

Study of Optical Constants of Al₂O₃ Doped Polystyrene

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Abstract

We have studied the effect of Al₂O₃ dopant on the optical properties of a polymer polystyrene. Pure and Al₂O₃ doped polystyrene samples were prepared using the hot press method. The adding percentages of Al₂O₃ 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 Al₂O₃ 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 Al₂O₃ 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 Al₂O₃ concentration on some of its optical properties was studied.

Experimental Details

In this work polystyrene were used as basic polymeric materials and Al₂O₃ as additive. The electronic balanced of accuracy 10⁻⁴ have been used to obtain a weight amount 2gm of Al₂O₃ 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 Al₂O₃ 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 Al₂O₃ 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]

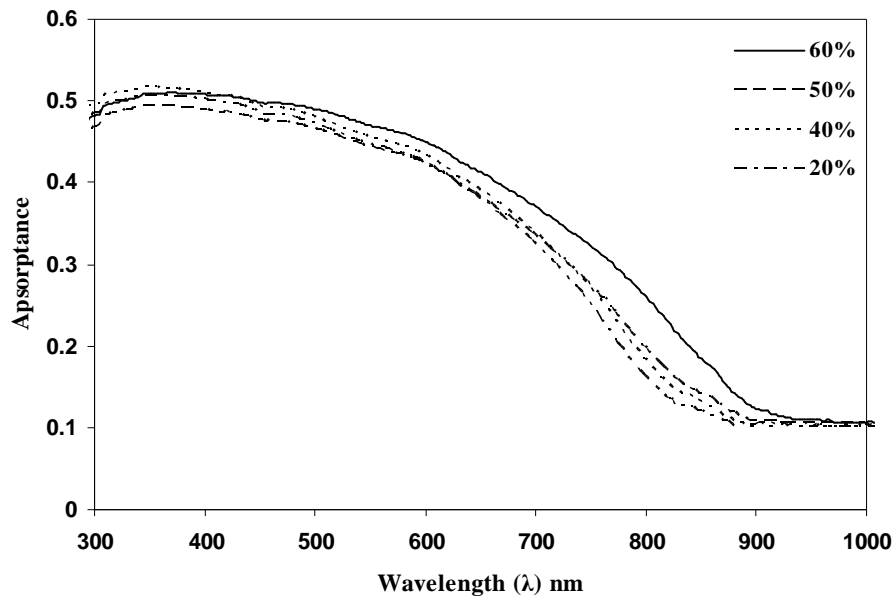


Fig. (1) Absorption spectra for different percentage of Al₂O₃.

Fig. (2) Shows the optical transmission spectra of the polystyrene samples with different Al₂O₃ 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].

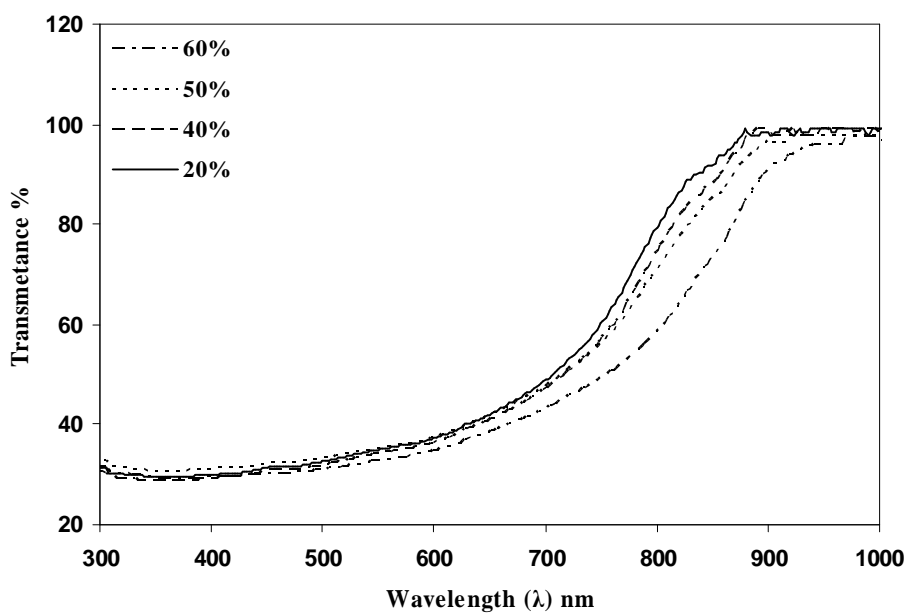


Fig. (2) Transmittance spectra for different percentage of Al₂O₃.

