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Study the optical characteristics of polystyrene polymer before and after doping with methyl orange

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ABSTRACT

In this study, effect of incorporation different percentages of methyl orange (MO) (0%,10% and 20%) with polystyrene (PS)substance were investigated. The optical characteristics of the prepared specimens were studied in term of absorbance spectrum for wave lengths of (300-1100 nm) before and after doping process, using UV-Visible Spectrophotometer device. The study results included calculations of the following properties: absorbance and extinction coefficient, refractive index, real and imaginary parts of dielectric constant and optical gap energy coefficients of allowed and forbidden indirect transition. Further, results show that each of absorbance property, refraction property, absorbance coefficient, extinction property, and real and imaginary insulation constant increasing proportionally with increasing of (MO) concentration. While the values of Transmittance and optical gap energy of allowed and forbidden indirect transition properties have an inverse relationship, where the values of these properties were decreased with increasing of (MO) concentration.

Keywords: Polystyrene (PS) polymer, methyl orange (MO) , optical energy gap , absorbance and extinction coefficients , real and imaginary parts of dielectric constant .

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1. Introduction

It is necessary to study the optical properties of polymers since they are involved in various applications nowadays, especially in manufacturing of filters, solar cells … etc. polymers can be classified based on their thermal behavior into two types are, thermoplastics and thermosets. Thermoplastics polymers are those polymers that their shapes are changing by heating and pressure processes which result in modifications on their physical properties. Such polymer is polystyrene one, which shall have been considered in this study. The second type of polymers are thermosets polymers, which their characteristics doesn’t change or affected by heating process [1,2]. Polystyrene is characterized by its insolubility in acids and bases substances, but it dissolves in gasoline. It is also characterized by its high transparency. Further, the solid and pure state of polystyrene polymer has colorless property which with such property enabled it to be utilized in various manufacturing process such as: cups, smoke detectors in buildings, in laser cases, packaging materials, insulation and other applications. It worth to be mentioned that The Glass transition temperature and melting point (T_g and T_m) of such polymers are about (100 ^oC) and (240 ^oC), respectively [3] . In the other side, Methyl orange which has an International Non Proprietary Name (INN) of (Methyl Thioninium Chloride), is an organic compound whose chemical formula is (C_{14} H_{14} N_3 Na O_3 S). It considers as a toxic organic dye. It can be used as a guide in the calibration of acids and bases substances. In addition, it is an orange powder that can dissolve in water but cannot be dissolved in alcohol [4].

2. Experimental method

In this study, polystyrene polymer has been used in powder form, which was supplied from Dent aurum, the

German Company, in addition to the methyl orange substance. The experimental work was achieved by addition of two different percentages of methyl orange substance (10% and 20%) to 1.5 gram of polystyrene polymer in thermal press which consists of a mold like a cylinder shape of 3 cm diameter. The specimens were conditioned under 145 ^{o}C temperature and 100 bar pressure for 10 min. finally, the prepared conditioned mixture was left to cool down to obtain specimens with 3 cm diameter, and 0.15 cm thickness. The optical characteristics of the prepared specimens were investigated by recording the obtained results of absorbance spectrums, transmissivity, and reflection properties at wave lengths range (300-1100 nm) , using a device UV-Visible spectrophotometer and factory by company (Shimadzu) Japanese All measurements were recorded at room temperature.

3. Results and discussion

Figure (1) illustrates the relation between absorbance property and wavelength for specimens, before and after addition of methyl orange, and for dosing ratios of (0%, 10%, and 20%). It can be observed from the figure that absorbance property increases proportionally with blending ratio because of high absorbance property of methyl orange particles. such material is non-transparent in term of the mentioned wavelengths, and this agree with some research results [5].

