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Study the Effect of Ultraviolet Radiation on the Optical Properties of Pure PC and Anthracene Doping PC Films

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Abstract: The aim of the present research is concerned with study the effect of UV radiation on the optical properties at wavelengths 254, 365 nm of pure PC and anthracene doping PC films prepared using the cast method for different doping ratio 10-60 mL. Films of pure PC and anthracene doping PC were aged under UV radiation for periods of up to 360 h. It found that the effect of UV radiation at wavelength 254 nm on the optical properties is great than the effect of UV radiation at wavelength 365 nm. Also, it found that the optical energy gap of pure PC and anthracene doping PC films is stable against radiation.

Key words: Effect of UV radiation, anthracene, polymer, polycarbonate, optical properties, PC

INTRODUCTION

Polymers are organic materials characterized by long chain-like molecules built up from many units (monomers) which in general repeated hundreds or thousands of times. All atoms in chain bonded to each other by covalent bond whereas the chains keep together by Van der Waals bonding (Lukkassen and Meidell, 2007). Over the past decades the production and consuming of polymeric materials has been increasing rapidly. Many of these polymers are used for outdoor applications. Polycarbonate (PC) is aromatic polymer used in different industrial applications. It is a condensation polymer in which benzene rings plus quaternary carbon atoms form bulky stiff molecules that promote rigidity and strength (Salh, 2013). The effect of UV radiation at wavelength 254 nm on PC leads to scission the carbonate linkage and formation phenyl salicylate and dihydroxybenzophenone, whereas the effect of UV radiation at wavelength 365 nm lead to photo-oxidation (Rivaton *et al*., 2002). Anthracene is a Polycyclic Aromatic Hydrocarbons solid (PAH) of formula $C_{14}H_{10}$, consisting of three fused benzene rings. It is a component of coal tar. Anthracene is used in the production of the red dye alizarin and other dyes .

Tjandraatmadja *et al*. (1999) studied the effect of ultraviolet radiation on polycarbonate glazing. The effect of UV radiation on polycarbonate sample is carried out by using air-rich environment and a source of UV (QUV panel with UVA-340 nm fluorescent lamp). The polycarbonate samples irradiation with UV light at wavelength (340 nm) for period up to 3000 h. After irradiation, the degradation mechanism is combination of photo-fries and photo-oxidation. The degradation leads to chain scission at polymer surface caused embrittlement of the surface and decreased the total amount of light transmitted.

Abdullah (2006) studied the effect of high irradiation energy (Gamma, UV-light) radiation on the energy gap of three types of polymers (PMMA, PS and PC) doped with anthracene. The pure polymers (PMMA, PS and PC) and anthracene doping polymers (PMMA, PS and PC) irradiation with UV source (OHD-300 watt high pressure Hg-lamp of the main emission lines at 254, 290 and 365 nm) for period up to 34 h. After irradiation, the energy gap for PC is stable against radiation, whereas the energy gap of PMMA and PS is very sensitive to radiation.

Diepens (2009) studied the photo-degradation and stability of bisphenol A polycarbonate in weathering conditions. Extruded films of bisphenol a polycarbonate with thickness 0.2 mm irradiation with UV light (atlas sun test containing a borosilicate filtered xenon lamp) at wavelength (340 nm). After irradiation, the UV spectroscopy show peaks at 320 and 355 nm refer to phenyl salicylate and dihydroxybenzophenone, respectively and this refer to formation photo-fries rearrangement.

The aim of this research is to study the effect of UV radiation at wavelengths 254-365 nm on the optical properties of pure PC and anthracene doping PC films for doping ratio 10-60 mL.

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The optical absorption coefficient can be calculated from the optical absorbance spectra by using the relation (Sloomi, 2016):

$$\alpha = \frac{2.303A}{T} \quad (1)$$

A is the absorbance. t is the thickness of the samples. The nature of electronic transition can be calculated by using the absorption coefficient. When the values of absorption coefficient are high ($\alpha > 10^4$ cm^{-1}) at higher energies, direct electronic transition will be expected and the energy and momentum conservation for the electron and photon included. Whereas when the values of absorption coefficients are low ($\alpha > 10^4$ cm^{-1}) at low energies, indirect electronic transitions have been expected (Rashid *et al*., 2013).

The optical band gap is the value of optical energy gap that is necessary to develop the electronic band structure of material. It can be obtained by plotting $(\alpha h\upsilon)^{1/r}$ versus ($h\upsilon$) in the high absorption range followed by extrapolating the linear region of the plots to $(\alpha h\upsilon) = 0$ (Al-Rubaie, 2008; Alwan, 2010).

The value of r is 1/2 for allowed direct transition, 3/2 for forbidden direct transition, 2 for allowed indirect transition and 3 for forbidden indirect transition.

