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RESEARCH ARTICLE

Fabrication of PS/PMMA/MgO Nano Composites: Structural and Optical Properties as Coating Materials for Antibacterial Applications

Ahmed A. Auda

Dept. of Health Food and Nutrition, College of Food Science, Al-Qasim Green University.

Abstract

Optical properties of P.S.P.M.M.A. polymer composite with doped MgO nanoparticles have been studied. The composite study was prepared by the solution of casting. Various concentrations were used for polymer material P.S- P.M.M.A/ (75 %-25 %). The weight ratios for Nano material (MgO) were 0 %, 2 %, 4% and 6 % of the total weight for the 1g sample. The optical spectrometers were measured at a wavelength of 220 nm-890 nm using a FTIR device optical properties of PS such as absorbance, transmittance, absorption coefficient, refractive index, extinction coefficient, real and imaginary parts of dielectric constant have been investigated. The results of the test on the refractive index, the attenuation coefficient and the insulation constant in its real and imaginary parts give good results with increasing the concentration of nanoparticles. The composite materials of polymer and nanoparticles were applied as antibacterial to Pseudomonas bacteria and they give the concentration (0.02 and 0.04 MgO) a good effectiveness to those bacteria.

Keywords: *Optical properties, Polystyrene, PMMA, Pseudomonas Bacteria.*

Introduction

Recently, many efforts have concentrated on nanomaterial with various structures by adding nanomaterial and polymers for the aim of producing materials that own new and better merits in their individual state and by mingling nanoparticles into the polymer matrix even with little nanoparticles many interesting optical properties can be obtained such as absorption, transmittance, refractive index and other properties. The gap energy can be characterized [1].

Polymers with optical properties have attracted a lot of attention on account of different applications in light sensors, light emitting diodes, etc. These properties can be easily ruled by controlling the concentration of fillers[2].One of the polymers that attracted attention is PS for its superior physical and chemical properties and it is regarded as an amorphous material and its main properties such as hardness, transparency, high refractive properties, good electrical insulation properties, low water absorption, and ease of processing which make it remarkable for variety applications in the industry as well as a good host of composites and based on these qualities form PS great interest in modern researches[3].Other polymer is PMMA, which has a high-transparent, non-amorphous thermoplastic and can be easily processed and converted into many products. It has good properties. It is thermoplastic and resistant to oils, alkanes and dilutes acids but it does not resist many solvents such as alcohol and organic acids. Low impact and increased strength of PMMA are adjusted with materials having higher impact strength and higher resistance [4].

PMMA can be used in many applications when high durability, such as coating, optical fiber, and sanitary fixtures, is not required. For the aim of obtaining a polymeric compound with both PS and PMMA properties, a compound of both types is made so that the weight ratios of the PS polymer are higher than the PMMA for the aim of gaining a compound with better tolerability and more applicable properties [5].

Nanotechnology has attracted a great deal of attention to its properties that can absorb

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light, convert it into electrical or chemical energy, as well as its small size and wide uses, its special properties, especially the optical ability to increase absorbance and the medical applications of which it has been remarkably focused[6].

MgO nanoparticles have been shown to be of great importance in several applications due to its unique physical properties such as optical properties and of its superior structure [7]. MgO nanoparticles have been used to motivate the treatment of toxic waste and heat-resistant materials as well as in antibacterial action and because it is one of the cheapest materials. Pseudomonas aeruginosa bacteria are considered to be one of the most resistant antibiotic bacteria [8]. It has been selected to be influenced by a polymeric compound containing MgO nanoparticles with a few weight ratios to mark its effectiveness against these bacteria spread in many essentially hospitals which have elucidated the presence of MgO nanoparticles as having the ability to inhibit and trap bacterial colonies of Pseudomonas aeruginosa bacteria. This compound can be used in anti-bacterial coatings.

Method

In this study, the PS polymer was prepared by 75% of the total sample weight of 1 g and the PMMA ratio of 25% of the weight ratios in the case of the nanoparticles ratio 0% and thus maintaining the total weight 1 g and reducing the polymer ratios by the same weight as the n nanoparticles (MgO). The percentage of nanoparticles was 2%, 4%, 6% of the total weight of the sample and the manufacturing process was done by casting method and Table (1) shows the proportions of each used material. The thickness of the composites was 0.11mm for each.

