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Effect of Indium Tin Oxide (ITO) Nanoparticles on the Optical Properties Of PMMA Polymer

دراسة تأثير إضافة (ITO) كجسيمات نانوية على الخصائص البصرية للبوليمر بولي مثيل مثيكولايت

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Abstract:

In this work the optical properties of the PMMA polymer doped with different concentrations of ITO nanoparticles had been studied. All samples were prepared by casting technique with thickness of 1 mm. The optical properties ((absorption, transmission, absorption coefficient, extinction coefficient and refractive index) had been investigated. The doped composites have shown shifted toward the visible region. Whereas measured energy gap for pure and doped polymer shows decreases in the energy gap from 5.5eV to 3.5eV. The refractive index of pure polymer decreases as wavelength increase, where the refractive index of the doped polymer increases with increasing ITO concentrations.

Key word: nanocmposites, Indium Tin Oxide nanoparticles, PMMA, optical properties.

الخلاصة :-

في هذا العمل تمت دراسة الخصائص البصرية للبوليمر PMMA الذي تم تطعيمه مع تراكيز مختلفه ل ITO للجسيمات النانويه التي تمت بواسطة تقنية الطلاء مع سمك 1 ملم . تم دراسة الخصائص البصريه (الامتصاصيه ،النفاذيه،معامل الامتصاص،معامل الانكسار، معامل الاخماد) ، لوحظ ازاحة المركبات المطعمه باتجاه المنطقه المرئيه . كما لوجظ ان فجوه الطاقه المقاسه للبوليمرات المطعمه تتناقص من 5.5الى3.5eV. بينت الدراسه ان معامل الانكسار للبوليمر النقي يقل بزيادة الطول الموجي، وعند تطعيم البوليمر مع تراكيز مختلفه من الجسيمات النانويه ITO (0.01، 0.03، 0.05) % معامل الانكسار يزداد.

1. Introduction

In recent years, polymer nanocomposites and understanding their physical and chemical properties have attracted great attention. The presence of nanoparticles in polymer improves the mechanical, electrical, and optical properties of the materials [1,2]. Metal oxide nanoparticles doped polymers have been studied as alternative materials for optical applications such as planar waveguide devices and micro optical elements[3,4,5,6].The polymers modified by metal oxide nanoparticles have been prepared by a sol-gel process, by polymerization of monomer containing nanoparticles and by dispersing of nanoparticles in a polymeric matrix[,7 8]

Transparent conducting oxide (TCO) films are important components in numerous applications whenever the unique combination of electrical conductivity and high optical transmittance within the visible spectral range is required. Indium tin oxide is one of the most widely used transparent conducting oxides because of its two chief properties, its electrical conductivity and optical transparency, as well as the ease with which it can be deposited as a thin film [9].

In this work the effect of additives ITO nanoparticles on the optical properties of polymer was investigated. The polymer used is PMMA, with additives ITO nanoparticles with different concentrations.

2. Experimental work

The Poly (methyl methacrylate) (PMMA) with density 1.18 g/cm^3 was used as a polymeric matrix for preparation of the composite. Indium Tin Oxide (ITO) nanoparticles with different concentrations (0.01, 0.03 and 0.05) wt% were dissolved in 25ml chloroform and sonicated for 2h to disperse the individual nanoparticles , then (1g) of PMMA was dissolved in (25ml) chloroform . The solution was slowly mixing at room temperature. The composite samples of PMMA/ITO nanoparticles with concentrations (0.01, 0.03 and 0.05) wt% were prepared in the cast form to produce thick films with a thickness (1mm).

3. Result and Discussion

3.1 Optical properties

3.1.2 Transmission and Absorbance

The UV-visible absorption spectroscopy is an efficient technique to monitor the optical properties of PMMA-ITO nanoparticles composites. . The Transmission and Absorbance spectrum of the composites are shown in Fig 1and 2.

Figure 1, shows the optical transmission spectrum of PMMA-ITO nanoparticles composites, the nanocomposites shows high transmission in visible and IR region and low transmission in UV region, The figure also shows that the transmittance intensity decreases with increasing ITO nanoparticles.
Figure 2, shows the absorbance spectrum of PMMA-ITO nanoparticles composites for different concentrations, the spectrum shows low absorbance in the infrared regions, however, the absorbance is increasing with increasing the concentrations of ITO nanoparticles and it can be noted that, there is shifting toward the visible region, this can be attributed to the contribution of ITO nanoparticles because it has a high absorption in the visible region.

