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Study of Gamma irradiation effect on the Optical Properties of Bromocresol Green Dye Doped Poly Methyl Methacrylate Thin Films

A. J. Almusawe[1],*, R.J. Kadhum[2] T. F. Hassen[2], and N. F. Abd alrasheed[3]

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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.

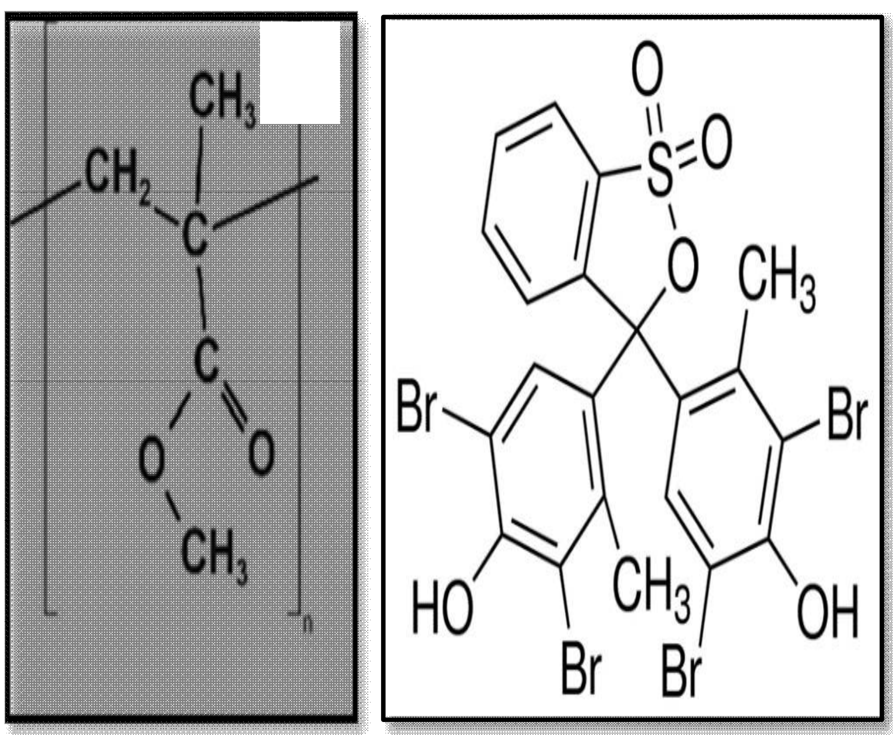
The measurement taken to the optical properties such as absorption coefficient, refractive index and optical energy band gap of dye-doped polymers were investigated using spectroscopic absorbance combined with transmittance measurements of samples before and after irradiation.

Samples Preparation and Irradiation Procedure

TheBromocresolgreen dye from(Sigma-Aldrich),itschemicalstructureisshown in Figure (1). Thebromo group canimprove the transparencyandthe thermalstability ofcompounds[8, 9].

Polymethyl methacrylate(PMMA)polymerfrom (Sigma-Aldrich),itschemicalstructure is showninFigure(1).Itisusedashostmaterialfordyeduetoits excellentopticalproperties.Itishighly amorphous withaverageM_W ofabout120,000,andglass transitiontemperature105°C[5].Itisan aromaticpolymermadefromthearomatic monomerstyrene,aliquidhydrocarbonthatiscommercially manufacturedfrom petroleum by thechemicalindustry.PMMAisathermoplastic substanceandoneof the mostwidelyused kinds ofplastic [8-9].

PMMA-BCG filmswerepreparedbycastingmethod.ThePMMA solutionwaspreparedby adding1gofPMMApowderin10 mlofchloroformundervigorous stirringfor60 min at 50oC.Each of dyeandpolymerwasdissolvedseparatelyin 1x10-3Mchloroform.Then,thesolutionofpolymerwas mixedwith20%dyesolution.dye-polymer mixtures solutionwith1x10-3M wascastedona cleanglass platewashedinacetone,Xanddistilledwater respectively.Finally,thefilmsweredriedinovenat50oCfor1hourstoremove theresidualsolvent.Theuniformxsurfacefilmswiththicknessaround50-60µm wereobtained[10]. Thetransmissionandabsorptionofthepreparedfilmswereinvestigatedby UV-Vis spectrophotometerin the range(300-800)nm. Then, PMMA-BCGsampleswith1mM concentration, withsize1*1.4cmwerecutfromthe commerciallyavailablesheet.Thesesamplesubjectedtoirradiationusing CS137sourcewithdoserate0.813rad/ha ndsourcestrengthwas7mci. Theirradiationprocess dividedintotwoperiod1hourand1weakthusthesamplewerehavingirradiationindoserangeof(0.813-136)rad/h .