Table 1: the weights of the materials for the composite

Total sample wt.(g)	MgO wt.(g)	PMMA wt.(g)	PS wt.(g)
1	0	0.2	0.8
1	0.02	0.196	0.784
1	0.04	0.192	0.768
1	0.06	0.188	0.752

Theoretical

The optical properties such as the absorbance, transmittance, the electronic band structure and the optical energy band gap can be obtained by absorption coefficient α. The absorption coefficient α can be estimated from the optical absorption spectrum using the following equation [9].

$$\alpha = 2.303\, A/t \quad \ldots\ldots (1)$$

Where **t** is the film thickness in mm and A is the absorbance defined by $\log (I_0 / I)$ where I_0 and I are the intensities of the incident and transmitted beams respectively.

Concerning the optical transitions resulting from photons of energy hv > E_{ph} the present optical data can be investigated according to the following relationship for the near edge optical absorption. The absorption edge for direct and non-direct transitions can be obtained in view of the models proposed by [10],

$$\alpha h v = C_o (hv - E_{ph})^n \quad \ldots\ldots (2)$$

Where, **α** is the absorption coefficient, **v** is the frequency, **h** is Planck's constant, C_0 is a constant, E_{ph} is the optical energy band gap between the valence band and the conduction band and n is the power that characterizes the transition process. Specifically, n can take the values 1/2, 3/2, 2 or 3 for transitions designated as direct allowed, direct forbidden, indirect allowed, and indirect forbidden respectively [11]. The determination of the value of optical energy band gap E_{ph} involves the plotting of $(\alpha hv)^{1/n}$ against **hv**.

The reflectance (R) has been found from values of transmission (T), and Absorbance (A), using the relationship:

$$A+R+T=1 \quad \ldots\ldots (3)$$

For normal reflectance, the refractive index can be determined from the relation [12]:

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

The extinction coefficient **k** is related to the absorption coefficient α by the relation:

$$k = \alpha\lambda/4\pi \quad \ldots\ldots (5)$$

Where, **λ** is the incident photon wavelength.

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The relation between the complex dielectric constant and the complex refractive index N is expressed by:

$$\varepsilon = N^2 \quad ....(6)$$

It can be concluded that

$$(n - ik)^2 = \varepsilon_r - \varepsilon_i \quad ....(7)$$

The real (ε_r) and imaginary (ε_i) parts of the dielectric constant thus related to (n) and (k) values and can be calculated using the following formulas [13]:

$$\varepsilon_r = n2\text{-}k2 \text{ and } \varepsilon_i = 2nk \quad ....(8)$$

Results and Discussion

The obtained optical properties of (PS-PMMA)/MgO nanocompsites of the optical spectra are showed in the figures. Figure (1) shows that absorbance spectra varied as (PS-PMMA)/MgO nanocompsites concentration variation when the proportion of nanomaterial increases. This means that the blend PS-PMMA has limited absorbance which could be enhanced by adding MgO nanoparticles because of high energy gap (Fig.3).

At low concentration of MgO nanoparticles it behaves as a cluster, however when nanoparticles increase in concentration, the nanoparticles became a network of paths in the polymer blend (Ps-PMMA). It could be noticed that band gap decreased (Fig.6) as MgO nanoparticles increased in concentration [14].