3.2.2 The Energy Band Gap Calculation

The measurement of absorbance as a function of wavelength is used to calculate the absorption coefficient (α) and the optical energy gap (E_g^{opt}) . The energy gap is determined by applying Tauc equation (1) [10]. Tauc put the empirical equation between the optical energy gap and energy of incident photon which is

$$\alpha h\upsilon = A(h\upsilon - E_g)^r \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where A is a constant, h (is the energy of the incident photon, which can be calculated using the equation $h\upsilon = \frac{1240}{\lambda nm}$, and r is the order of the optical transition depending on the nature of electronic transition[11].

Figures (3) indicate that the transition is a direct optical energy gap by plotting $(\alpha h\nu)^2$vs hν curves. Also shown the absorption coefficient increases with increasing the weight percentages of ITO nanoparticles; this may be attributed to increase the absorbance with increasing the weight percentages of ITO.

The optical energy gap is determined from equation 1, which listed in table 1. The explaining for the decreasing the energy gap is the formation of defect state in the prepared sample as a result of ITO doping.

Figure.4 shows the relationship between the extinction coefficient (k) and wavelength (λ) of the composites. The extinction coefficient ($k=\alpha\lambda/4\pi$) [12] increases with increasing of ITO nanoparticles concentrations, this may be attributed to high absorption coefficient, and there is shifting toward the visible region. This result indicates that the doping atoms of ITO nanoparticales will modify the structure of the host polymer.

The variation of the refractive index for (PMMA-ITO) nanocomposites as a function of wavelength is shown in Fig. 5. The figure shows that the refractive index of the pure PMMA polymer decreased as wavelength increase, while the refractive index of nanocomposites increases as a result of increasing the percentage of ITO; this behavior can be attributed to the ITO nanoparticles because it has a higher refractive index ($n > 1.85$) than the polymer, one can expect an increase in the refractive index of the polymer doped with ITO. The refractive index was calculated according to the formula (2) [1], (when the reflectance (R) and (k) are known)

$$n=\sqrt{\frac{4R}{(1-R)^2}-K^2}+\frac{1+R}{1-R} \qquad \text{.............2}$$

4. Conclusions

Nanocomposite films of PMMA polymer doped ITO nanoparticles have been successfully prepared using casting method. It was found that the transmittance and energy gap decreases with increasing ITO nanoparticles concentrations, while the refractive index of these films were increased with the increasing of ITO concentrations.