(a) (b)

Figure (1):Chemicalstructure and molecularformulaof(a)PMMAand (b)BCGdye.

Results and Discussion

Optical Constant

The figures (2),(3)and (4) shows theAbsorption(A),Transmittance (T)andReflection (R)spectraof PMMA-BCGfilm measuredbyUV-visspectrophotometer beforeandafterirradiation.The results from Figure(2)showstheabsorbancespectraasa functionofthe wavelengthoftheincidentlightforPMMA-BCGfilm.Asitisclear,increasingtheirradiationdoseleadstoanincreaseinthepeakintensity.TheFigure (3) shows the increasein irradiation dose caused decrease intransmittance spectra because the transmissionrelationship withabsorptionisalogarithmic relationship.Inaddition,figure(4)showsthe Reflection spectra (R) for PMMA-BCG films before and after Irradiation where the reflectance R obtainedfromthe relation(1)[11].

$$A + T + R = 1 \quad \text{..................(1).}$$

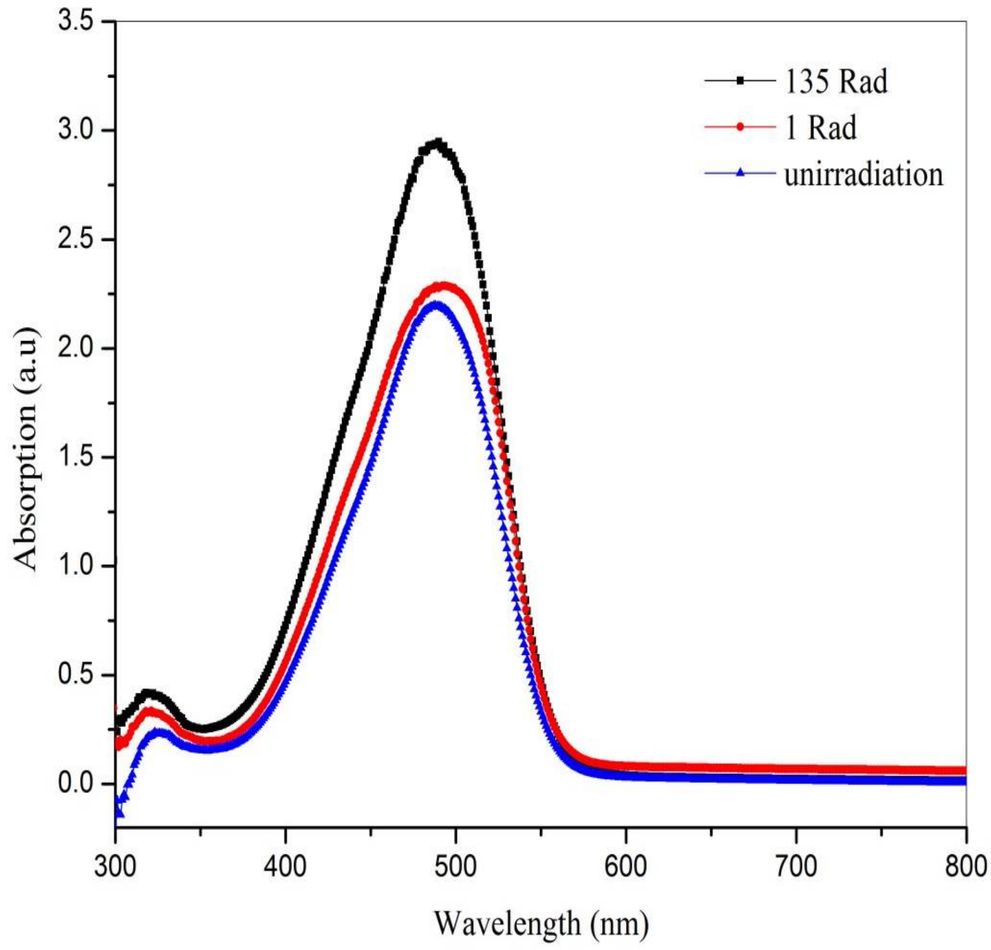


Figure (2): Absorption spectrum of of PMMA doped by BCG dye thin films before and after irradiation.