MATERIALS AND METHODS

Experimental work: Polycarbonate processed by the company Sabic with trade name lexan and anthracene processed by the chemical point company with chemical formula $C_{14}H_{10}$ utilized in this research. The cast method used to prepare pure PC film and anthracene doping PC films for different doping ratio 10-60 mL. PC solution is prepared by dissolving (0.3 g) of PC in 10 mL chloroform. The PC solutions cast onto glass petri dish with diameter (10 cm) and then leave it dry at room temperature for 24 h. The anthracene solution with concentration (1×10^{-4} mol./L) is prepared according to the method (AL-Kadhemy, 1995). Then, different volume ratio of anthracene solution 10-60 mL were added to PC solution and mixed very well. The mixture cast onto glass petri dish with 10cm diameter and left to dry at room temperature for 24 h to get homogeneous films. The irradiation of samples was carried out by UV-cabinet using a mercury lamp, type Leicarm 2145 (Germany). The distance between the UV source and samples is 15 cm. The pure PC and anthracene doping PC films irradiation with UV light at wavelengths 254 nm for period 24, 240, 360 h and at wavelengths (365 nm) for period 24, 240, 360 h. The UV-visible spectrophotometer type (T70/T80 Series UV/VIS Spectrometer) used to measure the absorption and transmission spectra in the wavelength range (200-900) nm.

RESULTS AND DISCUSSION

Absorption spectrum: Figure 1 shows the absorption spectrum of pure PC film and anthracene doping PC films for different doping ratio 10-60 mL. For pure PC, the absorption spectrum has two peaks; the first peak at wavelength (305 nm) with intensity (0.638) and the second peak at wavelength (345 nm) with intensity (0.609) the different between these peaks is 40 nm which refers to the same formation origin (Gupta *et al*., 2000). So that, these two peaks are attributed to carbonyl group. In

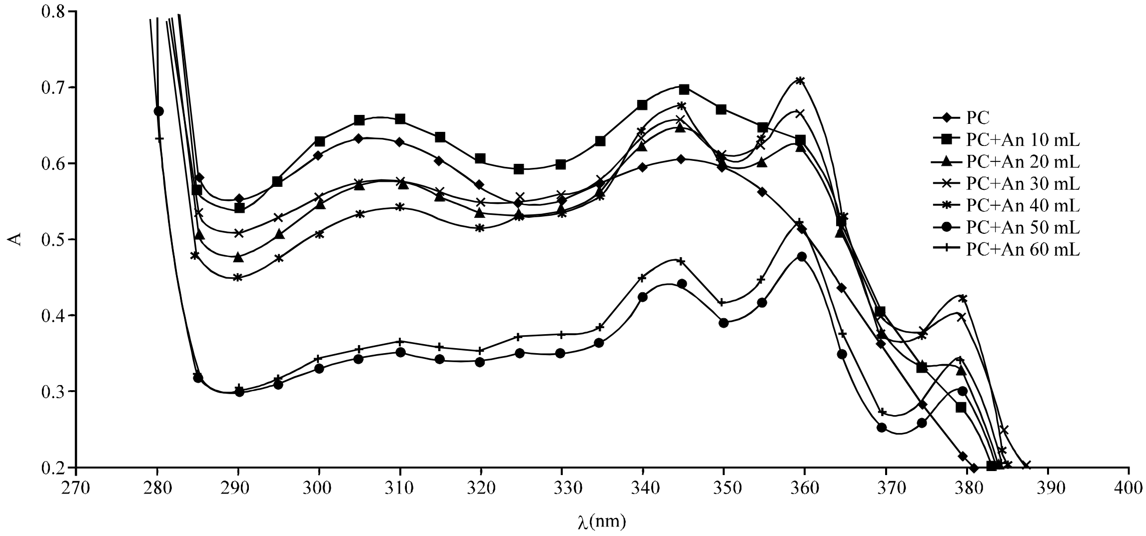

Fig. 1: Absorption spectrum of anthracene doped PC films in different doping ratio

