Eurasian Journal of Analytical Chemistry
ISSN: 1306-3057 OPEN ACCESS 2018 13 (3): 209-215

Investigation of GI Effect on the Optical Properties of Bromocresol Green Dye Doped Poly Methyl Methacrylate Thin Films

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Received ▪ 02 Jan 2018 Revised ▪ 07 March 2018 ▪ Accepted 30 March 2018

Abstract: In this paper, we investigated the effect of the gamma irradiation on the optical properties and energy band gap of PMMA doped by BCG dye thin films. Films of Poly Methyl Methacrylate doped by 20% BCG doping ratio to prepared concentrations 1x10-3 M were deposited on glass substrate using free casting method at room temperature. The optical properties of the films were determined using UV-Visible absorbance and transmittance spectra at the 300 - 800 nm wavelength range. The linear absorption coefficient, the extinction coefficient, and the optical and electrical conductivity were calculated in addition to the energy band gap. The results showed that the optical properties were increasing by increasing the dose irradiation, while the optical energy gap was decreasing with the increasing dose irradiation.

Keywords: Thin Films, Optical Properties, Gamma Ray.

INTRODUCTION

Organic dye doped polymers have a great deal of concern in recent years due to their chain arrangement, behave differently from other familiar materials and hold unique properties due to which they are widely used in various scientific and technological applications[1–3].

The unique properties of polymers such as low density, ability to form intricate shapes, good mechanical strength versatile, electrical properties and low manufacturing cost made them promising materials that have been successfully used as host matrices for dyes. The wide range of polymer applications can be even more extensive by incorporation of filler into polymer matrix, because dispersed filler may increase the concentration of absorptive or fluorescence centers as well as the opto-chemical and opto-physical stability of host polymer[4–6]. Many previous study led to more understanding the relation between polymer structure and physical properties and advantage behaver, thus the optical, mechanical properties gives complete idea on polymer science [2]. The result of radiation on polymeric materials is of unlimited importance as it allows modifying and improving the physical properties of polymers. The exposure of polymeric materials using gamma rays, X-rays, faster electrons, and ion beams, for example, leads to the formation of reactive intermediates and free radicals, which then lead to significant reactions such as degradation or cross-linking. These interactions have been controlled by the given amount of radiation dose [7]. In our study, we report our result on the effect of gamma irradiation on optical constants of doped PMMA films with (BCG) dye.

The measurement taken to the optical properties such as absorption coefficient, refractive index and optical energy band gap of dye-doped polymers were investigated using spectroscopic absorbance combined with transmittance measurements of samples before and after irradiation.

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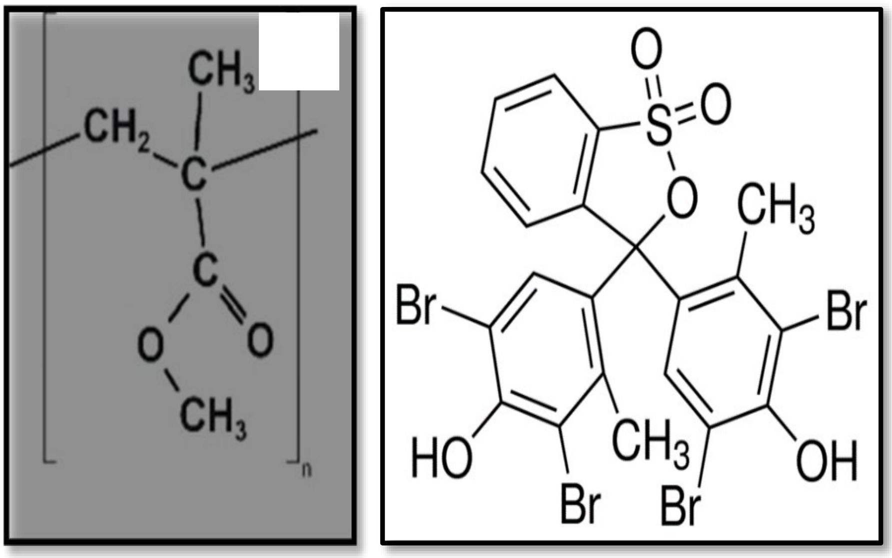

(a) (b)

Figure (1): Chemical structure and molecular formula of (a) PMMA and (b) BCG dye.