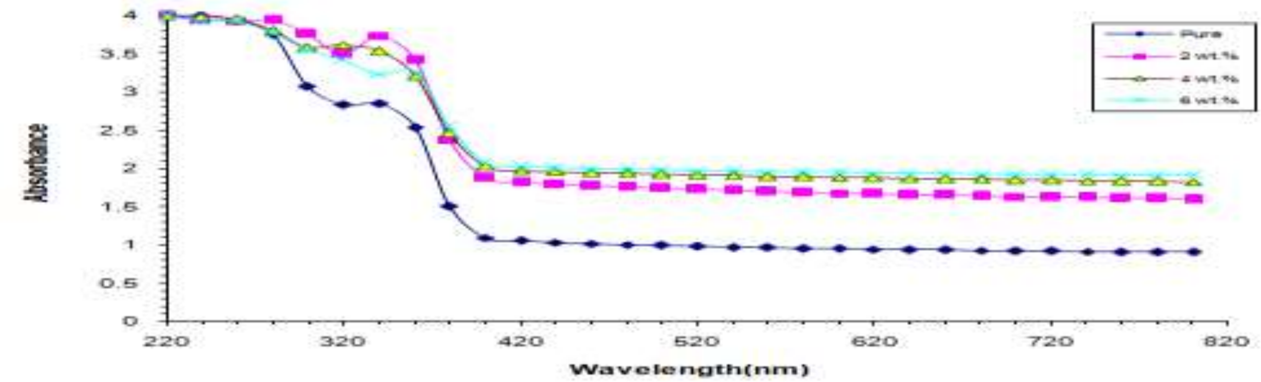

Fig.1: Absorbance vs. Wave length (nm)

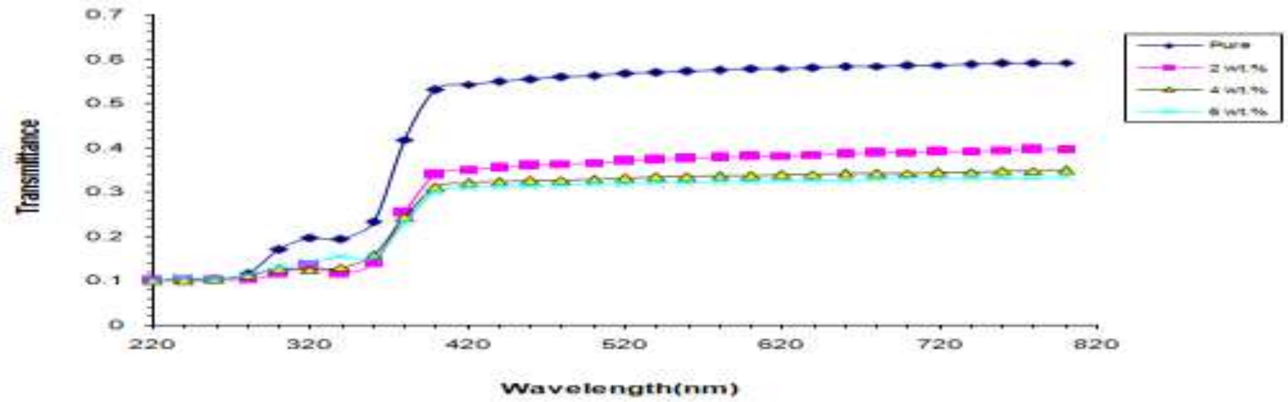

Fig. 2: Transmittance vs. Wavelength (nm)

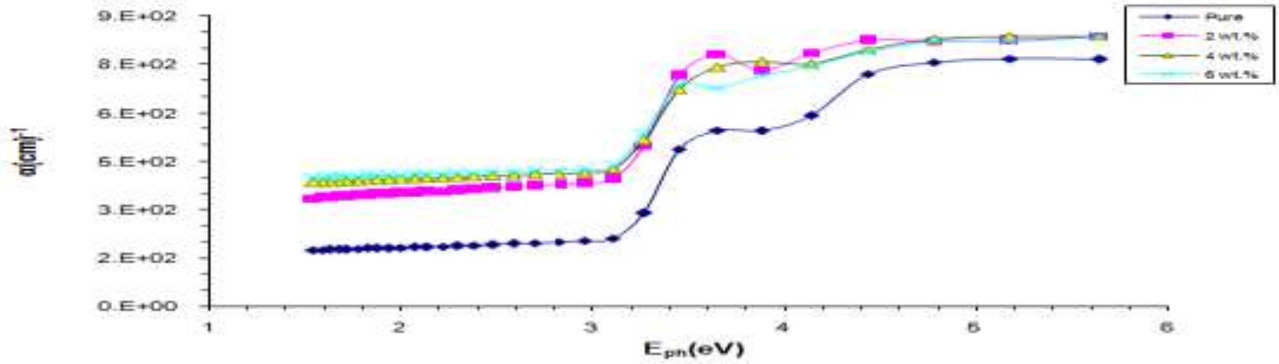

Fig. 3: Absorption coefficient vs. photon energy (E_{ph} (eV))