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]:

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

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.

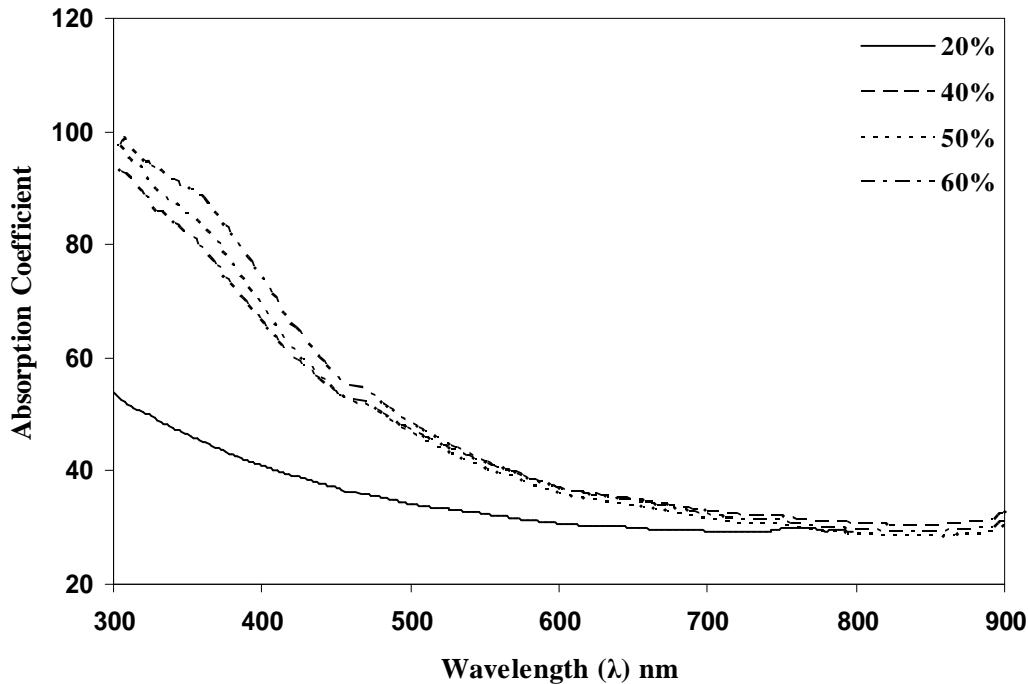


Fig. (3) Absorption coefficient versus photon energy for different percentage of Al_2O_3 .

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].

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

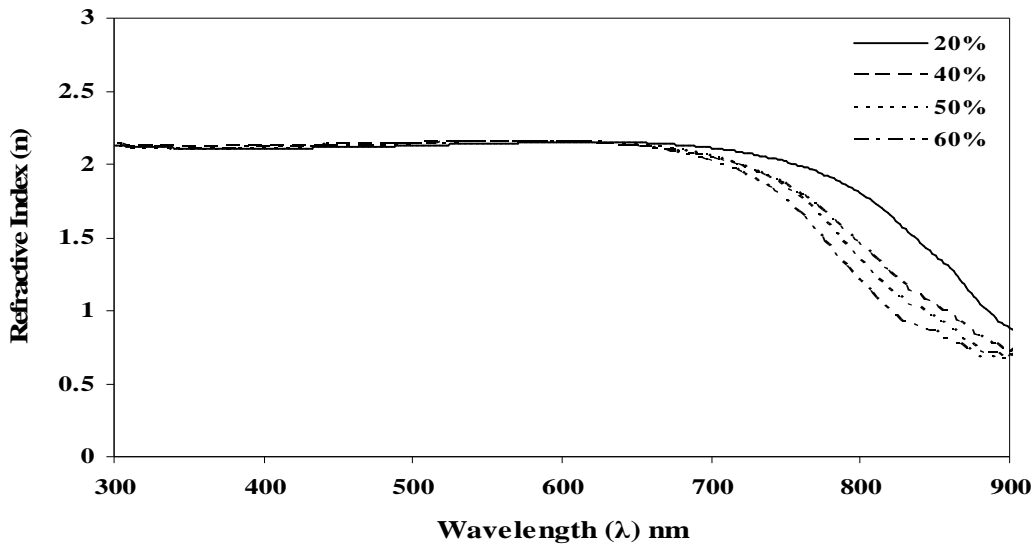


Fig. (4) Refractive index versus wavelength for different percentage of Al₂O₃.