Results and Discussion

Optical Constant

The figures (2) ,(3) and (4) shows the Absorption (A), Transmittance (T) and Reflection (R) spectra of PMMA-BCG film measured by UV-vis spectrophotometer before and after irradiation . The results from Figure (2) shows the absorbance spectra as a function of the wavelength of the incident light for PMMA-BCG film. As it is clear, increasing the irradiation dose leads to an increase in the peak intensity. The Figure (3) shows the increase in irradiation dose caused decrease in transmittance spectra because the transmission relationship with absorption is a logarithmic relationship. In addition, figure (4) shows the Reflection spectra (R) for PMMA-BCG films before and after Irradiation where the reflectance R obtained from the relation (1) [11].

$$A + T + R = 1 \quad \ldots\ldots\ldots\ldots\ldots\ldots (1).$$

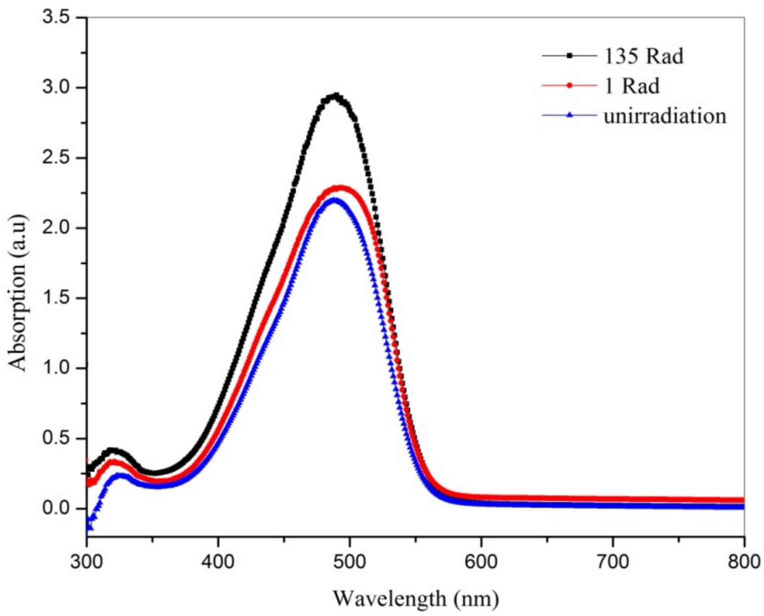

Figure (2): Absorption spectrum of of PMMA doped by BCG dye thin films before and after irradiation

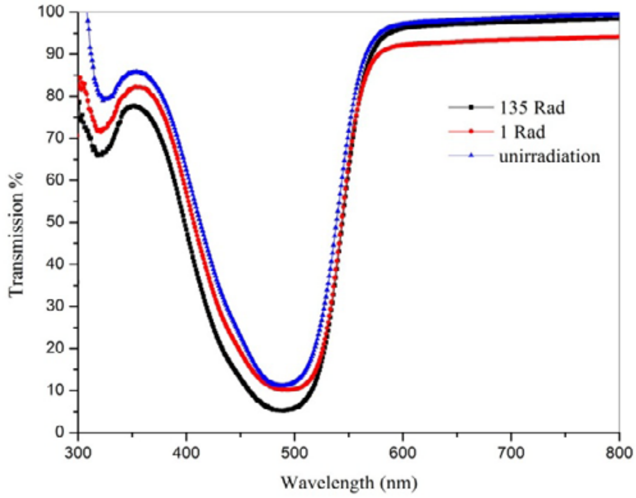

Figure (3): Transmittance spectrum of of PMMA doped by BCG dye thin films before and after irradiation.

