Study of Optical Constants of Al_2O_3 Doped Polystyrene

Saad Farhan Oboudi
Department of Physics, College of Science, Baghdad University.
E-mail : saadoboudi@hotmail.com.

Abstract

We have studied the effect of Al_2O_3 dopant on the optical properties of a polymer polystyrene. Pure and Al_2O_3 doped polystyrene samples were prepared using the hot press method. The adding percentages of Al_2O_3 in the prepared samples were (0, 20, 40, 50, 60) wt%. The thickness of the samples were measured by using indicating micrometer and ranged (1.2 - 1.4) mm. Transmission and absorption spectra have been recorded in order to study the effect of increasing Al_2O_3 percentage on the optical parameters such as absorbance, transmittance, absorption coefficient, refractive index, extinction coefficient, and, real and imaginary parts of dielectric constant. This study reveals that all these parameters affect by increasing Al_2O_3 percentage.

Keywords: polymers, hot press method, optical constants, doping effect.

Introduction

Polystyrene has attracted the attention of scientists for its interesting features and its superior physical and chemical properties, such as its good processability, rigidity, low water absorbability, transparency as well as its low cost which makes it required in many applications in industry [1,2]. Moreover, this polymer is traditionally considered as an excellent host material for composites. Recently, the doped polymers have been the subjects of interest for many studies, because of the physical and chemical properties needed for specific application [3].

The electrical and optical properties of the polymers can be suitably modified by the addition of dopants depending on their reactivity with the host matrix. There are many studies on pure polystyrene and on polystyrene with different additives [4-7]. Rui-Juan and Thomas [8] studied the optical properties of polymer composites and they showed that they are strongly affected by particle content, particle size, and especially by difference in refractive indices between polymer matrix and particles. It is also revealed that the light transmittance and haze of composites are mainly affected by difference in refractive indices, whereas the clarity is more affected by particle size**.** Andre et.al.[9] have decoupled the synthesis of the CdS nanoparticles from the polymer matrix by synthesizing a colloidal suspension of CdS nanoparticles in water that is compatible with a polymer latex water suspension. In the present work, the absorption coefficient, refractive index, extinction coefficient and real and imaginary parts of dielectric constant were determined, and the effect of Al_2O_3 concentration on some of its optical properties was studied.

Experimental Details

In this work polystyrene were used as basic polymeric materials and Al_2O_3 as additive. The electronic balanced of accuracy 10^{-4} have been used to obtain a weight amount 2gm of Al_2O_3 powder. These mixed by mixer and microscopic examination used to obtain homogenized mixture. The weight percentages were (0, 20, 40, 50, 60) wt%. The hot press method was used to compact the powder mixture. Then the samples have disc shaped of diameter of about 30mm and thickness ranged between (1.2-1.4) mm. The samples with different Al_2O_3 percentage have been compacted at temperature 165°C under a pressure of 100 bar for 10 min. The absorbance and transmittance measurements were carried out using a Shimadzu UV-210A° double beam spectrophotometer of wavelength range from (300- 900) nm.

Results and Discussions

Fig. (1) Shows the absorption spectra of the prepared samples in the wavelength range 300-900nm which is the suitable spectral region, the absorptions increases as the Al_2O_3 percentage increases, adding different concentration of the filler material to the polymer do not change the chemical structure of the polymer but new physical properties to the mixture will formed. There are no absorption bands in the visible region since the samples are transparent and this result agree with previous studies [10,11]