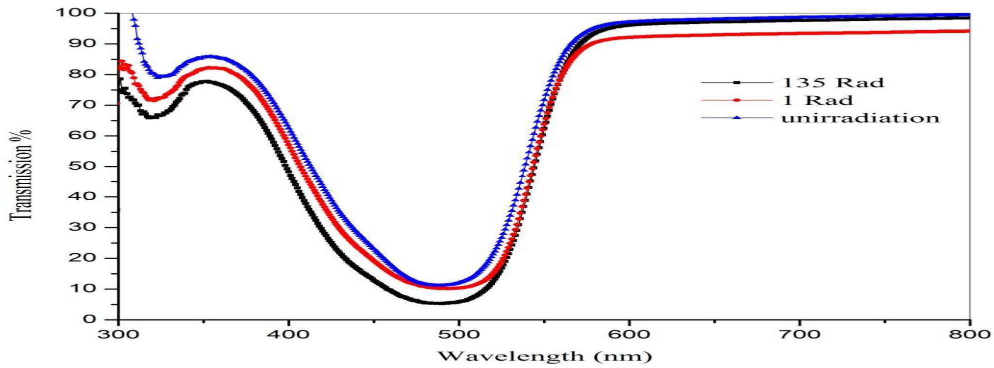


Figure (3): Transmittance spectrum of of PMMA doped by BCG dye thin films before and after irradiation.

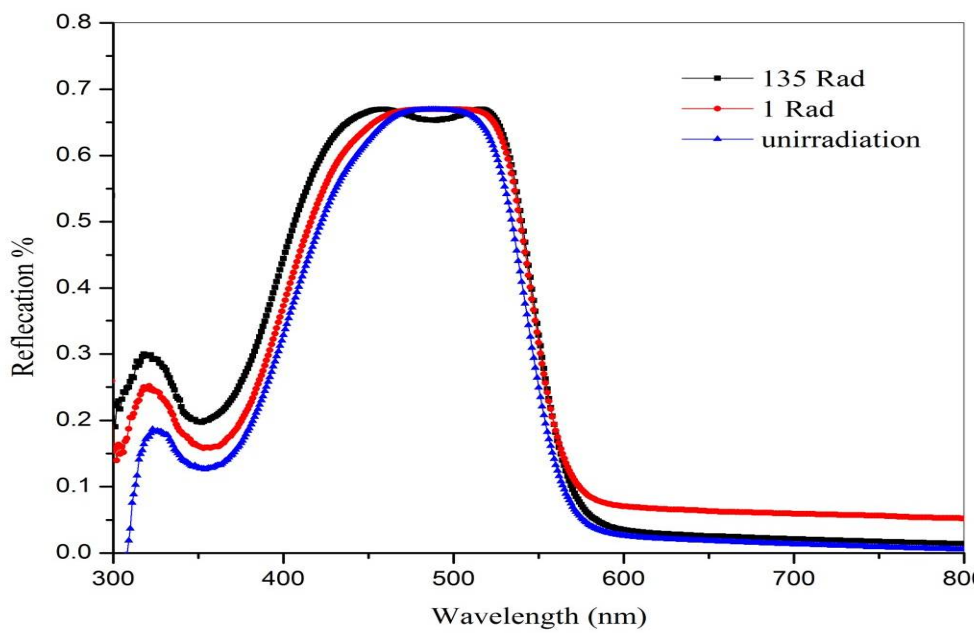


Figure (4): Reflection spectrumofof PMMA doped byBCGdye thinfilms before and afterirradiation.

Theoptical constantsuchasrefractiveindex(n)andextinction coefficient(k)canbe calculated bythe equations[11]

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

$$k=\frac{\alpha\lambda}{4\pi}$$

(�−*R*)�

(3)

Whereα is absorption coefficientand given by

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

where tisthethicknessofthin film. and λis the wavelength ofincidentlight(nm).