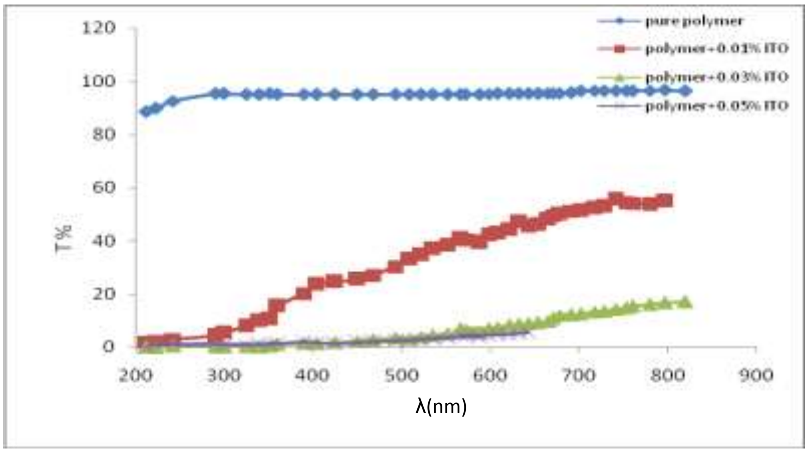

Fig.1. Transmission spectrum for pure and doped polymer

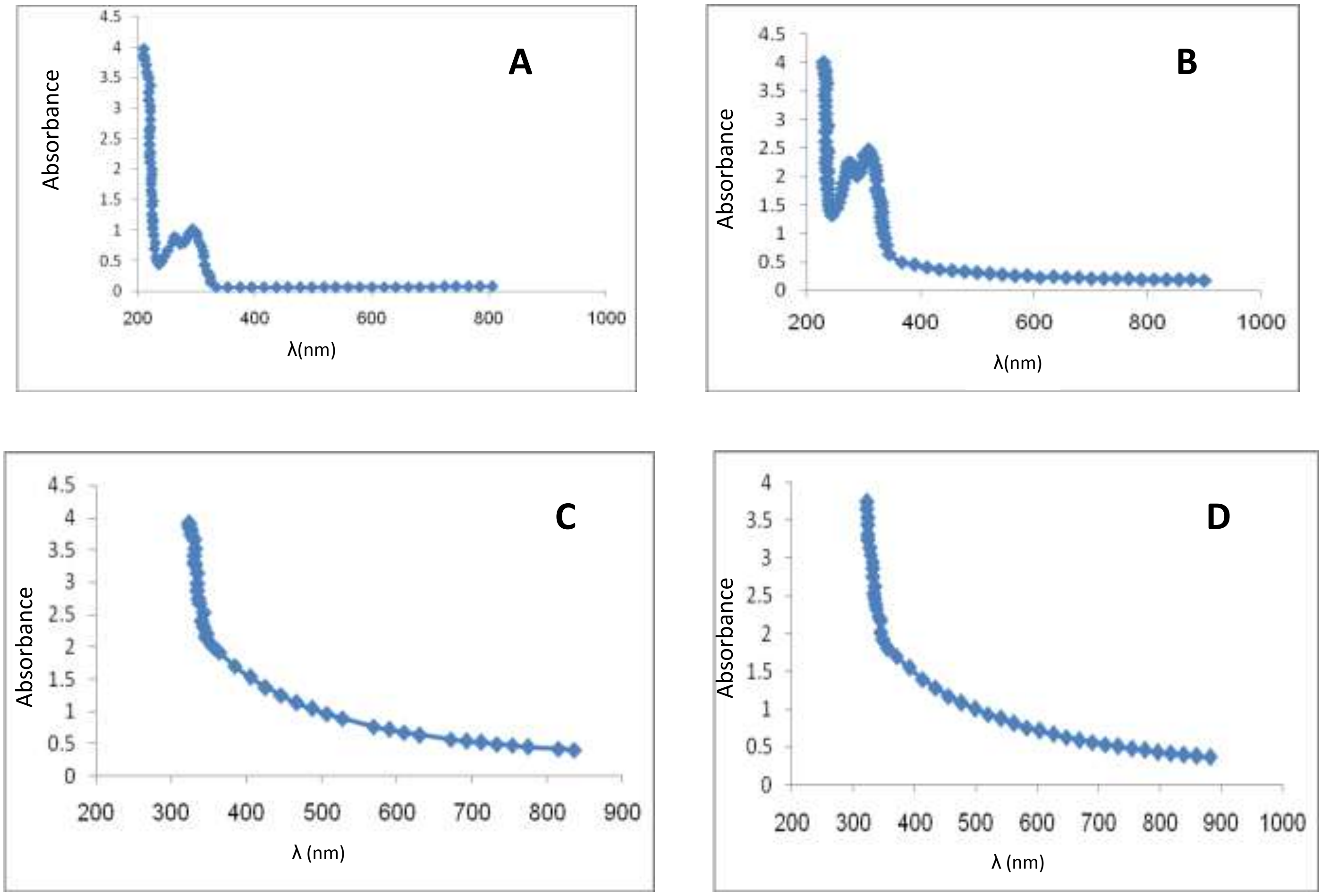

Fig.2. The absorption spectrum of of PMMA-ITO composites. A-pure polymer, B- 0.01% , C- 0.03%, D- 0.05% polymer doped ITO