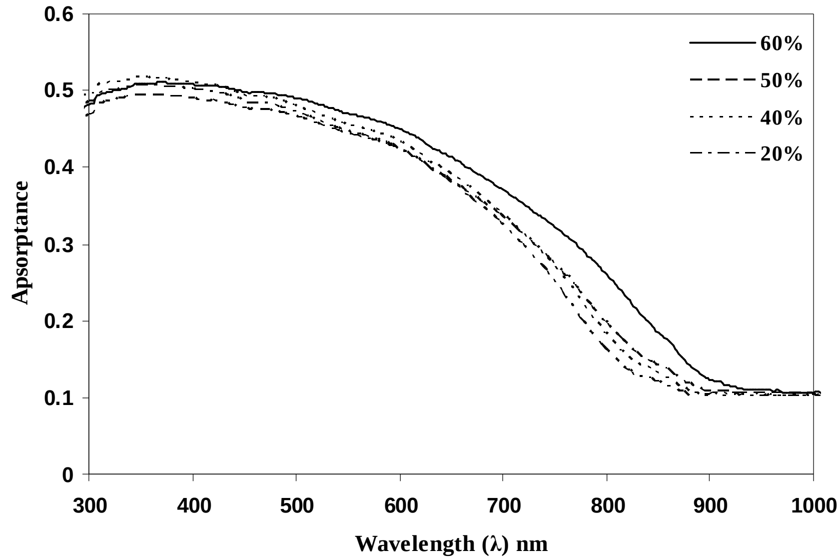

Fig. (1) Absorption spectra for different percentage of Al_2O_3.

Fig. (2) Shows the optical transmission spectra of the polystyrene samples with different Al_2O_3 percentage in the region 300-900 nm. One can observe from the figure that the transmission intensity is decreases with the increasing of the addition percentages due to the fact that the particle size of the filler is bigger than the particle size of the matrix which increase the absorption and decrease the transmittance, this result is in agreement with previous studies on polystyrene optical properties [12, 13].

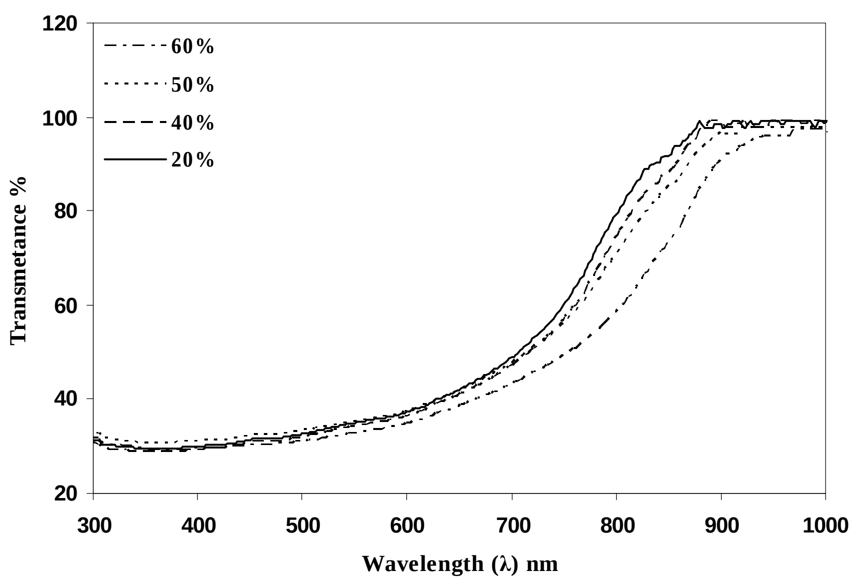

Fig. (2) Transmittance spectra for different percentage of Al_2O_3.

Since the reflectivity was insignificant near the absorption edge, so the following relation could be use for calculation the absorption edge. The following relation could be use for calculating the absorption coefficient (α) [14]:

$$a = \frac{2.303A}{t} \quad ....(1)$$

Where (A) is the absorbance and (t) is the film thickness.

Fig.(3) shows the dependence of the absorption coefficient (α) on the wavelength for the samples with different concentration of Al_2O_3, The absorption coefficient increases with the increasing of Al_2O_3 concentration. This could be related to the extended states that located inside the energy gap, near the conduction band which increase the absorption of photons that have long wavelength. The absorption coefficient gives the information to conclude the nature of electronic transitions.