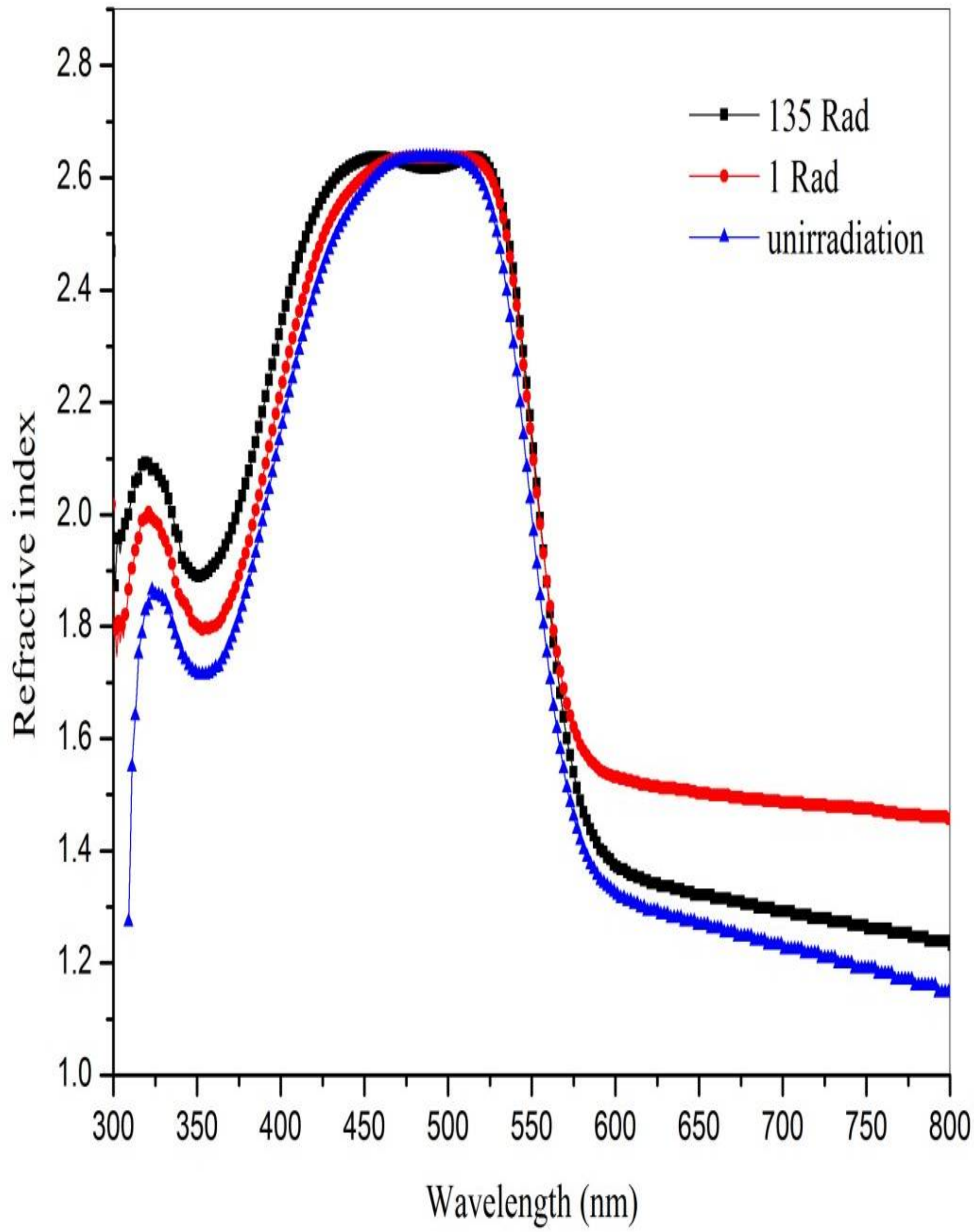


Figure (5): Refractive index of PMMA doped by BCG dye thin films beforeand afterirradiation.