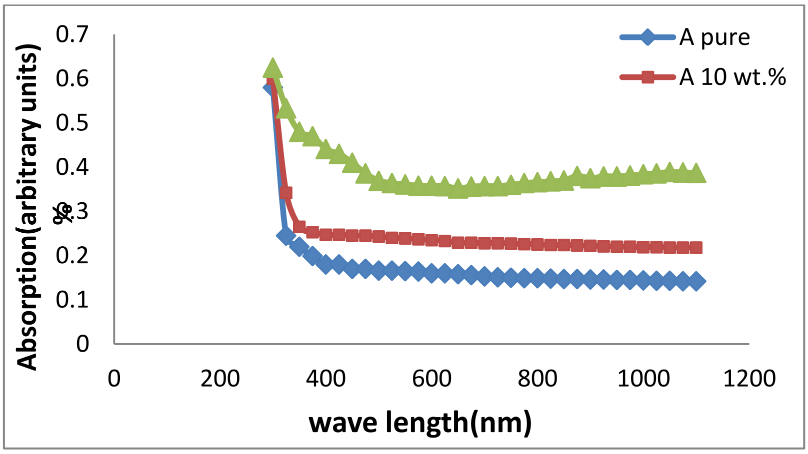

Figure 1. Relation between the absorption and wave length of PS before and after doping with MO at different concentration

Figure (2) represents behavior of transmissivity curve with the polymer wavelength before and after doping process. It can be observed that transmissivity values decrease with higher doping ratios, which go with the results of reference [6].

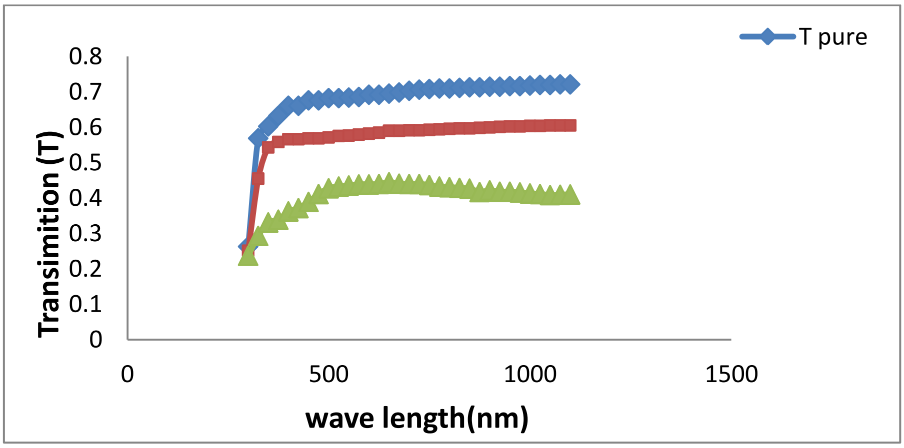

Figure 2. Relation between transmition property and wavelength of PS before and after doping with MO at different concentration

Figure (3) clarifies the behavior of reflection property curve with wavelength for the treated and untreated polymers specimens. Form the pervious figure, it can be noticed that reflection property has the same behavior of absorbance property curve, and this agree with the results of reference [7]. It worth to be mentioned that the reflection property values was calculated utilizing from Lambert Law as follows [8]:

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

Where:
R : is the reflection property;
A: is the absorbance property.
T: is the transitivity.

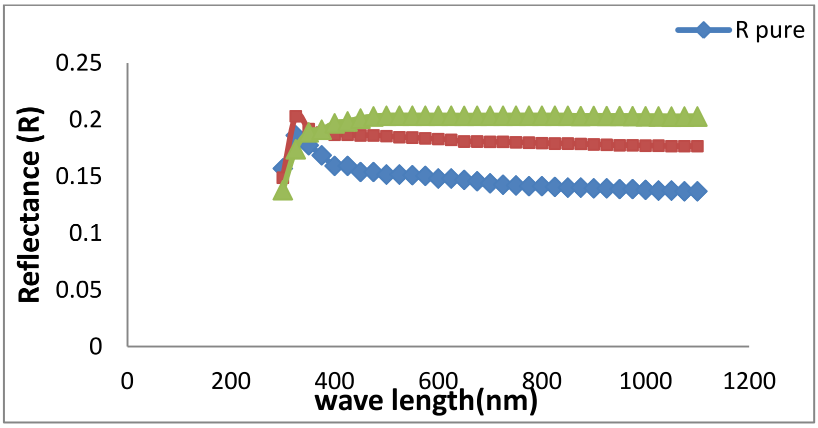

Figure 3. Relation between Reflectance property and wave length of PS before and after doping with MO at different concentration