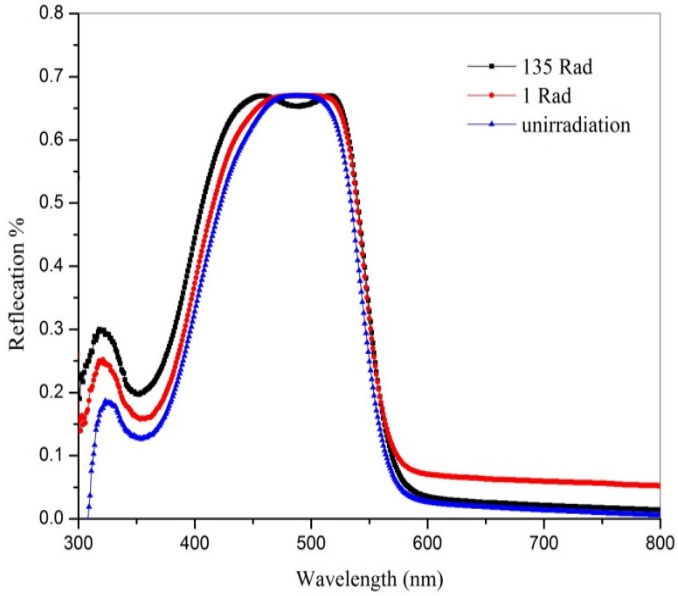

Figure (4): Reflection spectrum of of PMMA doped by BCG dye thin films before and after irradiation.

The optical constant such as refractive index (n) and extinction coefficient (k) can be calculated by the equations [11]

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

$$k = \frac{\alpha\lambda}{4\pi} \quad (3)$$

Where α is absorption coefficient and given by

$$\alpha = 2.303\, A/t \quad (4)$$

where t is the thickness of thin film. and λ is the wavelength of incident light (nm).

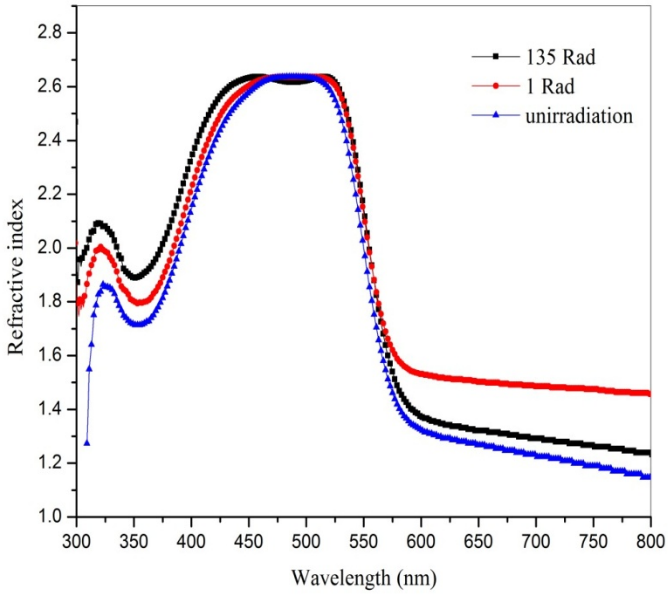

Figure (5): Refractive index of PMMA doped by BCG dye thin films before and after irradiation.

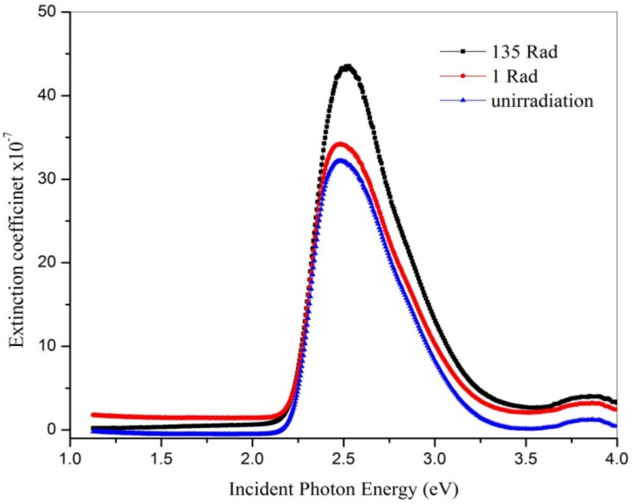

Figure (6): Extinction coefficient of PMMA doped by BCG dye thin films before and after irradiation.