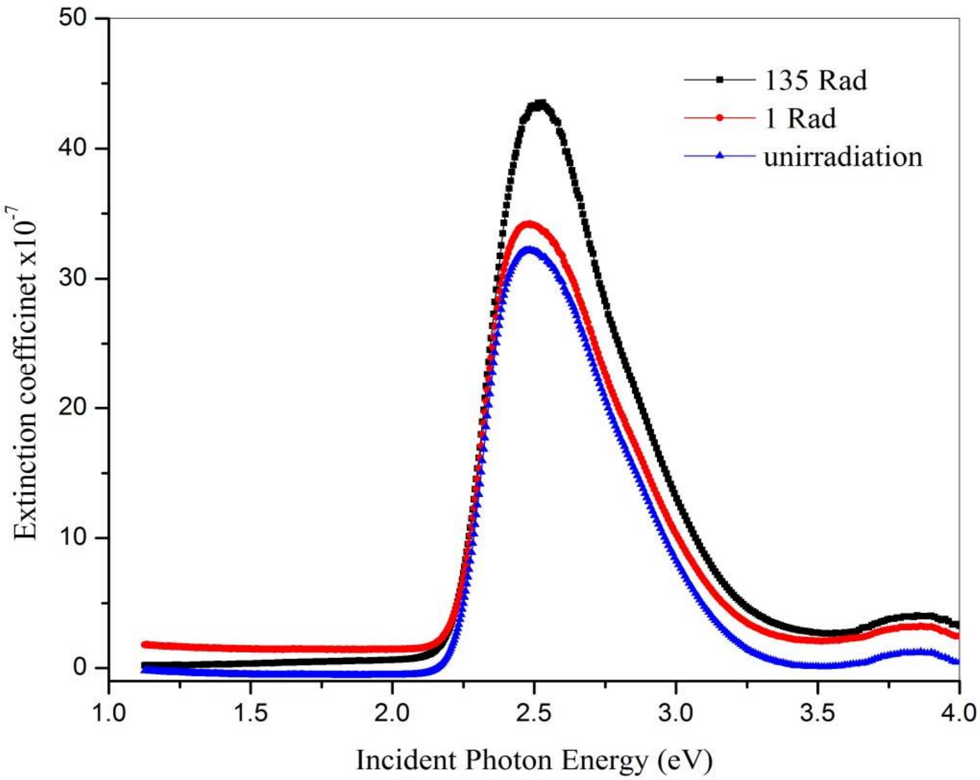


Figure (6): Extinction coefficient of PMMA doped by BCG dye thin films before and after irradiation.

Figures(5)and(6)showsthe refractiveindex(n)andextinctioncoefficient(k)ofofPMMAdopedby

BCGdye thinfilmsbeforeandafter irradiation,respectively.Theincrease ofnvalues withincreasing thedose irradiationled to increaseabsorbanceandmakethefilmsdenser,whichinturndecreased propagationvelocityoflight throughthemresultingto increase(n)values.While(n) representsthe ratio oflightvelocitythroughvacuumtovelocitythroughanymaterial.Then,thematerialbecome moreopaqueto the incident lights thus the velocity of light decreases and consequently n and k increases [7][12].This resultindicates that theirradiationofPMMA-BCG thin film willchange in the structure of the host-guest polymer- dye [17]. The irradiation has increased the absorbance in the visible regionInaddition;theopticalconductivity(σoptical) andelectricalconductivity canbe obtained fromthe equationsas[11]

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

$$\sigma_{electrical} = 2\lambda\sigma_{optical}/\alpha \quad (6)$$

Theopticalandelectrical conductivityofPMMAdopedbyBCG dyethinfilms beforeandafter irradiationis showninfigure(7),and(8)inwhichanincreaseinoptical conductivitywithincreasing the irradiation dosewas observed.