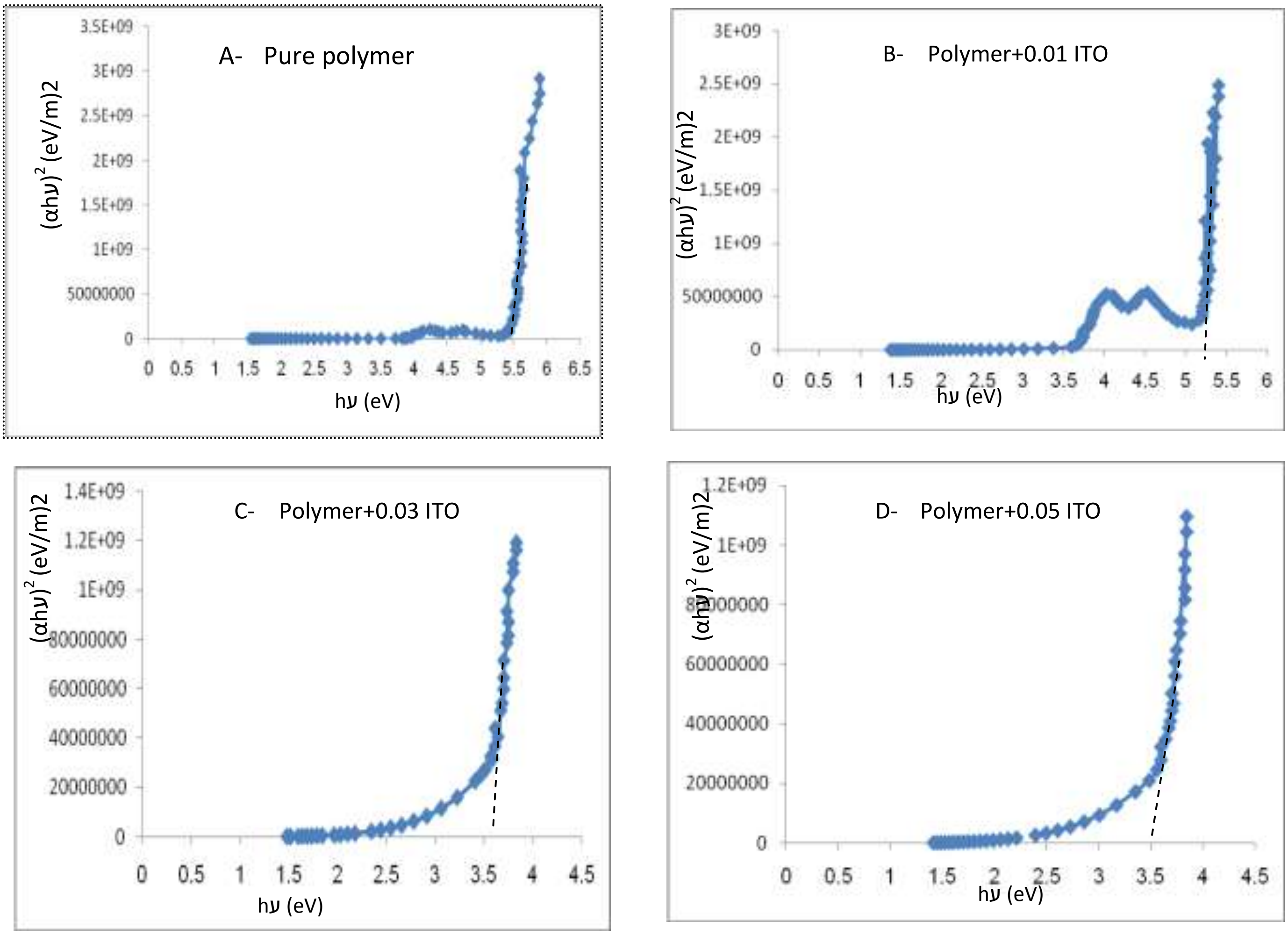

Fig.3. $(\alpha h\nu)^2$ vs. hν plots of PMMA-ITO composites. A-pure polymer, B- 0.01% , C-0.03%, D- 0.05% polymer doped ITO