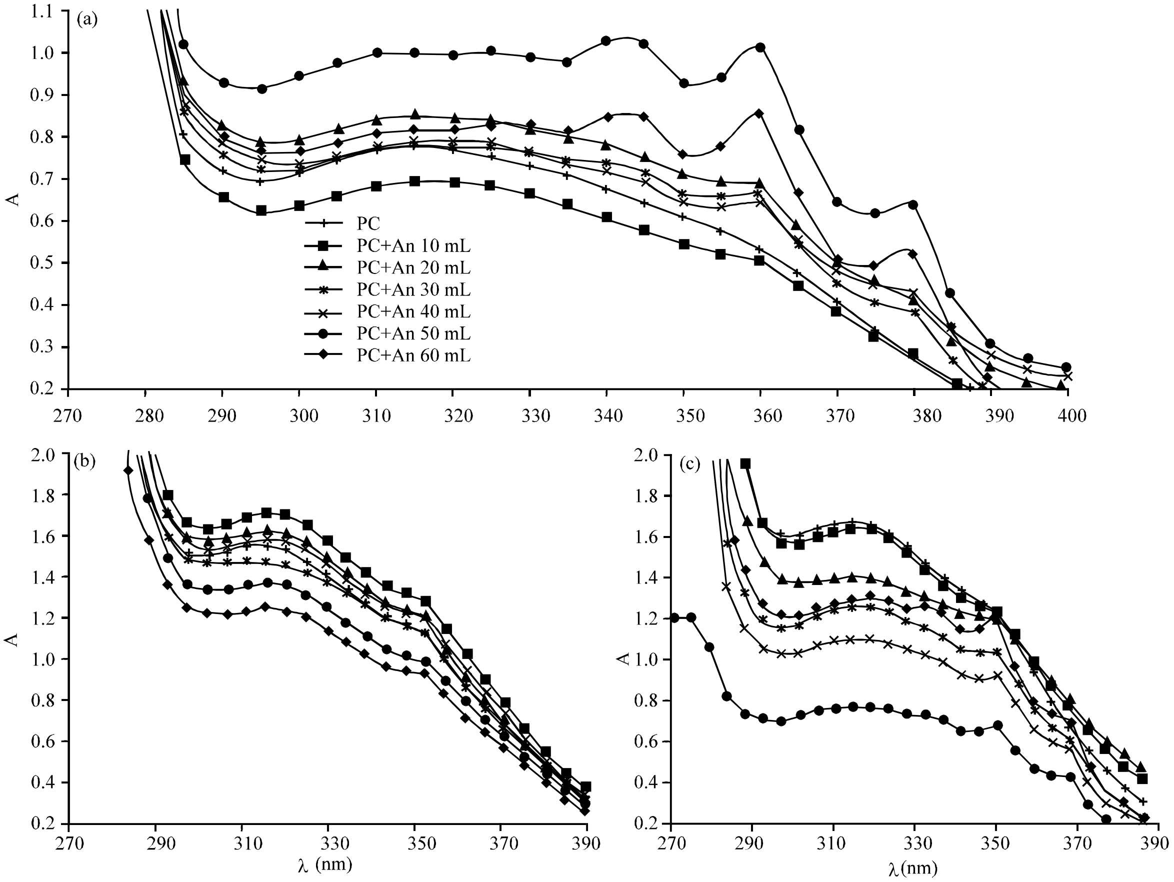

Fig. 2: The effect of UV radiation at wavelength (254 nm) on the absorption spectrum of pure PC and anthracene doping PC films for different doping ratio for period: a) 24 h; b) 240 h and c) 360 h

anthracene doping polycarbonate films, the change in wavelength is clearly shown by appearing single peak at wavelength (360 nm) for doping ratio (20 mL) and then additional peak appears at wavelength (380 nm) for doping ratio (30 mL), these two peaks are attributed to anthracene.

The effect of UV radiation at the wavelengths (254 nm) on the absorption spectrum for pure PC and anthracene doping PC films for different doping ratio for period 24, 240, 360 h are shown in Fig. 2. The carbonyl peaks disappear completely in pure PC and anthracene doping PC films for irradiation time 240 h and peak appear at wavelength (320 nm) these peak refers to phenylsalicylate formation also the anthracene peak disappear. For irradiation time (360 h), peak appear at wavelength (360 nm) in anthracene doping PC films for doping ratio 30-60 mL which refer to dihydroxybenzophenone formation and peak appear at wavelength (340 nm) in anthracene doping PC film for doping ratio (60 mL).

The effect of UV radiation at wavelength (365 nm) on the absorption spectrum of pure PC and anthracene doping PC films for different doping ratio for period 24, 240 and 360 h are shown in Fig. 3. Irradiation pure PC and anthracene doping PC films with UV radiation at wavelength (365 nm) does not lead to disappear of polycarbonate peaks but only shown slight decrease in intensity of these peaks .This means that the irradiation of pure PC and anthracene doping PC films with long wavelengths does not lead to scission of carbonate backbone. The anthracene peaks disappear in anthracene doping PC films after irradiation with UV light at wavelength (365 nm).

Transmission spectrum: Figure 4 shows the transmission spectrum of pure PC and anthracene doping PC films for different doping ratio.

The effect of UV radiation at wavelength (254 nm) on transmission spectrum for pure PC and anthracene doping PC films for different doping ratio at different irradiation times are shown in Fig. 5. The transmission spectrum