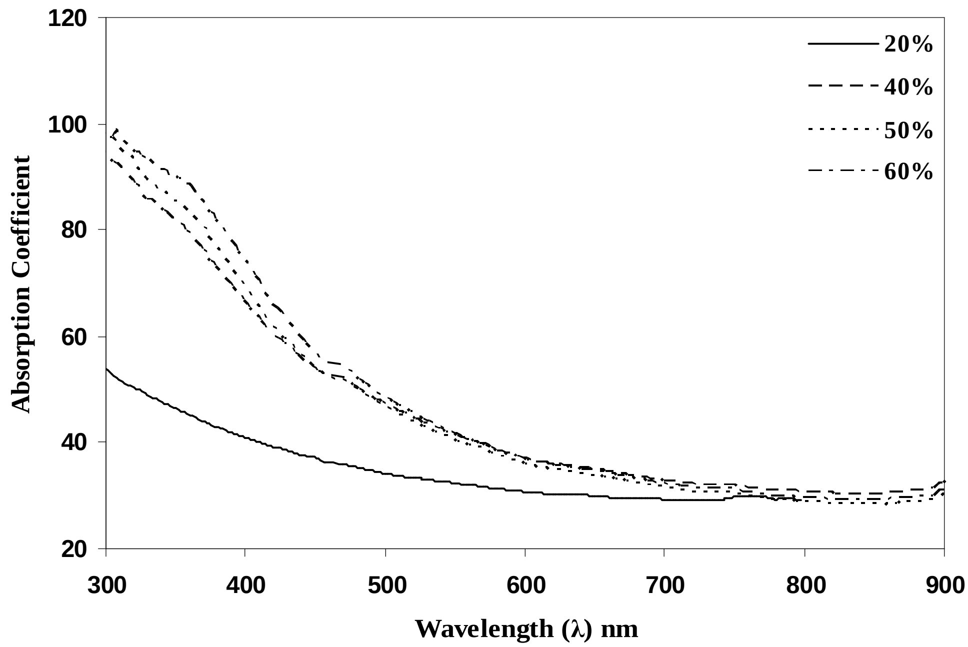

Fig. (3) Absorption coefficient versus photon energy for different percentage of Al_2O_3.

The refractive index is a suitable state parameter directly correlated to the material density. The refractive-index values in a polymer are around 1.3–1.6, which are almost comparable to those of silica glass. Fig.(4) shows the variation of the refractive index for all the samples. It is clear from this figure that the refractive index of the samples is influenced by increasing the Al_2O_3 percentage in the polystyrene. The refractive index of these samples is steady in the wavelength region (300-650) nm while it is decreases with the increase in the Al_2O_3 percentage within the wavelength region (650-900)nm. The refractive-index measurements can have a correlation with the electrical properties of the prepared films. The refractive index (n) can be determined from the reflectance (R) using the relation [15].