Figure (4) illustrates the relation between absorbance property coefficients and Photon energy for the polymers specimens before and after doping process. it should be noted that absorption coefficient values can be utilized to understand the behavior of electronic transitions. when the absorption coefficient values are high ($\alpha > 10^4$ cm^{-1}), the electronic transitions are of the direct type, but if the values of absorption coefficient are low ($\alpha < 10^4$ cm^{-1}) transitions are Indirect type. Hence, From Figure (4) it has observed that the values of the absorption coefficient were less than (10^4 cm^{-1}), which means that the electronic transitions of the samples under the study are indirect. Also, it can be seen that the values of the absorption coefficient increases proportionally with increasing doping ratios, and this is consistent with the results of reference [9]. Where the values of Absorption Coefficient were calculated from the following relationship [10]:

$$\alpha = 2.303 \ \frac{A}{X} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where X is the thickness of the tested specimens.

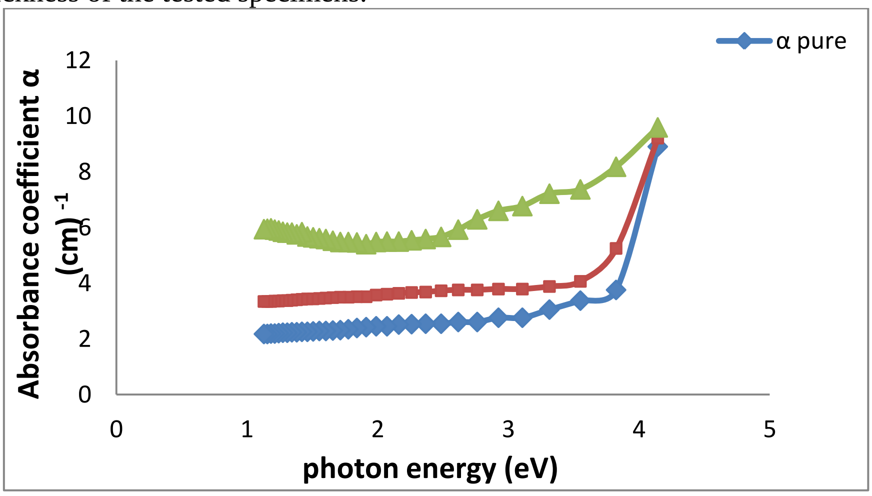

Figure 4. The relation between the absorbance coefficient and photon energy of *PS* before and after doping with MO at different concentration

Figure (5) shows the relationship between the extinction coefficient values and the wavelength of the tested samples before and after doping process and for different doping ratios. It can be observed from the figure that the values of extinction coefficient after doping process are higher than their values before the process, and the compatible with the results of reference [11]. Where values of extinction coefficient were calculated using the following formula [12]:

$$K = \frac{\alpha \lambda}{4 \pi} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \, (3)$$

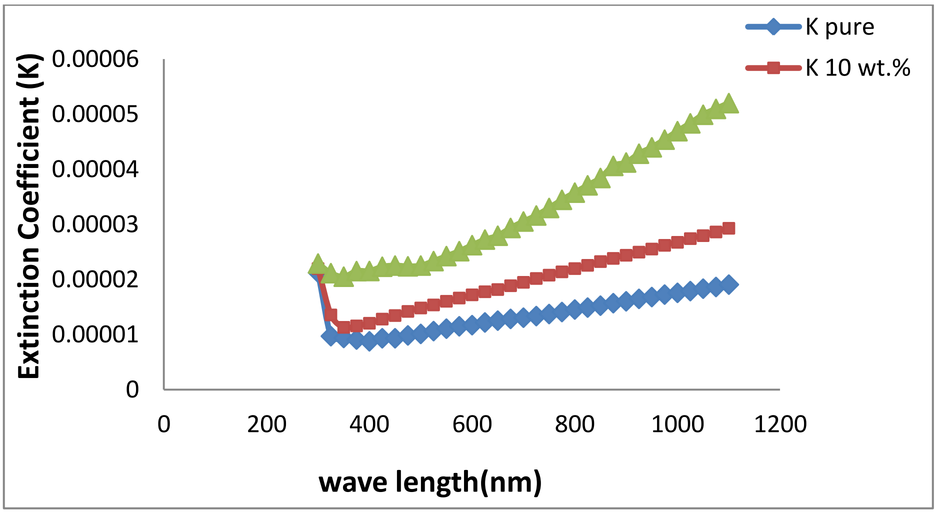

Figure 5. Relation between the extinction coefficient and wave length of PS before and after doping with MO at different concentration