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

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

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 Al₂O₃ percentage increase in the wavelength range (650-900). This increasing is due to the increasing in the absorption coefficient.

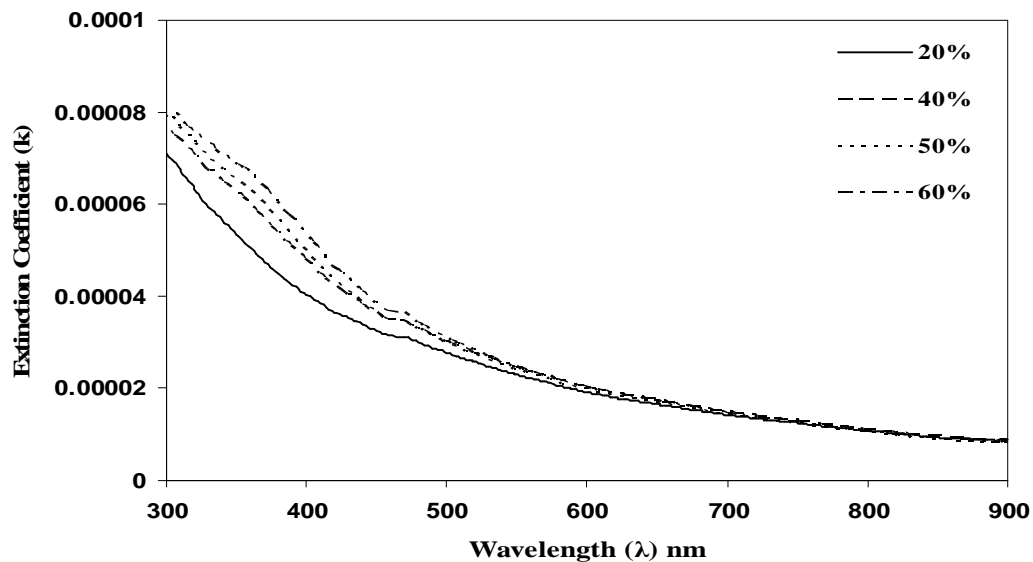


Fig. (5) Extinction coefficient versus wavelength for different percentage of Al₂O₃.

The real (ε₁) and imaginary (ε₂) parts of the dielectric constant related to (n) and (k) values. The (ε₁) and (ε₂) values were calculated using the following formulas [17]:

$$\epsilon_r = n^2 - k^2 \dots\dots\dots(4)$$

$$\epsilon_i = 2nk \dots\dots\dots(5)$$

Fig. (6) and Fig. (7) Shows (ε₁) and (ε₂) values dependence of wavelength. It can be notice from Fig.(6) that the (ε₁) 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.