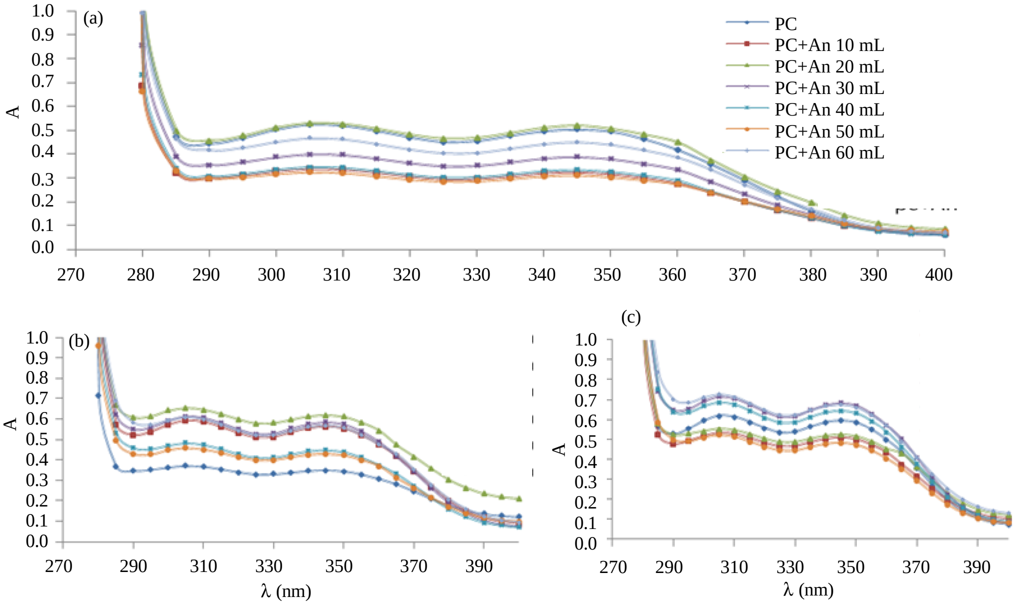

Fig. 3: The effect of UV radiation at wavelength (365 nm) on the absorption spectrum of Pure PC and anthracene doping PC films for different doping ratio for period: a) 24 h; b) 240 h and c) 360 h

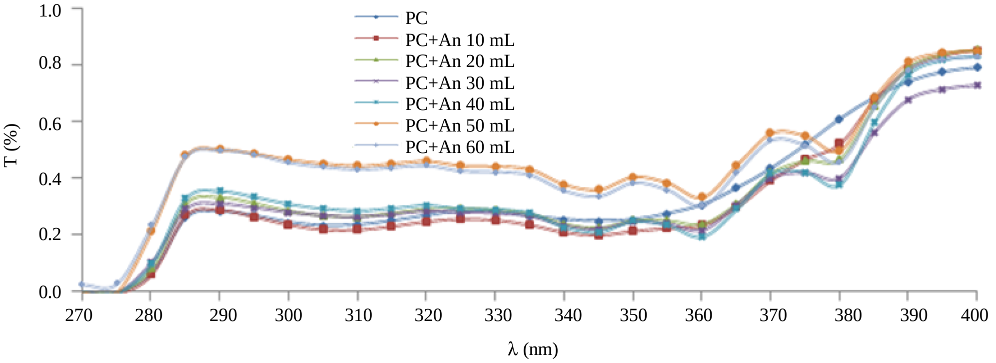

Fig. 4: Transmission spectrum of pure PC and anthracene doping PC films in different doping ratio

for pure PC and anthracene doping PC films decrease after irradiation with UV light. This is due to irradiation of polycarbonate with UV light lead to embrittlement of the polymer surface, making it more liable to corrosion and the polymer surface became uneven. Therefore, the scattering of light increased on the surface of the polymer and the amount of transmitted light through the polymer decrease after irradiation.

The transmission spectra for pure PC and anthracene doping PC films for different doping ratio after irradiation with UV radiation at wavelength (365 nm) with different irradiation times are shown in Fig. 6. Slight change on the transmission spectra after irradiation will be observed.

Absorption coefficient: The absorption coefficient is calculated from Eq. 1 for all samples. Figure 7 shows the absorption coefficient of pure PC and anthracene doping PC films for different doping ratio. The value of absorption coefficient for all samples $<10^4$ cm^{-1}, so that, the indirect electronic transition will deduced.

The effect of UV radiation on absorption coefficient for pure PC and anthracene doping PC films at wavelength (254 nm) for different irradiation times are shown in Fig. 8. The absorption coefficient for all samples increase after irradiation but still low than 10^4cm^{-1}, so that, the nature of electronic transitions is indirect after irradiation with UV light at wavelength (254 nm).

The effect of UV radiation on absorption coefficient for pure PC and anthracene doping PC films at wavelength (365 nm) for different irradiation times are shown in Fig. 9. It can be seen a slight change in the absorption coefficient after irradiation with UV light at wavelength (365 nm).

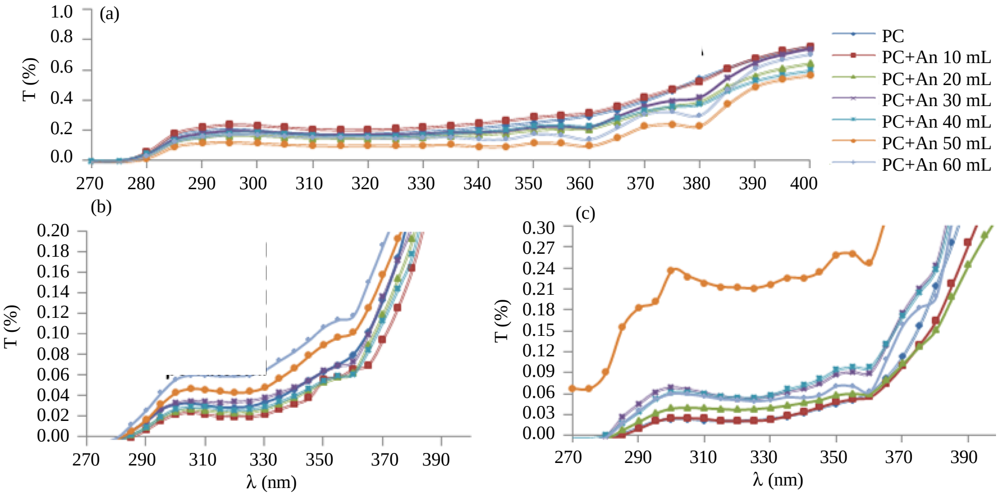

Fig. 5: Effect of UV radiation at wavelength (254 nm) on transmission spectrum for different irradiation times: a) 24 h; b) 240 h and c) 360 h