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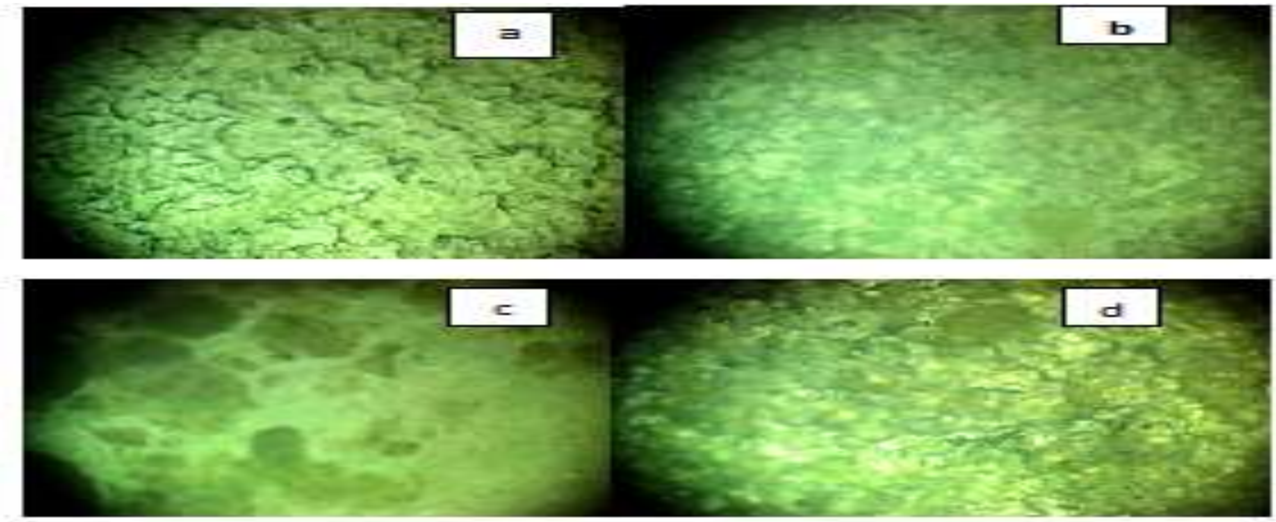

Fig. 4: Photomicrographs (x10) of (PS-PMMA/MgO) nanocompsites: for pure(a), 2%wt.MgO nanoparticles(b), 4%wt. (c), and 6% wt.(d)

Fig.5a :(2%wt. MgO) Image of the bacterial colony using polymer-nanoparticles composites as an anti-bacterial

Fig. 5b :(4%wt. MgO) Image of the bacterial colony using polymer-nanoparticles composites as an anti-bacterial

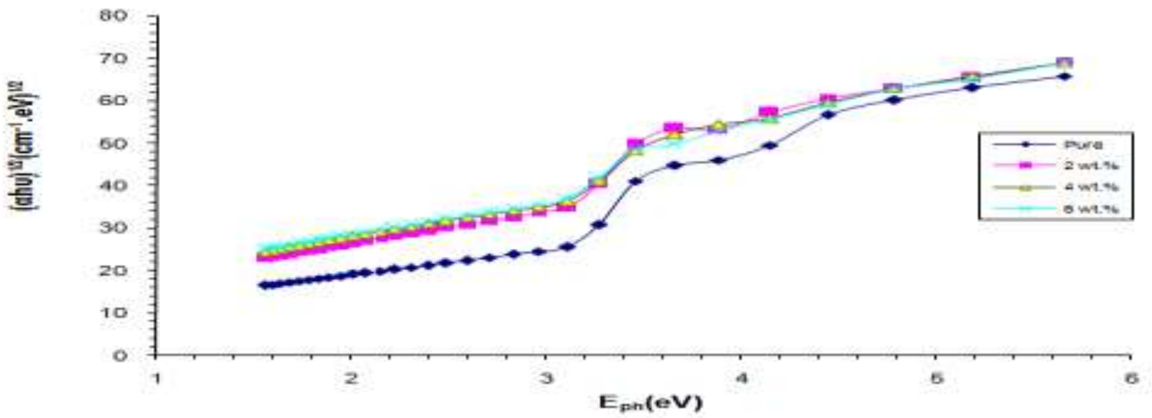

Fig. 6: Absorption coefficient vs. photon energy (E_{ph} (eV))