Figures (5) and (6) shows the refractive index (n) and extinction coefficient (k) of of PMMA doped by

BCG dye thin films before and after irradiation, respectively. The increase of n values with increasing the dose irradiation led to increase absorbance and make the films denser, which in turn decreased propagation velocity of light through them resulting to increase (n) values. While (n) represents the ratio of light velocity through vacuum to velocity through any material. Then, the material become more opaque to the incident lights thus the velocity of light decreases and consequently n and k increases [7][12].This result indicates that the irradiation of PMMA-BCG thin film will change in the structure of the host-guest polymer- dye [17]. The irradiation has increased the absorbance in the visible region In addition; the optical conductivity ($\sigma_{optical}$) and electrical conductivity can be obtained from the equations as [11]

$$\sigma_{optical} = \frac{nc\alpha}{4\pi} \quad (5)$$

$$\sigma_{electrical} = 2\lambda\ \sigma_{optical}/\alpha$$

The optical and electrical conductivity of PMMA doped by BCG dye thin films before and after irradiation is shown in figure (7),and (8) in which an increase in optical conductivity with increasing the irradiation dose was observed.

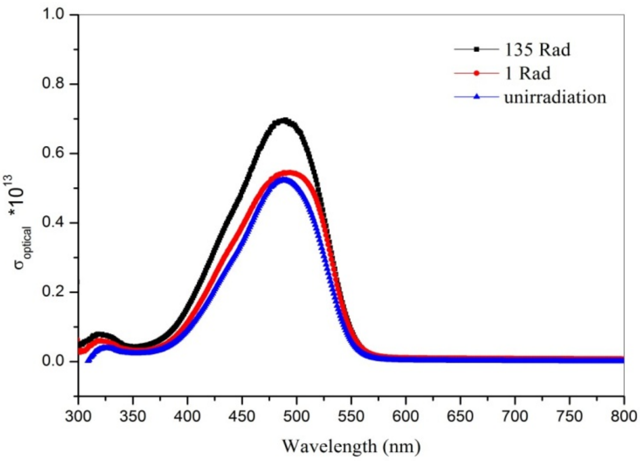

Figure (7): The optical conductivity of PMMA doped by BCG dye thin films before and after irradiation.

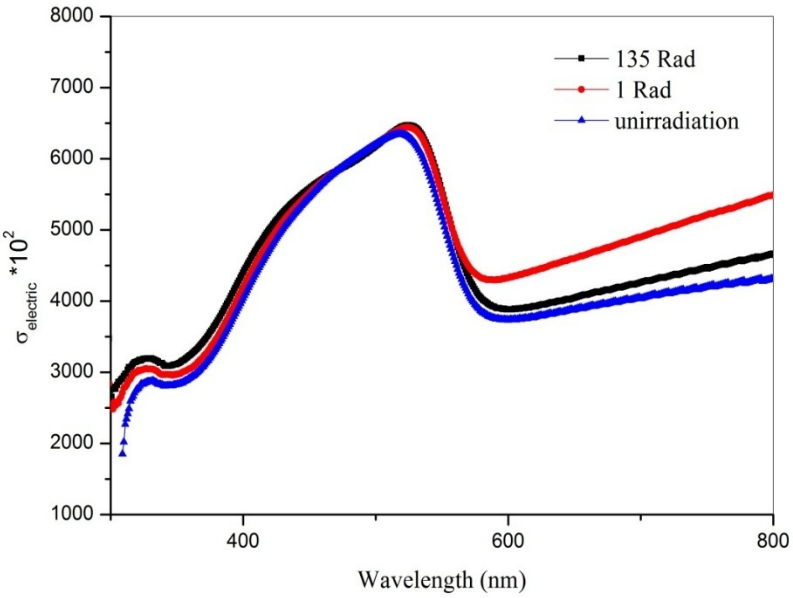

Figure (8): The electrical conductivity of PMMA doped3 by BCG dye thin films before and after irradiation.