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

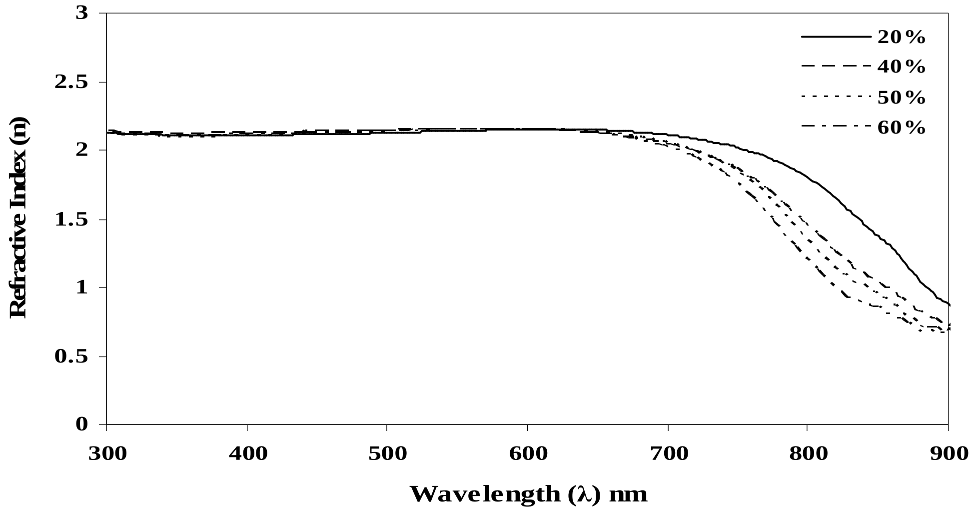

Fig. (4) Refractive index versus wavelength for different percentage of Al_2O_3.

The extinction coefficient (k) can be determined by using the relation [16]:

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

Where (α) is the absorption coefficient and (λ) is the wavelength of the incident photon.

Fig. (5) Shows the variation of the extinction coefficient k as a function of the wavelength, It can be notice that the extinction coefficient is slightly increases as Al_2O_3 percentage increase in the wavelength range (650-900). This increasing is due to the increasing in the absorption coefficient.

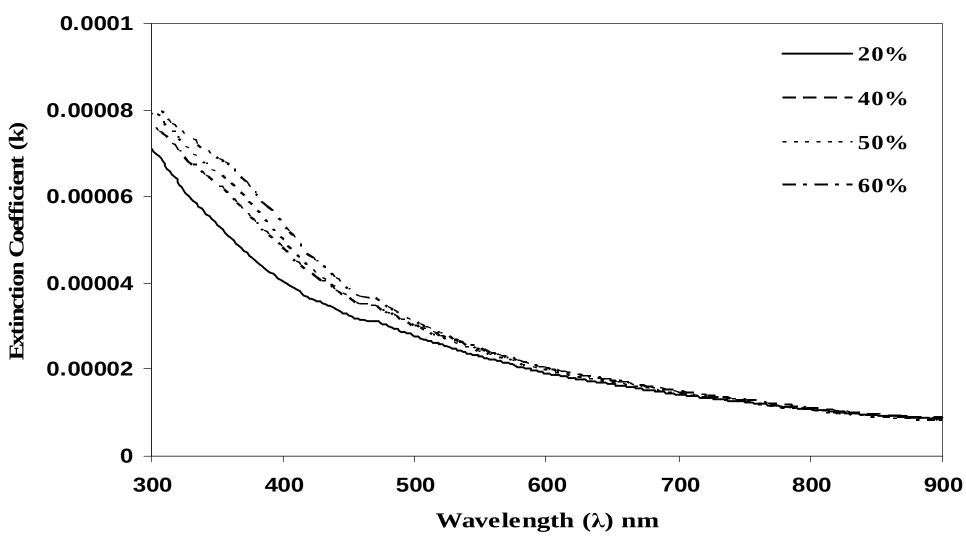

Fig. (5) Extinction coefficient versus wavelength for different percentage of Al_2O_3.

The real (e_1) and imaginary (ε_2) parts of the dielectric constant related to (n) and (k) values. The (e_1) and (ε_2) values were calculated using the following formulas [17]:

$$\varepsilon_r = n^2 - k^2 \qquad (4)$$

$$\varepsilon_i = 2nk \qquad (5)$$

Fig. (6) and Fig. (7) Shows (e_1) and (ε_2) values dependence of wavelength. It can be notice from Fig.(6) that the (e_1) value increases with increasing the additive percentage to 60% and (ε_2) values of the samples slightly increased as the Al_2O_3 percentage increases. The real and imaginary parts of the dielectric constant indicate the same pattern and the values of real part are higher than imaginary part.