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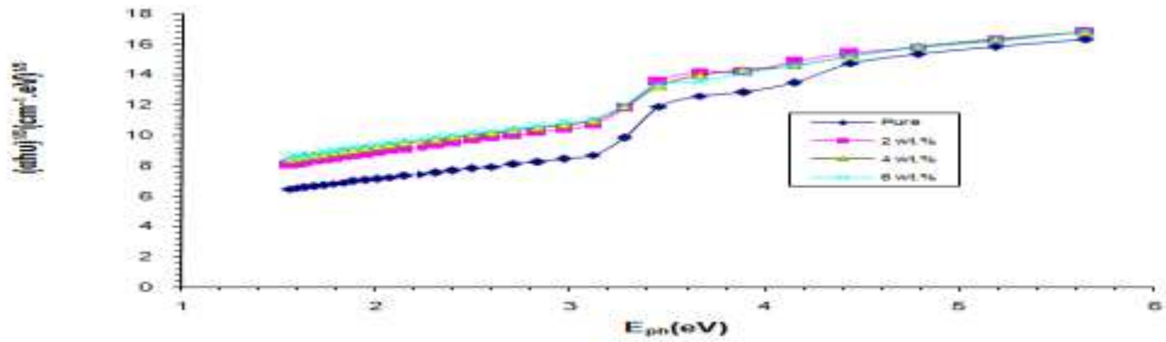

Fig. 7: Absorption coefficient vs. photon energy (E_{ph} (eV))

Figure (8) shows the extinction coefficient of (PS-PMMA/MgO) nanocomposites as a function of the photon wavelength. The extinction coefficient signals the amount of absorption loss when electromagnetic wave propagates through a material, which is a measure of the fraction of light lost owing to the scattering and absorption per unit distance of a penetration medium. The extinction coefficient is directly related to the absorption of a material and to the absorption coefficient. From Figure (8), the exponential decreases in the extinction coefficient with an increase in the photon energy that represents the fraction of light lost owing to the scattering and absorbance increases. Additionally, the loss factor decreases, as the photon energy increases [11]. Figure (9) shows the relationship between the refractive index of (PS-PMMA/MgO) nanocomposites and the wavelength. It can be observed that the refractive index of an as-synthesized material decreases, as the photon energy increases.