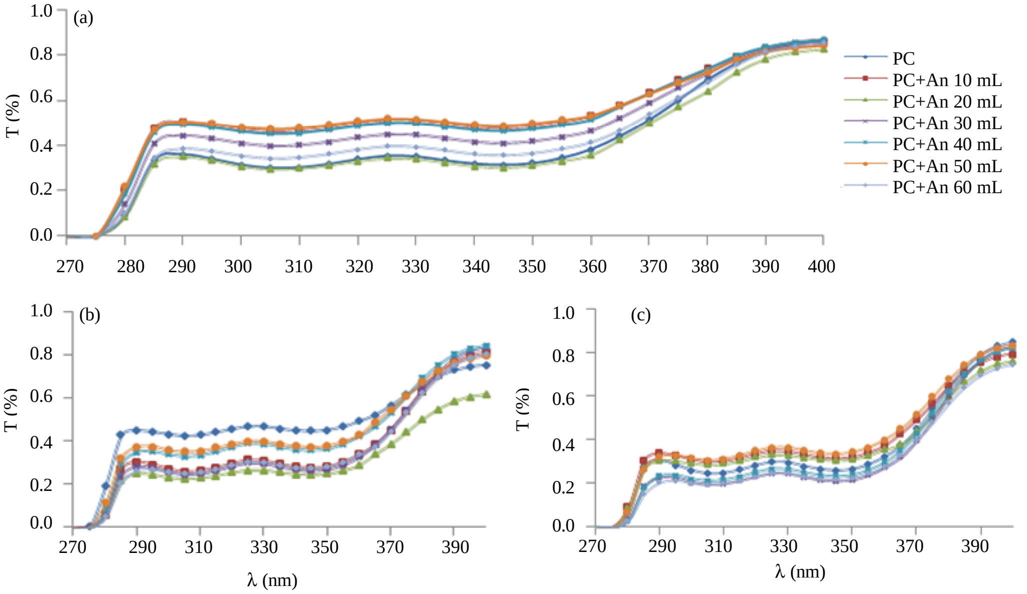

Fig. 6: Effect of UV radiation at wavelength (365 nm) on transmission spectrum for different irradiation times: a) 24 h; b) 240 h and c) 360 h

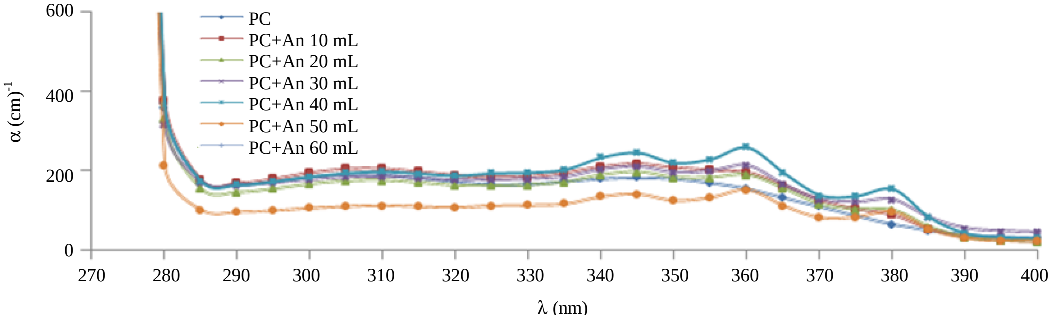

Fig. 7: Absorption coefficient of pure PC and anthracene doping PC films for different doping ratio