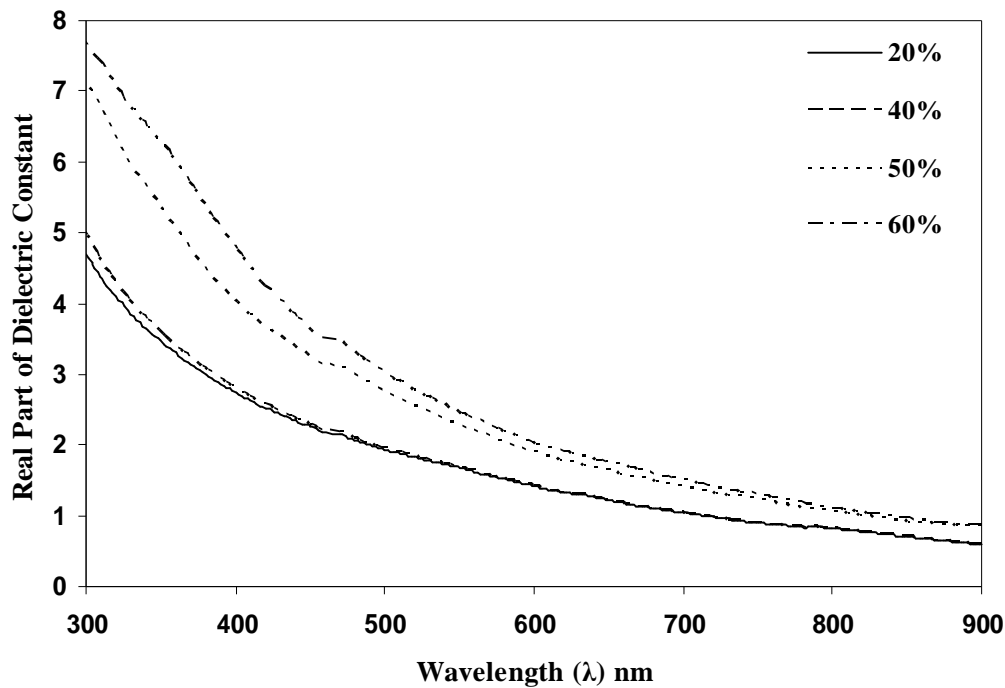


Fig. (6) Real part of dielectric constant versus wavelength for different percentage of Al_2O_3 .

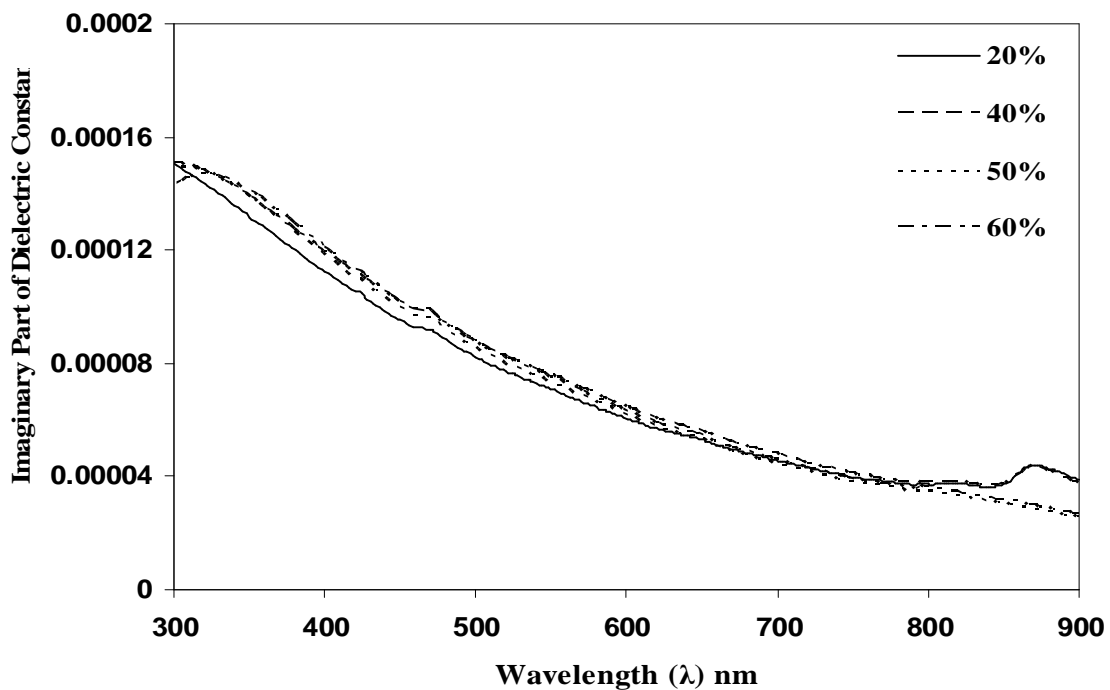


Fig. (7) Imaginary part of dielectric constant versus wavelength for different percentage of Al_2O_3 .

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.

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الخلاصة

تم دراسة تأثير إضافة Al_2O_3 على الخواص البصرية لبوليمر البوليستايرين. حضرت أغشية بولي ستايرين النقيه والمشويه بـ Al_2O_3 باستعمال طريقة الكبس الحراري. نسبة إضافة Al_2O_3 في العينات المحضره كانت (0, 20, 40, 50, 60) wt% تم قياس سمك العينات باستعمال المايكروميتر وقد كانت ما بين (1.2 - 1.4) mm. 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 إضافة Al_2O_3 .