Figure (6) illustrates the relationship between the refraction coefficient values (n) and the wavelength of the tested samples before and after doping process for different doping ratios. It can be observed from the figure that the values of refraction coefficient after doping process were lower than their values before the process, and the compatible with reference [13]. Where values of (n) were calculated using the following formula [14]:

$$n = \frac{1+\sqrt{R}}{1-\sqrt{R}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \, (4)$$

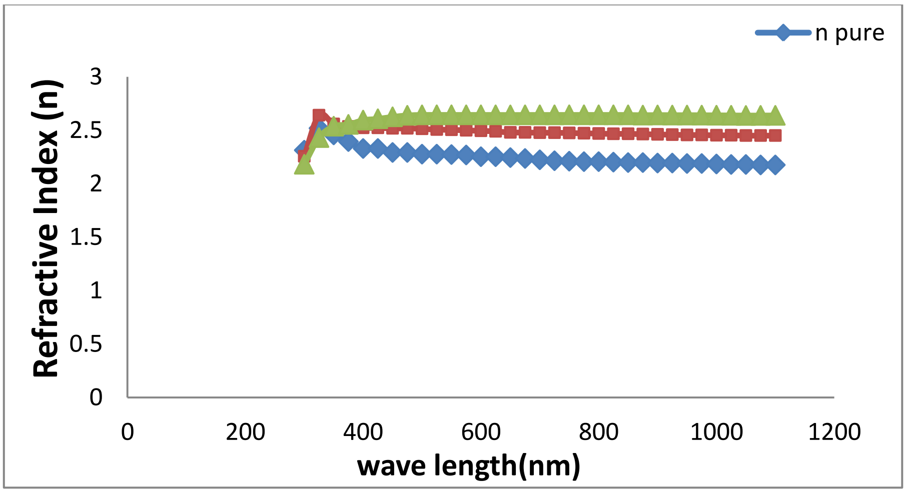

Figure 6. The relation between Refractive Index and photon energy of PS before and after doping with MO at different concentration

Figures (7) and (8) illustrate the relationship between the real and imaginary isolation constant with the photon energy of the tested samples before and after doping process. where it has noticed from these figures that the behavior of values of (ε_r) coefficient are similar to extinction coefficient (K) curve behavior, and this go with the results of reference [15] . Both rε and i were calculated from the following equations [16] :

$$\varepsilon = \varepsilon_r - i\varepsilon_i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