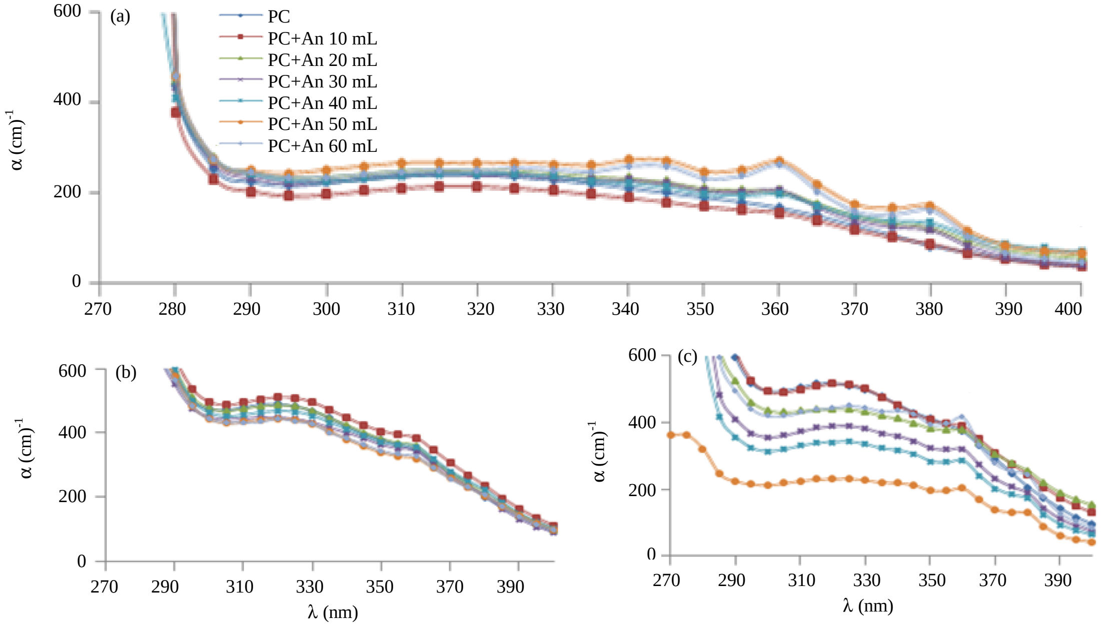

Fig. 8: Effect of UV radiation at wavelength (254 nm) on absorption coefficient for different irradiation times: a) 24 h; b) 240 h and c) 360 h

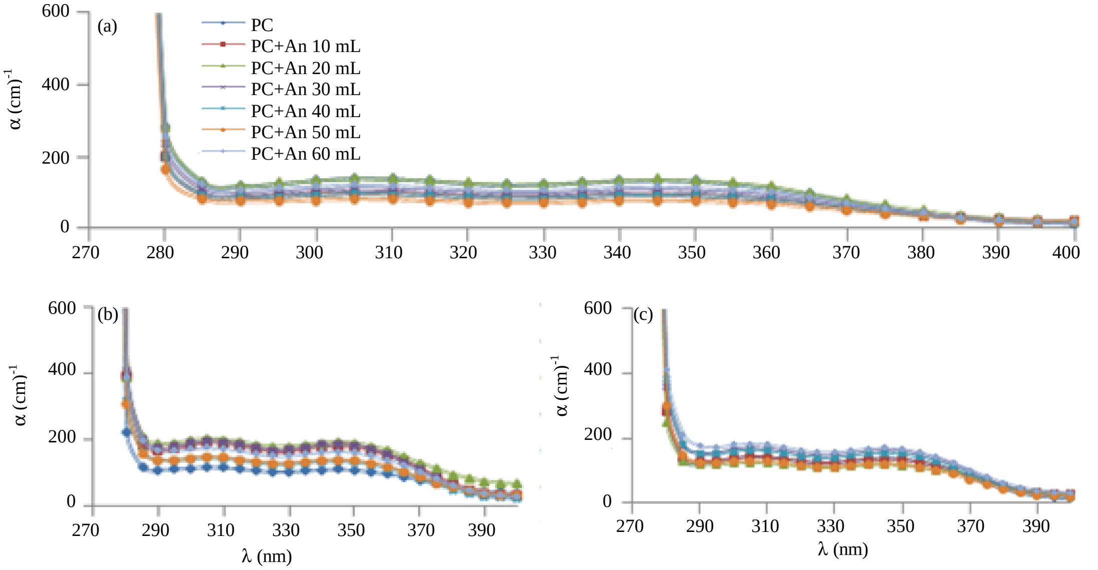

Fig. 9: Effect of UV radiation at wavelength (365 nm) on absorption coefficient for different irradiation times: a) 24 h; b) 240 h and c) 360 h

Optical energy gap: The optical energy gap of pure PC and anthracene doping PC films for different doping ratio are shown in Fig. 10 and Table 1.

The effect of UV radiation at wavelength (254 nm) on energy gap of pure PC and anthracene doping PC films are shown in Fig. 11 and Table 1. It can be seen a slight changes in the absorption edge and value of energy gap after irradiation. This mean the energy gap of pure PC and anthracene doping PC films is stable against radiation.

Table 1: The energy gap for pure PC and anthracene doping PC films irradiation with UV radiation at wavelength (254 nm)

	Energy gap (eV)						
	Doping ratio of anthracene-PC films						
Time (h)	PC	10 (mL)	20 (mL)	30 (mL)	40 (mL)	50 (mL)	60 (mL)
0	4.42	4.42	4.43	4.43	4.43	4.44	4.39
24	4.43	4.43	4.42	4.43	4.39	4.43	4.42
240	4.33	4.18	4.31	4.33	4.32	4.33	4.33
360	4.32	4.31	4.34	4.33	4.41	4.34	4.34

Table 2: The energy gap for pure PC and anthracene doping PC films irradiation with UV radiation at wavelength (365 nm)

	Energy gap (eV)						
	Doping ratio of anthracene-PC films						
Time (h)	PC	10 (mL)	20 (mL)	30 (mL)	40 (mL)	50 (mL)	60(mL)
0	4.42	4.42	4.43	4.43	4.43	4.43	4.40
24	4.43	4.43	4.43	4.43	4.43	4.43	4.43
240	4.44	4.41	4.42	4.41	4.43	4.43	4.42
360	4.43	4.43	4.43	4.42	4.42	4.43	4.42