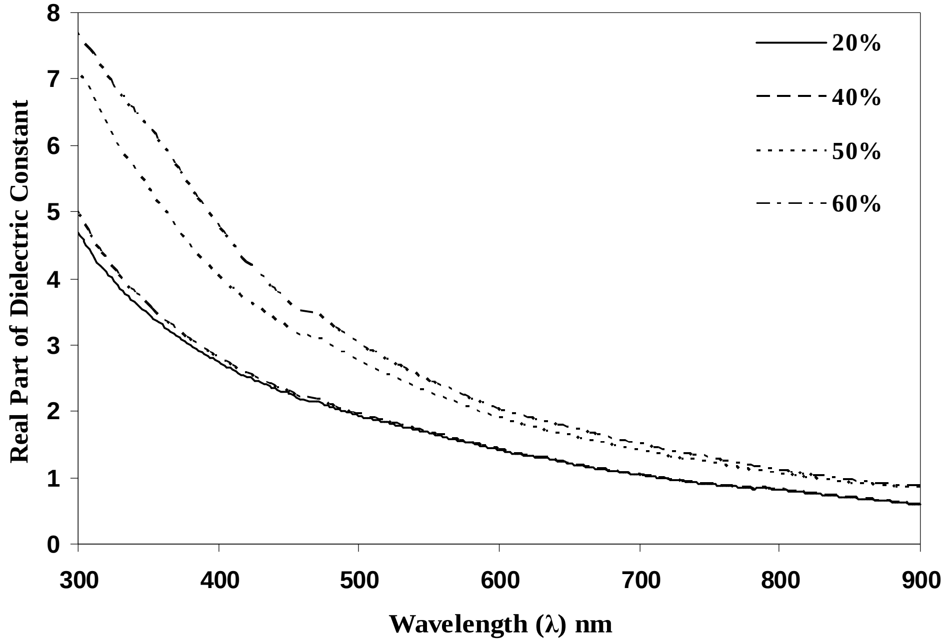

Fig. (6) Real part of dielectric constant versus wavelength for different percentage of Al_2O_3.

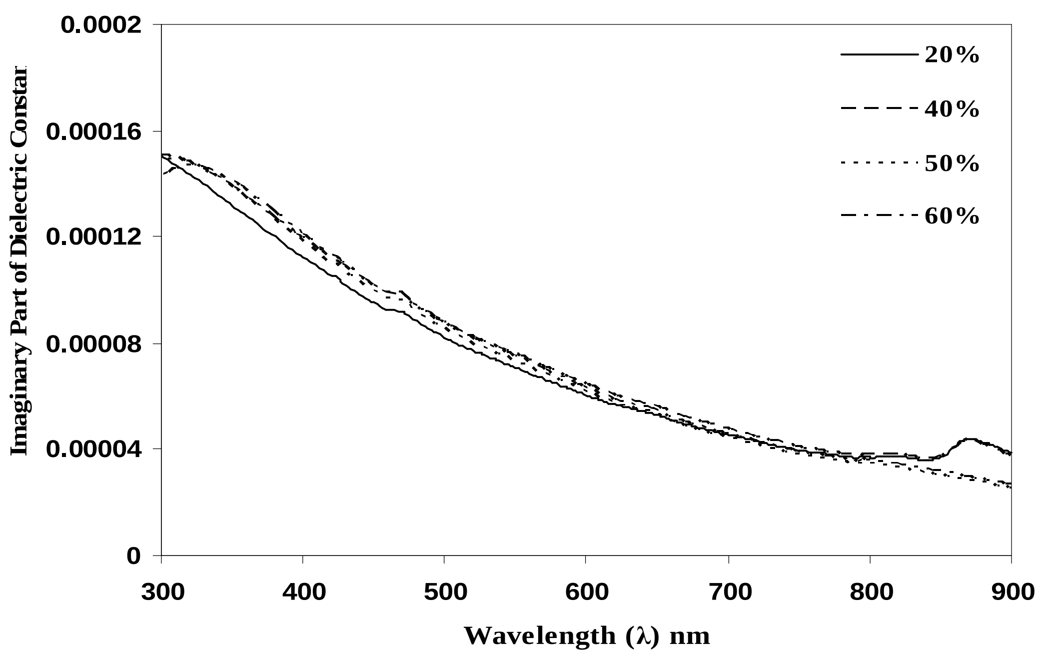

Fig. (7) Imaginary part of dielectric constant versus wavelength for different percentage of Al_2O_3.