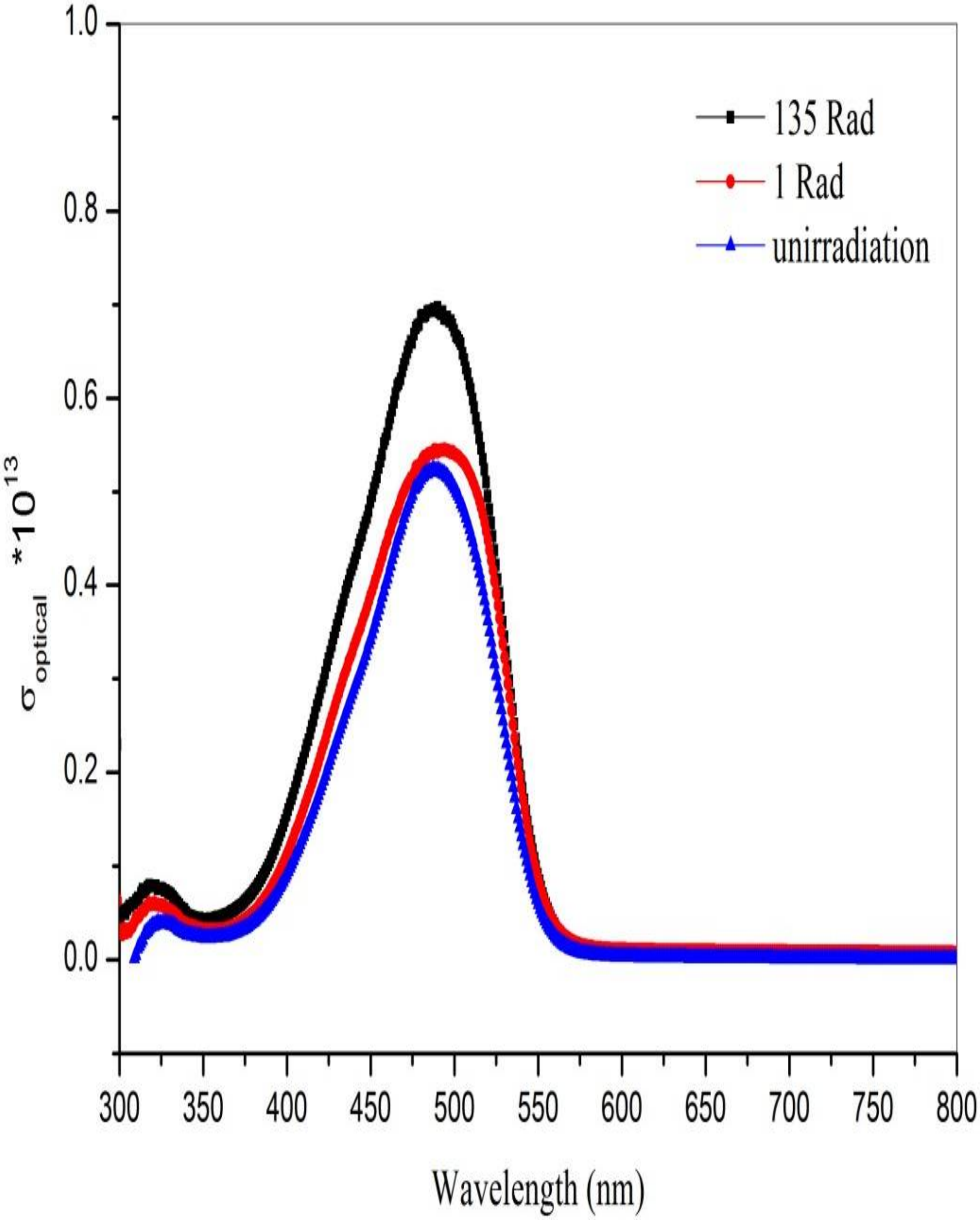


Figure (7): The optical conductivity of PMMA doped by BCG dye thin films before and after irradiation.