$$\varepsilon_r = n^2 - K^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

$$\varepsilon_i = 2nK \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

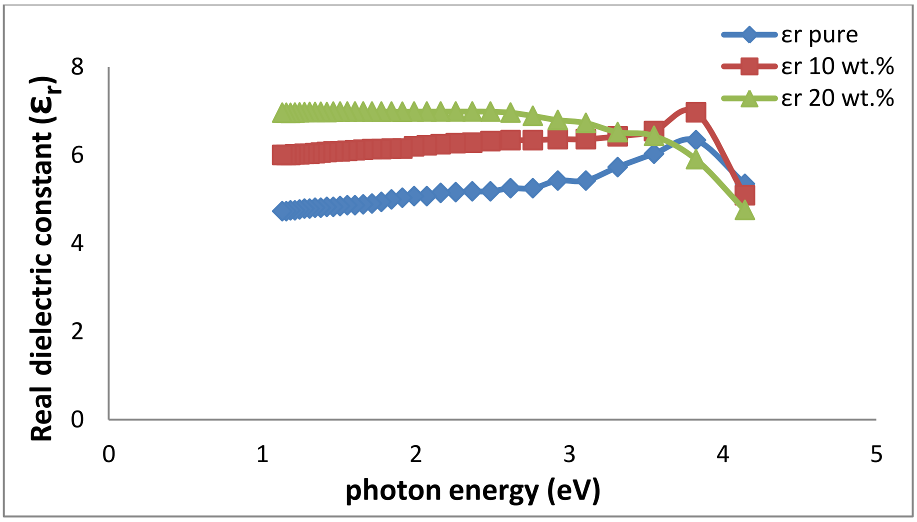

Figure 7. The relation between the Real dielectric constant (εr) and photon energy of PS before and after doping with MO at different concentration

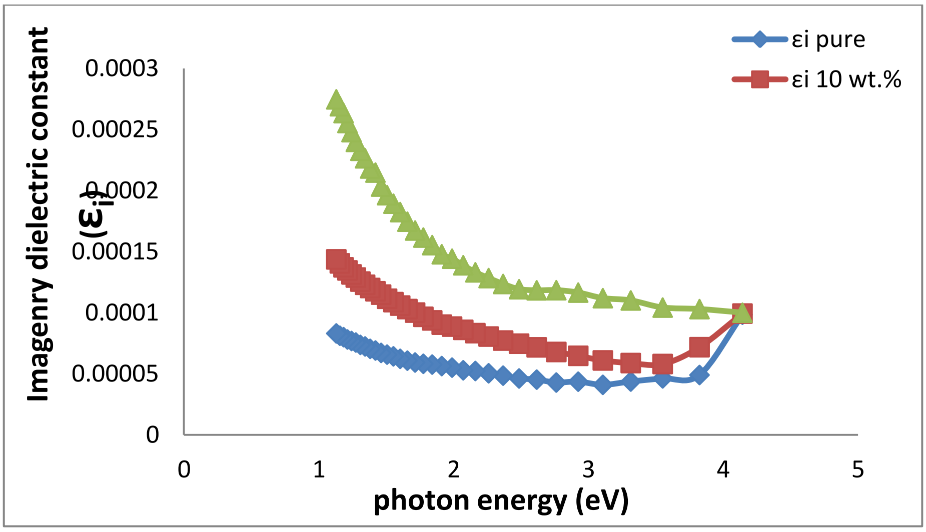

Figure 8. The relation between imaginary dielectric constant (εi) and photon energy of PS before and after doping with MO at different concentration

The optical energy gap for the allowed and prohibited indirect transmission was calculated from the following relationship:

$$\alpha h\upsilon = B\,(\alpha h\upsilon - E_g)^r \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

Where:

B : is a constant

$h\upsilon$:is the absorbed photon energy,

E_g :is the optical energy gap

r :is an exponential coefficient depending on the type of transition.

Figure (9) shows the relationship between $(\alpha h\upsilon)^{1/2}$ and the photon energy of the tested samples before and after doping process. it can be observed form the figure that value of $(\alpha h\upsilon)^{1/2}$ of the pure polymer was about (0.98 eV), while this value was equal to (1.7 eV) and (2 eV) after doping process with doping ratio of 10% and 20% respectively.