Conclusions

The detailed study of the effect of adding concentration of Al_2O_3 on the optical parameters has shown that its absorbance, absorption coefficient, extinction coefficient, and the real and imaginary parts of dielectric constant increases, while transmittance and refractive index decreases as the percentage of Al_2O_3 increased.

References

[1] M. Shaffer and K. Koziol, Chem. Commun., Vol. 18, pp. 2074, (2002).
[2] J. P. Walker and S. A. Asher, Analyical Chemical, Vol. 77 (6), pp. 1596, (2005).
[3] R.F.Bhajantri, V. Ravindrachary, A. Harisha, V. Crasta, S. P. Nayak, B. Poojary. Polymer 47(2006)3591-3598.
[4] Zidan HM. J Appl. Poly. Sci. 88 (2003) 104–11.
[5] Alexander Chandra, Lih-Sheng Turng, Padma Gopalan, Roger M. Rowell and Shaoqin Gong, Jurnal of applied polymer science, 105(2007) 2728-2736.
[6] S. A. Kalele And S. S. Ashtaputre and N. Y. Hebalkar, Chemical Physics Letters, Vol. 404 (1-3), pp. 136, (2005).
[7] P. L. Ku, Advances in Polmer Technology, Vol. 8(3), pp. 201, (1988b).
[8] Rui-Juan Zhou , Thomas Burkhart, Journal of applied polymer science, 115 (2009) 1866-1872.
[9] Andre Chevreau, Brian Phillips, Brian G. Higgins and Subhash H. Risbud, Journal of Material Chemistry**,** 6(1996) 1643 – 1647.
[10] S A Sbeih and A M Zihlif, Jurnal of Physics D: Applied Physics, 42(2009) 145405.
[11] Mijeong Han, Eunha Lee and Eunkyoung Kim, Optical Materials, 21(2003) 579-583.
[12] F. Sharaf, M. H. I. El-Eraki, A. R. El-Gohary, F. M. A. Ahmed, Polymer Degradation and Stability 47 (1995) 343-348.
[13] R. T. Morrison, R. N Boyed, Organic Chemistry, 6^{th} ed., prentice Hall, NeYork, 1992, pp. 600-624.
[14] Han, X., Liu, R., Chen, W. and Xu, Z, Thin Solid Films, 516(2008) 4025- 4029.
[15] A. Ashour, M. A. Kaid, N. Z. El-Sayed and A. A. Ibrahim, Applied Surface Science, 252(2006) 7844.
[16] S.W. Xue, X. T. ZU, W. L. Zhou, H. X. Deng, X. Xiang and H. Deng, Journal of Alloys and Compounds, 448(2008) 21-26.
[17] E. Elangovan and K. Ramamurthi, Cryst. Res. Technol., Vol. 38(9) (2003), pp. 779.

الخلاصة

تم دراسة تأثير أضافة Al_2O_3 على الخواص البصرية لبوليمر البوليستايرين. حضرت أغشية بولي ستايرين النقيه والمشوبه بـــ Al_2O_3 باستعمال طريقة الكبس الحراري. نسبة أضافة Al_2O_3 في العينات المحضره كانت (0, 20, 40, 50, 60) wt% تم قياس سمك العينات باستعمال المايكروميتر وقد كانت مابين mm (1.4 - 1.2). سجل طيفي النفاذية والامتصاصية وذلك لغرض دراسة المعلمات البصرية مثل: النفاذية، الامتصاصية، معامل الانكسار، معامل الخمود، ثابت العزل الحقيقي وثابت العزل الخيالي. توصلت هذه الدراسة الى أن كافة هذه المعلمات تتأثر بزيادة نسبة أضافةAl_2O_3 .