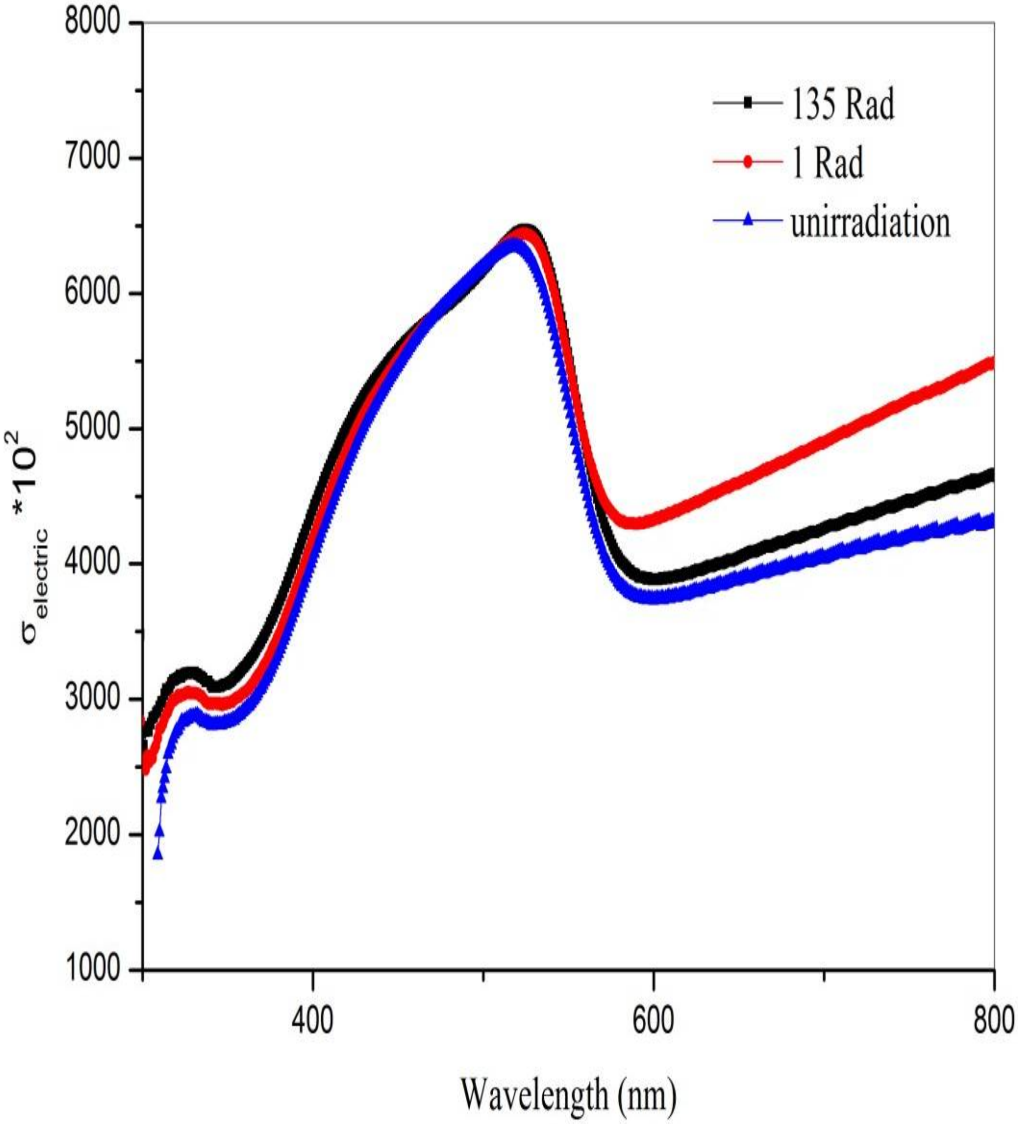


Figure (8): The electricalconductivityofPMMA doped3 byBCGdye thin films beforeand after irradiation**.**

Theabsorptioncoefficient(α)asafunction ofthewavelengthwerecalculatedfrom theequation (4)and showninfigure(8),itcanbeclearlyobservetheabsorptionis relativelysmallatlongwavelengths.In addition,theabsorptioncoefficienthelpstoconclude thenatureofelectronictransitions.Whenthehigh absorptioncoefficient values (α>120cm-1)athigherenergies, weexpected directelectronictransitions, and the energyandmomentumpreserve of the electron and photon .Whereasthe valuesofabsorption coefficient is low (α<120 cm-1)atlowenergies,we expected indirect electronic transitions[13][4].Inour results, the value of α for all samplesless than 120 cm^{-1},sothat theindirect electronic transitions willdeduced.