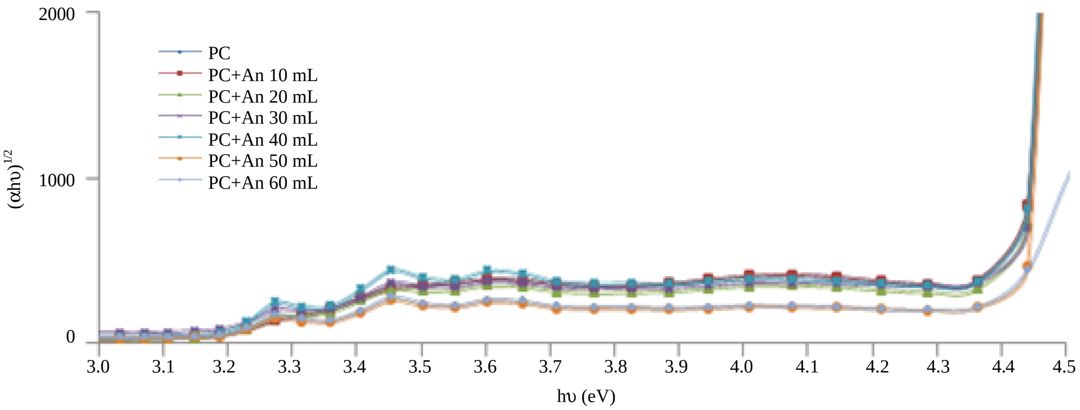

Fig. 10: Energy gap of pure PC and anthracene doped PC films in different doping ratio

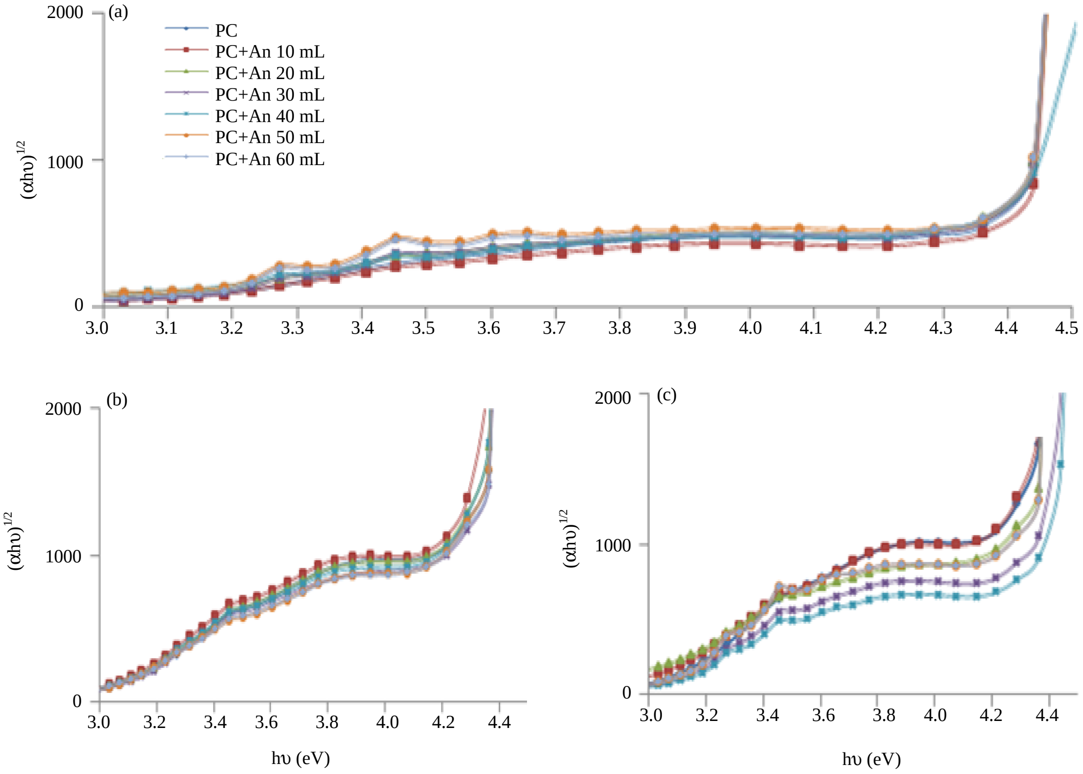

Fig. 11: Effect of UV radiation at wavelength (254 nm) on energy gap for different irradiation times: a) 24 h; b) 240 h and c) 360 h

Figure 12 and Table 2 show the effect of UV radiation at wavelength (365 nm) on energy gap of pure PC and anthracene doping PC films for different doping radio. The energy gap does not change significantly after irradiation.

