إلى انقسام وترابط السلسلة الناتج عن الإشعاع، وتكوين هياكل مترافقة ومراكز اللون. عند الجرعات المنخفضة، يرتبط الارتفاع الحاد في الامتصاص بتكوين حالة عيب وتكوين الكروموفور، مما يتسبب في اصفرار المادة. بعد الجرعة 6 كيلو جراي، يميل الامتصاص إلى الاستقرار، مما يشير إلى تشبع مواقع التعديل النشطة. تتوافق هذه النتائج مع التقارير السابقة عن التحلل الضوئي وزيادة الكثافة البصرية في البوليمرات المشعة. تُسلط التغييرات البصرية المرصودة المعتمدة على الجرعة الضوء في التطبيق المحتمل للبولي كربونات كمادة لقياس جرعات الإشعاع والكشف عنها.

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***Corresponding author email:** Sattar.Jabbar@uobasrah.edu.iq

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