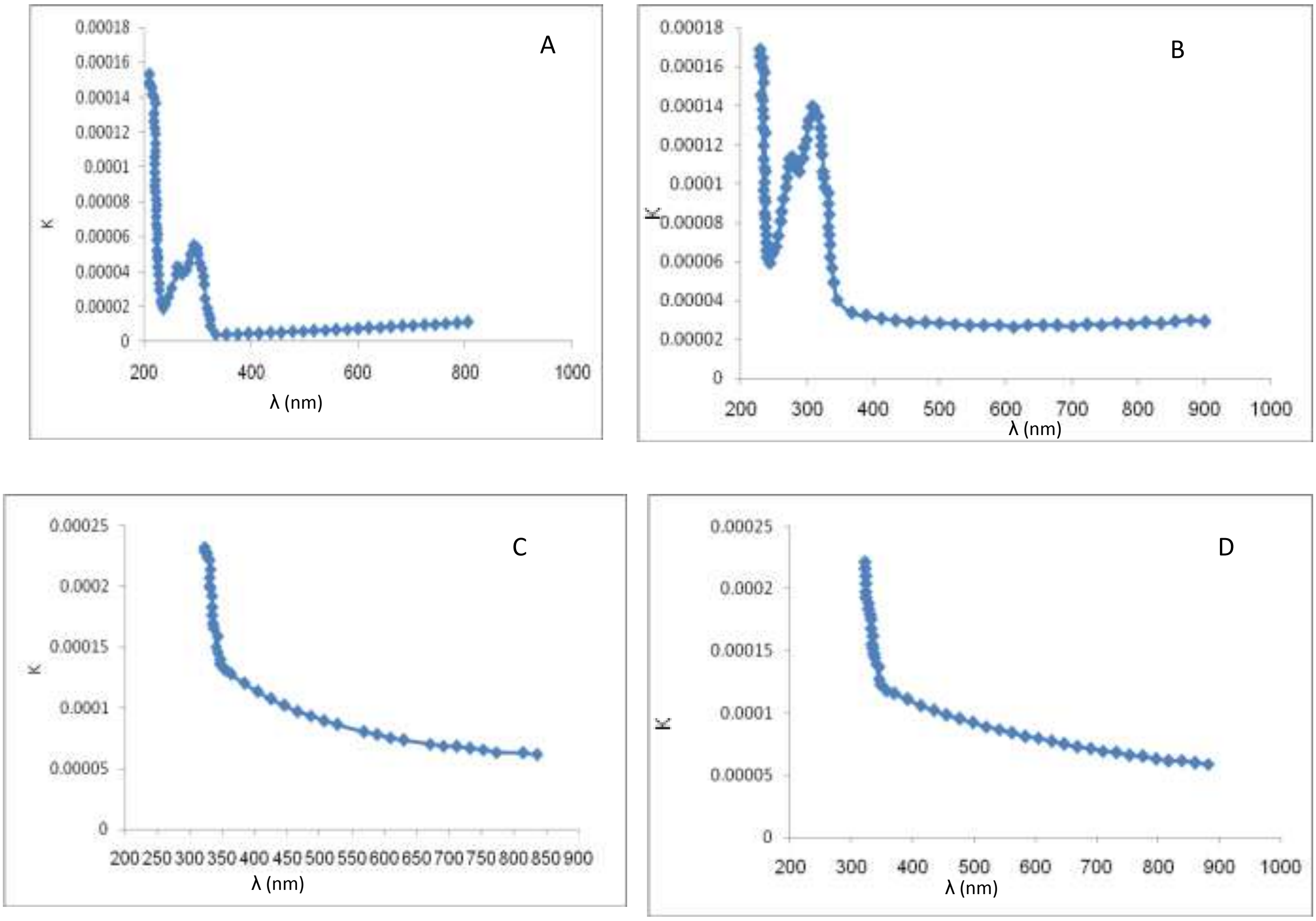

Fig.4. Extinction coefficient as a function wavelength for A-Pure PMMA polymer, B- 0.01% , C-0.03%, D- 0.05% polymer doped ITO

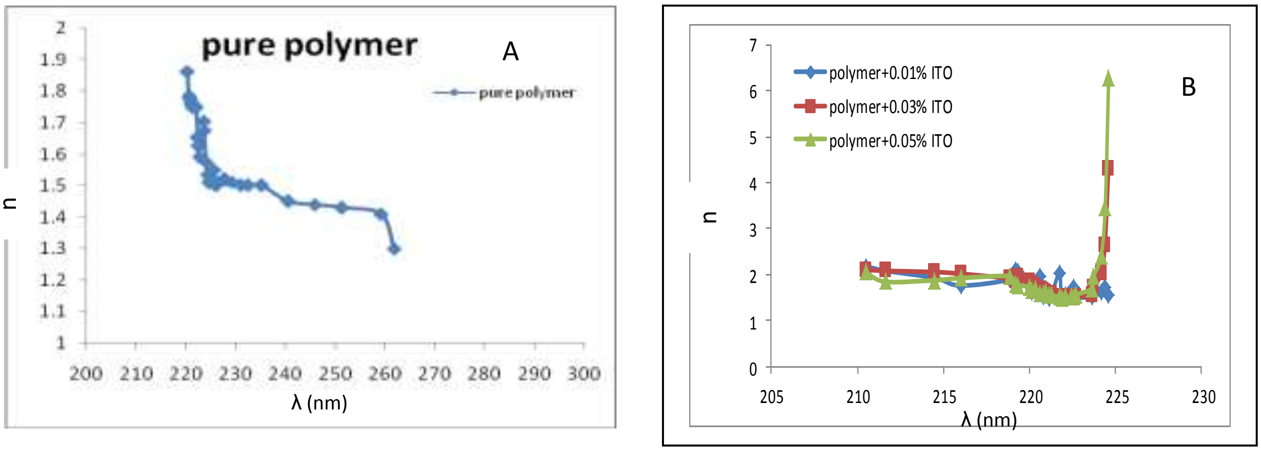

Fig. 5. Refractive index vs. wave length (λ) plots for A- Pure polymer, B- doped polymer composites.

Table. 1. Direct band gaps for pure polymer and doped films

NO.	CONCENTRATION Wt%	ENERGY GAP (eV)
Pure polymer	0	5.5
1	0.01	5.3
2	0.03	3.6
3	0.05	3.5

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