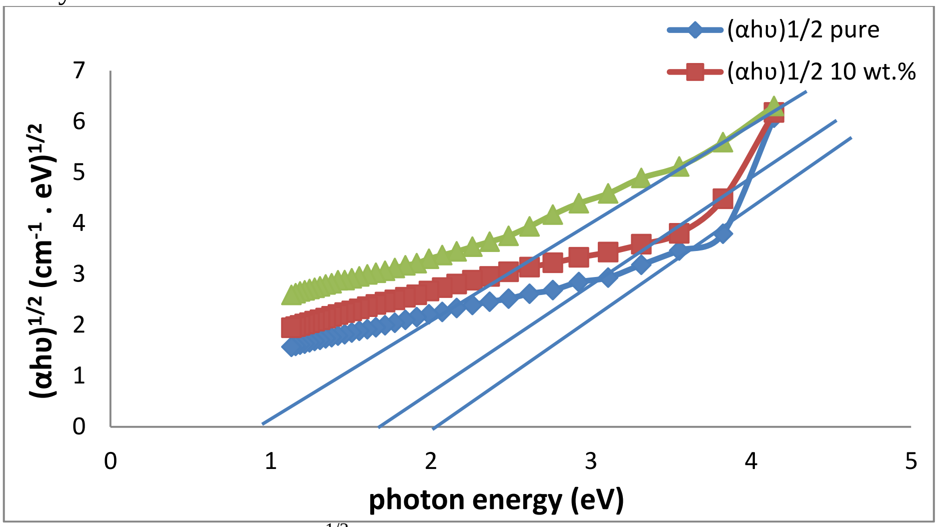

Figure 9. The relation between the $(\alpha h\nu)^{1/2}$ and photon energy of PS before and after doping with MO at different concentration

Figure (10) illustrates the relationship between $(\alpha h\upsilon)^{1/3}$ and the photon energy of the tested samples before and after doping process. it can be observed form the figure that value of $(\alpha h\upsilon)^{1/3}$ of the pure polymer was about (1 eV), while this value was equal to (1.48 eV) and (1.8 eV) after doping process with dosing ratio of 10% and 20% respectively, and this agree with the findings of reference [18].

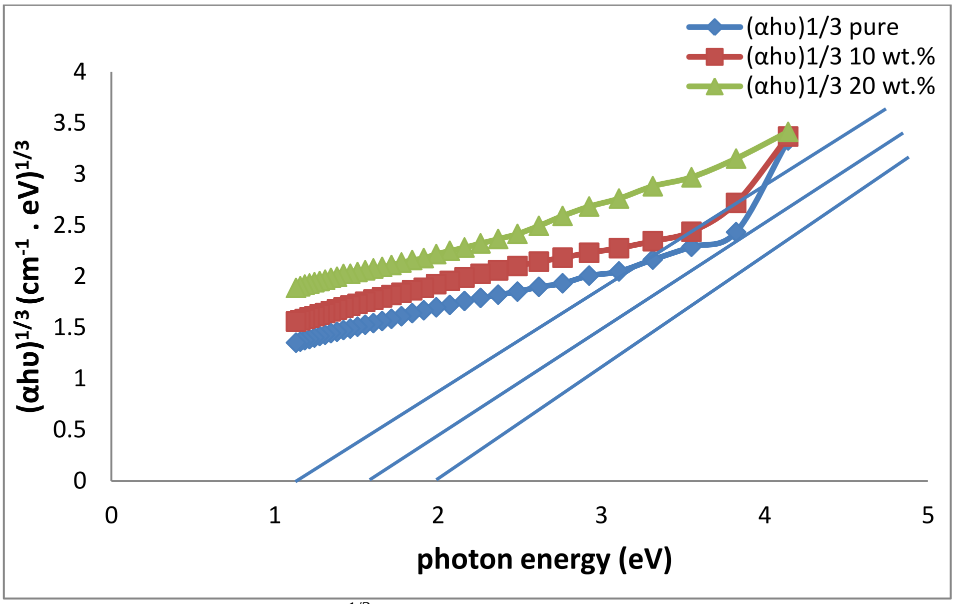

Figure 10. The relation between the $(\alpha h\nu)^{1/3}$ and photon energy of PS before and after doping with MO at different concentration

4. Conclusions

From the previous results, it can be concluded that doping polystyrene polymer with methyl orange resulted in some positive modifications such as, increasing values of absorbance and reflective properties, increasing absorbance coefficients, extinction, and refraction properties, in addition to real and imaginary parts of dielectric constant. From the other side, it has found that the values of the optical energy gap of the allowed and forbidden indirect transmission as well as the transmissivity has decreased due to the optical impedance caused by the doped material. The doped material contributed to rising absorption values within a range of (300-420 nm) as noticed in Figure (1). Such process shifts the absorbance property curves of the tested specimens to the range of short wavelengths. Further, due to the logarithmic relation between the absorbance and transmissivity properties, it was observed a noticeable reduction in transmissivity property at the same range of wavelengths, in addition to its clear effect on the other coefficients that depended mathematically on the absorbance and transmissivity properties. From the relationship between the extinction coefficient with the wavelength as shown in Figure (5), it has been noticed a slide shifting of the curve towards the short wavelengths (high energies of the fallen photon), which with such modification the conclusion has been drawn as the possibility of using the prepared specimens in the anti-reflection materials within short ray wavelengths.