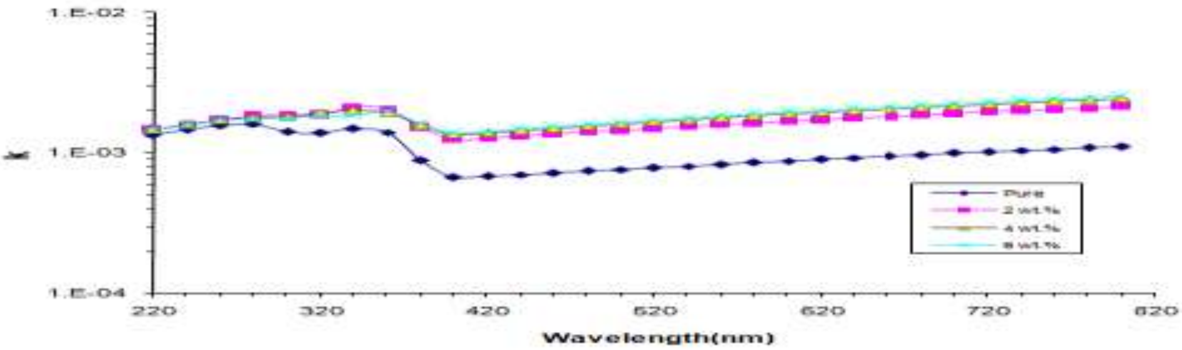

Fig. 6: extinction coefficient vs. wavelength

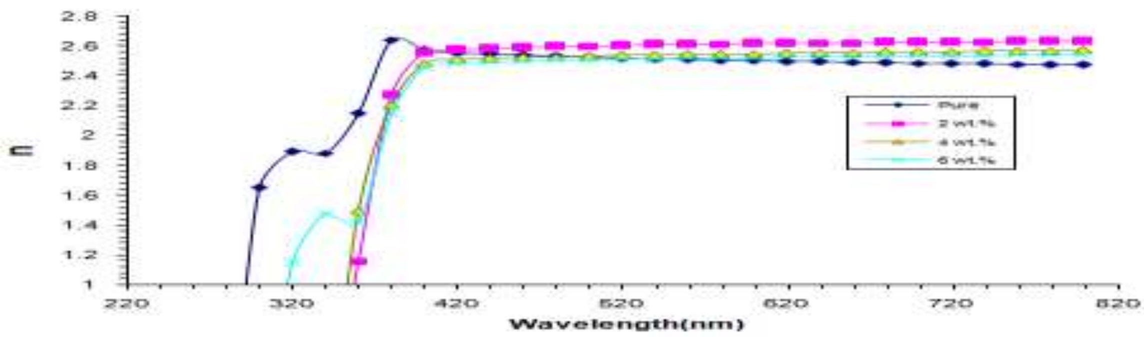

Fig. 9: refractive index vs. wavelength

This reflects that the synthesized polymeric samples represent the normal dispersion behavior. The variation in n values with the photon energy shows that the interaction between a photon and electrons happens. Thus, one can obtain the desired material for fabricating the optoelectronics devices, by estimating the photon energy, as the internal energy of a device relies on the photon energy. The decrease in the extinction coefficient and refractive index with an increase in the photon energy may be correlated with an increase in the absorption coefficient and a decrease in the transmittance [11]. The complex dielectric constant is the basic intrinsic property of materials.

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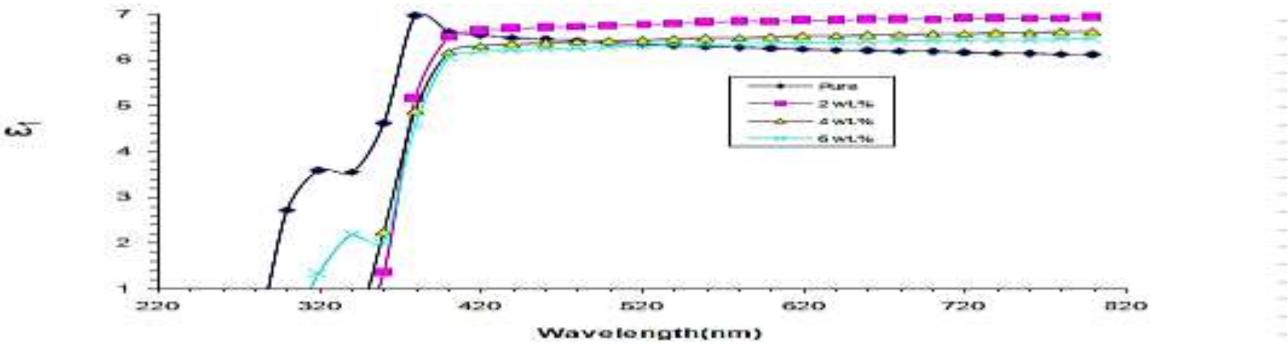