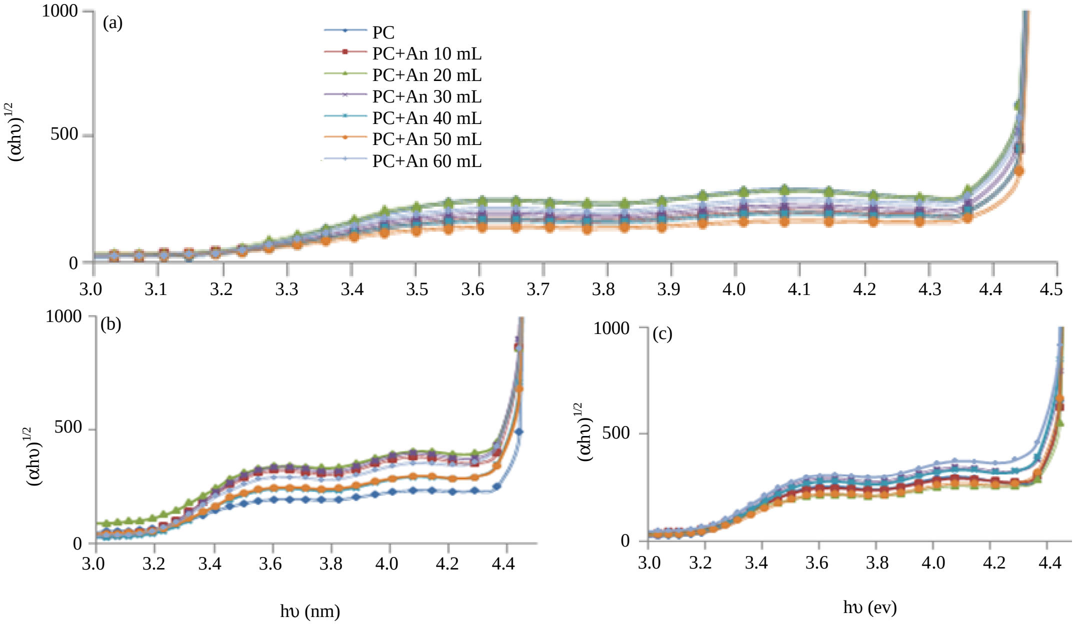

Fig. 12: Effect of UV radiation at wavelength (365 nm) on energy gap for different irradiation times: a) 24 h; b) 240 h and c) 360 h

CONCLUSION

From this study it can be concluded that: The effect of UV radiation at wavelength (254 nm) on the absorption spectrum lead to disappear the carbonyl peaks and this mean that the carbonate backbone linkage scission, whereas the effect of UV radiation at wavelength (365 nm) on the absorption spectrum does not lead to disappear of carbonyl peaks .Therefore, the energy of UV radiation at wavelength 365 nm is not sufficient to break the carbonate backbone.

The transmission spectrum decrease after irradiation with UV light at wavelength (254 nm) whereas the effect of UV radiation at wavelength (365 nm) lead to slight change in the transmission spectrum.

The absorption coefficient increase after irradiation with UV light at wavelength (254 nm) whereas the effect of UV radiation at wavelength (365 nm) lead to slight change in absorption coefficient.

The energy gap of all samples does not change significantly after irradiation and this mean that the energy gap of pure PC and anthracene doping PC films is stable against radiation.

REFERENCES

AL-Kadhemy, M.F., 1995. Photo physical properties of some organic dyes using as active medium in dye laser. MSc Thesis, University of Baghdad, Baghdad, Iraq.

Abdullah, A.K., 2006. The effect of high irradiation energy (Gamma, UV-light) radiation on the energy gap of polymers doped with Anthrancene. Iraqi J. Sci., 47: 99-103.

Al-Rubaie, N.J.O., 2008. Preparation of lead iodide layer and studying the influence of both deposition conditions and doping on its physical properties. MSc Thesis, Eindhoven University of Technology, Eindhoven, Netherlands.

Alwan, T.J., 2010. Refractive index dispersion optical properties of dye doped polystyrene films. Malaysian Polym. J., 5: 204-213.

Diepens, M., 2009. Photodegradation and Stability of Bisphenol a Polycarbonate in Weathering Conditions. Eindhoven University of Technology, Eindhoven, Netherlands, ISBN:978-90-386-1741-1, Pages: 134.

Gupta, S., D. Choudhary and A. Sarma, 2000. Study of carbonaceous clusters in irradiated polycarbonate with UV-vis spectroscopy. J. Polym. Sci. Part B Phys., 38: 1589-1594.

Lukkassen, D. and A. Meidell, 2007. Advanced Materials and Structures and their Fabrication Processes. UiT The Arctic University of Norway, Campus Narvik, Narvik, Norway,.

Rashid, F.L., A. Hashim, M.A. Habeeb, S.R. Salman and H. Ahmed, 2013. Preparation of (PS-PMMA) copolymer and study the effect of Sodium Fluoride on its optical properties. Chem. Mater. Res., 3: 55-58.

Rivaton, A., B. Mailhot, J. Soulestin, H. Varghese and J.L. Gardette, 2002. Comparison of the photochemical and thermal degradation of bisphenol: A polycarbonate and trimethylcyclohexane-polycarbonate. Polym. Degrad. Stab., 75: 17-33.

Salh, R., 2013. Spectroscopic properties of HALS doped polycarbonate by fluorescence spectroscopy. Phys. Rev. Res. Intl., 3: 42-54.

Sloomi, N.M., 2016. Spectrophotometric study of gamma irradiated polystyrene composites. MSc. Thesis, Al-Mustansiriya University, Baghdad, Iraq.

Tjandraatmadja, G.F., L.S. Burn and M.J. Jollands, 1999. The effects of ultraviolet radiation on polycarbonate glazing. Proceedings of the 8th International Conference on Durability of Building and Construction Materials Vol. 30, May 30-June 3, 1999, National Research Council Canada, Ottawa, Canada, pp: 884-898.