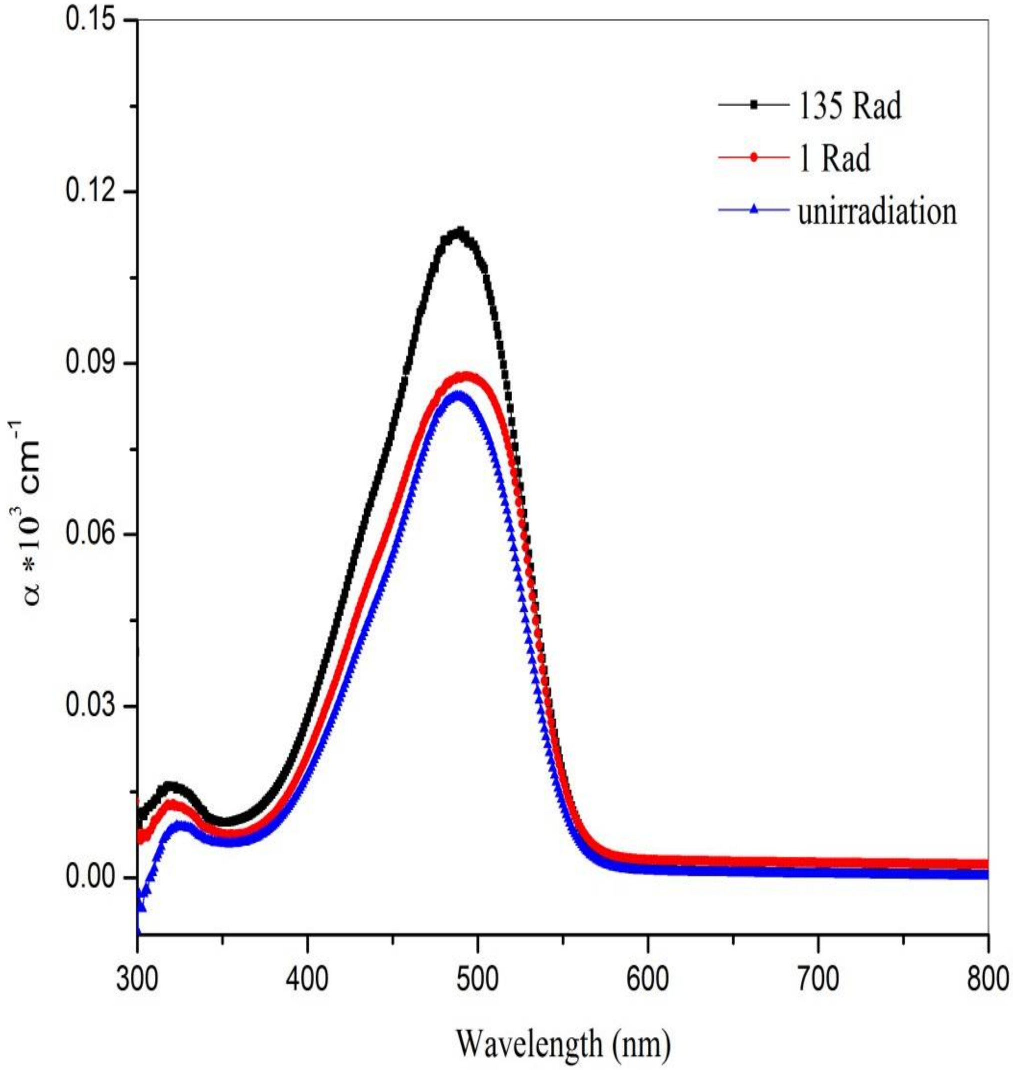


Figure (9): Absorption coefficientof PMMA dopedbyBCG dye thinfilms before and afterirradiation.

Finally,fromtheabsorptionspectrumofPMMA-BCGfilmtheopticalenergybandgap(Eg)wascalculatedbytheTaucrelation[9]

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

Where Bisa constant, anddepended ontype ofmaterial,υisthefrequencyofincident light, andristhe exponential constant,itsvaluedependsonthetypeoftransition,wherer=1/2forallowed directtransition, r=3/2fortheforbiddendirecttransition,r=2forallowedindirecttransition,andr=3forthe forbidden indirecttransition.

Figure(10)showsTheopticalindirectenergygap(Eg indirect)valueswhichwascalculatedbythe evaluationofthestraightlineof$(\alpha h\upsilon)^{1/2}$ plotagainst photonenergyinthehighabsorptionrange followed byextrapolatingthe linear region of the plotsto$(\alpha h\upsilon)^{1/2}$=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]

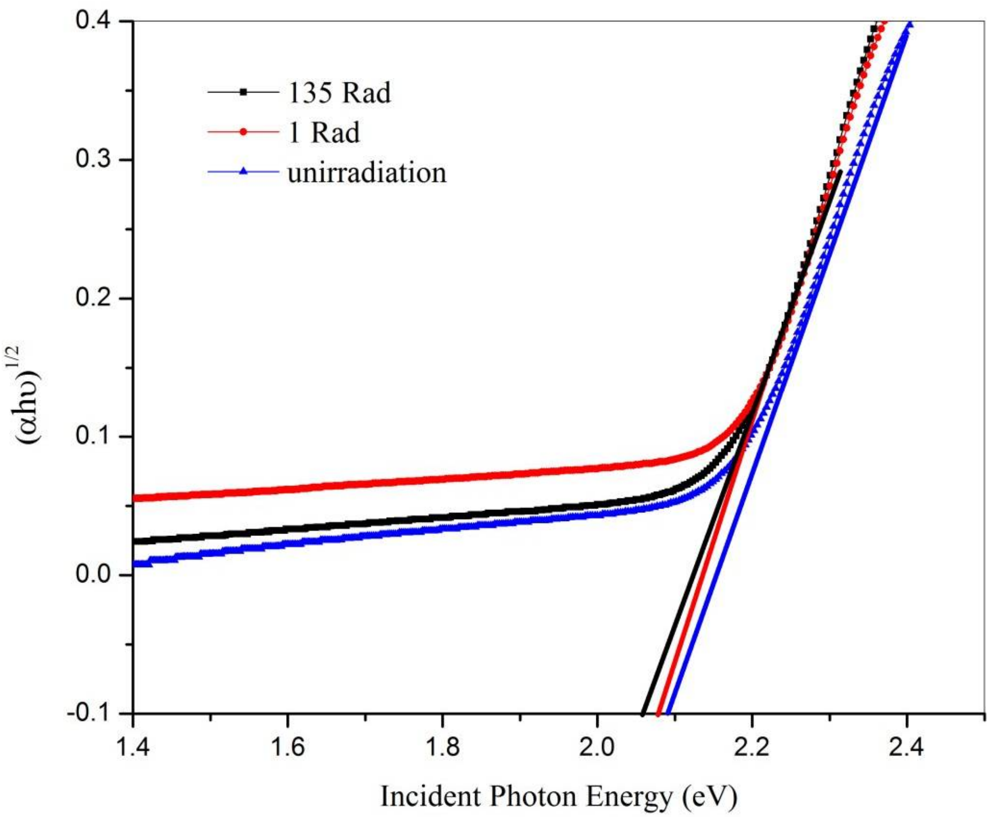


Figure (10):Indirectenergy gap PMMA doped byBCGdye thinfilms beforeandafterirradiation.

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 offilm.Therefore,itcanbeconcludedthattheBCG/PMMAthinfilmsconsiderapromisedmaterialsfordose meterapplication.

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