The absorption coefficient (α) as a function of the wavelength were calculated from the equation (4) and shown in figure (8), it can be clearly observe the absorption is relatively small at long wavelengths. In addition, the absorption coefficient helps to conclude the nature of electronic transitions. When the high absorption coefficient values ($\alpha > 120$ cm-1) at higher energies, we expected direct electronic transitions, and the energy and momentum preserve of the electron and photon .Whereas the values of absorption coefficient is low ($\alpha < 120$ cm-1) at low energies, we expected indirect electronic transitions[13][4].In our results, the value of α for all samples less than 120 cm^{-1},so that the indirect electronic transitions will deduced.

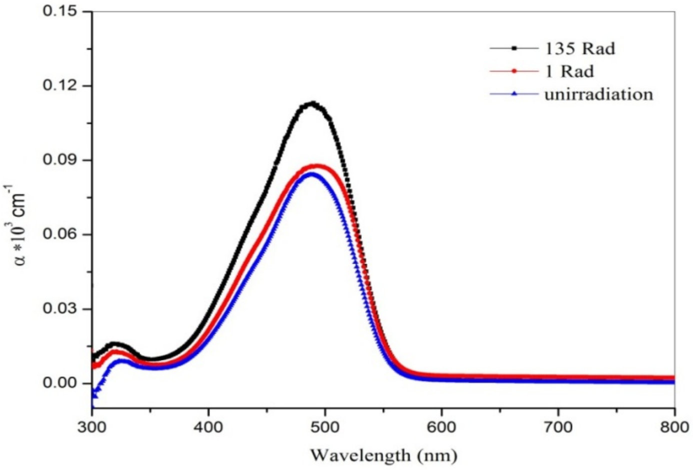

Figure (9): Absorption coefficient of PMMA doped by BCG dye thin films before and after irradiation.

Finally, from the absorption spectrum of PMMA-BCG film the optical energy band gap (Eg) was calculated by the Tauc relation [9]

$$\alpha h\upsilon = B\,(h\upsilon - E_g{}^{opt})^r \quad (6)$$

Where B is a constant, and depended on type of material, υ is the frequency of incident light, and r is the exponential constant, its value depends on the type of transition, where r =1/2 for allowed direct transition, r =3/2 for the forbidden direct transition, r =2 for allowed indirect transition, and r =3 for the forbidden indirect transition.

Figure (10) shows The optical indirect energy gap (Eg indirect) values which was calculated by the evaluation of the straight line of $(\alpha h\upsilon)^{1/2}$ plot against photon energy in the high absorption range followed by extrapolating the linear region of the plots to $(\alpha h\upsilon)^{1/2}$=0.

The indirect energy gap of the PMMA-BCG film before irradiation was found to be equal to 2.1eV, as shown in figure (10), and this value begins to decrease to 2.08 eV and 2.04 eV respectively, after irradiation. This decrease can be attributed to the creation of the site levels in forbidden indirect energy gap leading to facilitate the crossing of electron from the valence band to the local levels to conduction band [14– 16].

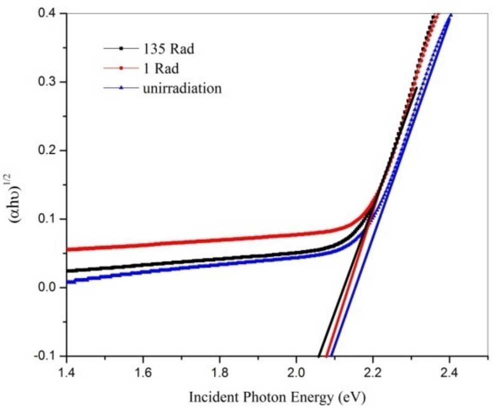

Figure (10): Indirect energy gap PMMA doped by BCG dye thin films before and after irradiation.

CONCLUSION

In this experimental study, we have investigated the effects of Gamma irradiation on the optical properties of PMMA-BCG thin films. Using absorption and transmittance spectrum for samples before and after irradiation, the optical constant such as absorption coefficient, refractive index, extinction coefficient, and optical conductivity, have been studied. Irradiation dose increment effect in the structure of film led to enhance the optical properties of PMMA-BCG, while the irradiation dose increment in the structure of PMMA-BCG film has been leaded to small decreasing in the bad gap of film. Therefore, it can be concluded that the BCG/PMMA thin films consider a promised materials for dose meter application.

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