Fig.10: Real dielectric constant vs. wavelength

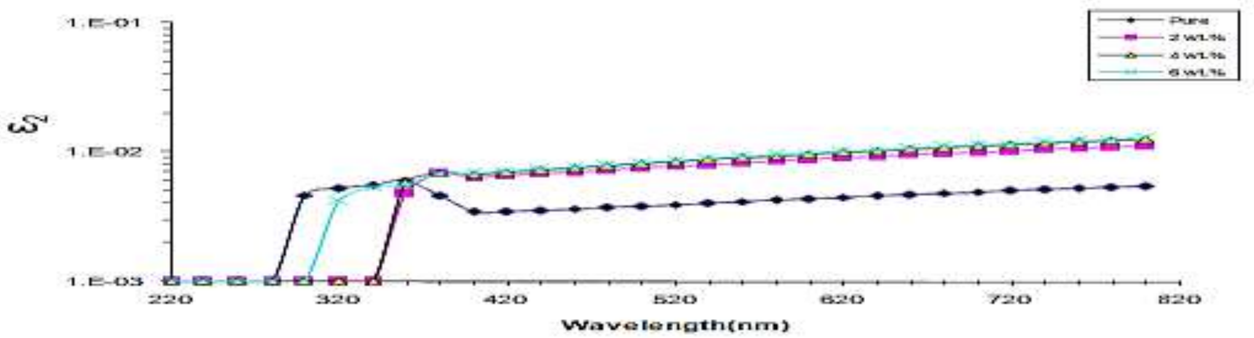

Fig.11: Imaginary dielectric constant vs. wavelength

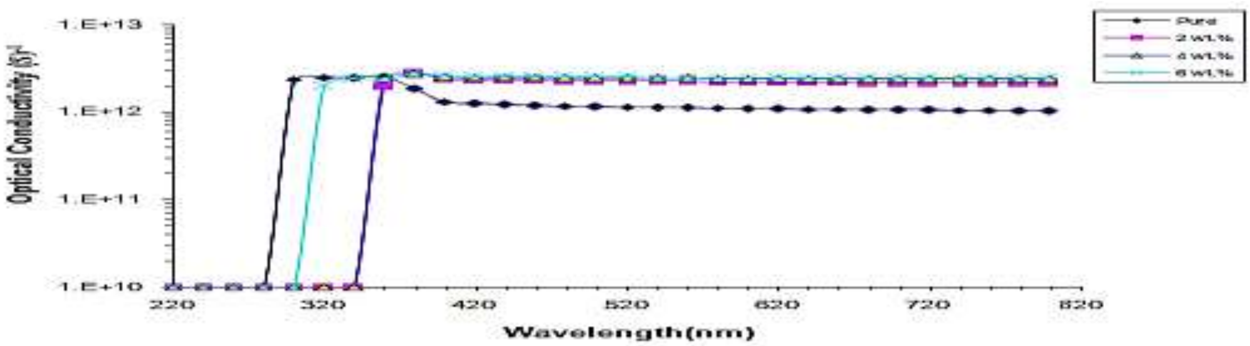

Fig.12: Optical conductivity vs. wavelength

The real part of the dielectric constant represents how much it will slow down the velocity of light in the material, while the imaginary part of the dielectric constant signals how a dielectric material absorbs the energy from an electric field owing to the dipole motion. Figure (10) shows the real dielectric constant of (PS-PMMA/MgO) nanocomposites as a function of the photon energy, while Figure (11) offers the imaginary dielectric constant as a function of the photon energy.

Figures (10) and (11) show that the real and imaginary parts of the dielectric constant. Variation of the absorption coefficient of (PS-PMMA/MgO) nanocomposites with the photon energy increase with an increase in the photon energy .The data on the real and imaginary parts of the dielectric constant provide knowledge concerning the loss factor, which is the ratio between the imaginary and real parts of the dielectric constant.

These results suggest that in the synthesized material, the loss factor increases with a decrease in the photon energy. The real part of the dielectric constant decreases a little-bit rapidly with an increase in the photon energy in the higher energy region but it decreases gradually in the lower one. However, the imaginary part of the dielectric constant decreases gradually with an increase in the photon energy [15]. The optical conductivity is one of the powerful tools for studying the electronic states in materials.

The plot of the optical conductivity of (PS-PMMA/MgO) nanocomposites versus the photon energy is depicted in Fig. (12). the spectrum indicates that the optical conductivity increases with the photon energy. Due to a decrease in the direct band gap the addition of the dopant, the optical conductivity increases. It is very clear from the graph that the optical conductivity increases with the doping of material [16].

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Fig. (5), shows the effect of the composite on the Pseudomonas aeruginosa bacteria that have been on the inhibition of proliferation and its colonies limited by this installation.

Conclusions

The optical absorbance of the (PS-PMMA) blend increases with the concentration of MgO nanoparticles. The (PS-PMMA/MgO) nanocomposites have a high absorbance in the UV-region. The energy band gap of the (PS-PMMA) blend decreases with an increase of the concentration of MgO nanoparticles. The absorption coefficient, refractive index, extinction coefficient, real and imaginary parts of the dielectric constant, and optical conductivity of the (PS-PMMA) blend increase with the concentration of MgO nanoparticles. The effect of the composite on the Pseudomonas aeruginosa bacteria that have been on the inhibition of proliferation and its colonies limited by this installation , the fillers act as an anti-bacterial mode for limitation of this type of bacteria.

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