Reference

[1] G. J. Habi., “Effect of gamma-ray on some optical properties of polymetheylacrelate film (PMMA) doping with phenolphthalein (phph),” Periodicals of Engineering and Natural Sciences (PEN), vol. 7, no. 2, p. 853, 2019

[2] I. Çapan, Ç. Tarımcı, A. Hassan, and T. Tanrısever, “Characterisation and optical vapour sensing properties of PMMA thin films,” Materials Science and Engineering: C, vol. 29, no. 1, pp. 140–143, 2009.

[3] M. Mihai, M. A. Huneault, and B. D. Favis, “Foaming of Polystyrene/ Thermoplastic Starch Blends,” Journal of Cellular Plastics, vol. 43, no. 3, pp. 215–236, 2007.

[4] E. Nitanai, “Measurements of dispersion properties of refractive indices and absorption coefficients in organic- dye- doped thin films by a prism- coupling method,” Optical Engineering, vol. 35, no. 3, pp. 900–919, 1996.

[5] M. H. Abdul-Allah, “Study of optical properties of (PMMA) doped by methyl red and methyl blue films,” Iraqi Journal of Physics (IJP), vol. 12, no. 24, pp. 47–51, 2019.

[6] F.J.K. Al-Nuaimi, "Optical Properties of Laser Dye Rhodamine B Doped Polymethylmethacrylate-Polycarbonate Films," Mustansiriyah Journal for Sciences and Education”, vol. 17, no. 3, pp. 37-46, 2016.

[7] J. Nahida, K. M. J. E. Ali, and T. Journal, "Study of Methyl Orange Effect on the Optical and Electrical Properties of Polystyrene (PS)," vol. 32, no., pp. 23-37, 2014.

[8] H.A.A Wadi,, "Influence of Gamma Radiation on Some Optical Properties and Urbach Energy of (PMMA-Doped Red Methyl) Films, “Ibn AL-Haitham Journal For Pure and Applied Science”, vol. 26, no. 3, pp. 219-224, 2017.

[9] R. Padmakumari, V. Ravindrachary, B. K. Mahantesha, R. N. Sagar, R. Sahanakumari, and R. F. Bhajantri, “Modification of fluorescence and optical properties of Rhodamine B dye doped PVA/Chitosan polymer blend films, vol. 14, no. 8, 269-285, 2018.

[10] A. Moustafa, A. Faizalla, and B. J. Abd El Hady, "Effect of filler type and concentration on some mechanical and electrical properties of poly (methyl methacrylate)," vol. 67, no. 4, pp. 637-641, 1998.

[11] G. Korotcenkov, "Composites for Optical Sensors," Springer, 2014.

[12] F.M. Harman, "Encyclopedia of polymer science and Engineering", 2nd Ed, .15, PP. 377-397, 1976.

[13] J.K. Dunnick, JR Hailey, "Phenolphthalein Exposure causes Multiple Carcinogenic Effects in Experimental Model Systems ", Cancer Research 56(21):4922-4926, November 1, 1996.

[14] A. M. Dhameer, "Gamma Irradiation Effects on some physical properties of polymer composites”, Ph.D. Thesis, Baghdad university, 2007.

[15] H. Ali, "Doping effect on optical constant of polymethylacrelate (PMMA with phenolphthalein" , Journal of Babylon university , Pure &Applied Sciences , No. 4 , Vol. 21 ,pp. 524-550, 2013 .

[16] H. Alia , S. Mohammed , H. Mohammed , "Study the effect of Gamma radiation on the optical energy gap of polymetheylacrelate (PMMA)", Diyala Journal for Pure Sciences , No. 4 , Vol. 6 , pp. 220-235, 2010 .

[17] K. Aden , " Influence of AlCl3 on the optical properties of new Synthesized armed Poly meth methacrylate Films " , Turk Journal Chem. , Vol.34 , pp. 67-79 , 2010 .