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Optical Properties of (PVA-PAA-Ag) Nanocomposites

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Abstract: ***In this paper, the effect of silver nanoparticles on optical properties of (PVA-PAA) nanocomposites has been investigated. The silver nanoparticles were added to the polymers (polyvinyl alcohol 80 wt.% and poly-acrylic acid 20 wr.%) with weight percentages of (0, 2, 4, 6) wt.%. The optical properties of nanocomposites were measured in the wavelength range (200-800) nm. The experimental results show that the absorbance (A) of polymers mixture, absorption coefficient (α), extinction coefficient (k), refractive index (n) and real and imaginary dielectric constants (ε_1 and ε_2) are increasing with the increase of the weight percentages of silver nanoparticles . The energy gap (E_g) of polymers is decreased with the increase of the silver nanoparticles concentrations.***

Keywords: Optical Properties, Nanocomposites, Polyvinyl alcohol, Silver Nanoparticles.

1. Introduction

Studies on optical properties of polymer have widely applications in electronic devices and optical devices like solar cells, fuel cells, solid state batteries. and also exhibits promising medical technological applications. The high dielectric strength (good insulating material), good charge storage capacity as well as the low electrical conductivity and high flexibility make the poly-vinyl alcohol (PVA) as an exceptional polymer for microelectronic industry. Electrical conduction in polymers has been extensively studied in recent years to understand the nature of charge transport in these materials. Various conduction mechanisms such as Schottky effect, the Pool-frenkel effect, space charge limited conduction and hopping conduction have been suggested for the charge transport [1]. Nanotechnology can be defined as the science and engineering involved in the design, synthesis, characterization, and application of materials and devices whose smallest functional organization in at least one dimension is on the nanometer scale or one billionth of a meter. At these scales, consideration of individual molecules and interacting groups of molecules in relation to the bulk macroscopic properties of the material or device becomes important, since it is control over the fundamental molecular structure that allows control over the macroscopic chemical and physical properties. The applications of nanotechnology has only been increasing in the recent years, the highest potential application is in the field of materials, followed by electronics and medicine [2]. There is increasing research interest in polymeric nanocomposites owing to improvements in electrical, thermal, optical, and mechanical properties and their great potential for highly functional materials [3]. Metal nanoparticles combined polymers attracted great consideration because of the widened application goal offered by these hybrid materials. It is well established that polymers, as dielectric materials, are excellent host matrices for encapsulation of metal nanoparticles like silver, gold, copper, and so forth, as they act both as reducing as well as capping agents and also provide environmental and chemical stability. At the same time, these embedded nanoparticles inside the polymer matrix will also affect the properties of the host itself. Particularly, polymer - metal hybrid such as polymer-Ag-nanoparticles composites is promising functional materials in several fields such as optical, electrical, thermal, mechanical, and antimicrobial properties [4].

2. Materials and Methods

The polymeric materials are used in this study are polyvinyl alcohol (80 wt.%), poly-acrylic acid (20 wt.%) as a matrix and silver nanoparticles as additive. The polymers are dissolved in distill water by using magnetic stirrer and the silver nanoparticles was added to solution with different concentrations are (0,2 ,4 and 6) wt.%. The casting technique was used to preparation the nanocomposites. The optical properties of nanocomposites are measured by using UV/1800/ Shimadzu spectrophotometer in range of wavelength (200-800) nm.

Absorption coefficient (α) is given by equation [5]:

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

A: is the absorbance and t: is the sample thickness.

The electrons transitions are given by following equation[6]:

$$\alpha h\upsilon = B(h\upsilon - E_g)^r \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Where B is a constant, hυ is the photon energy , E_g is the optical energy band gap, r =2 for allowed indirect transition and r = 3 for forbidden indirect transition.

The Refractive index (n) is calculated by equation[7]:

$$n= (1+R^{1/2})/ (1-R^{1/2}) \quad \ldots\ldots\ldots (3)$$

Where R is the reflectance.

The extinction coefficient (k) is given by equation[7]:

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

The real and imaginary parts of dielectric constant (ε_1 and ε_2) are calculated by following equations [8]:

$$\varepsilon_1=n^2-k^2 \text{ (real part)} \quad \ldots\ldots (5)$$

$$\varepsilon_2=2nk \text{ (imaginary part)} \quad \ldots\ldots (6)$$

3. Results and Discussion

The UV spectra of nanocomposites with wavelength of incident light is shown in Fig.1. The absorbance of nanocomposites increases with the increase of concentration of nanoparticles. The increase of absorbance attributed to nanoparticles which absorb the incident light [9].

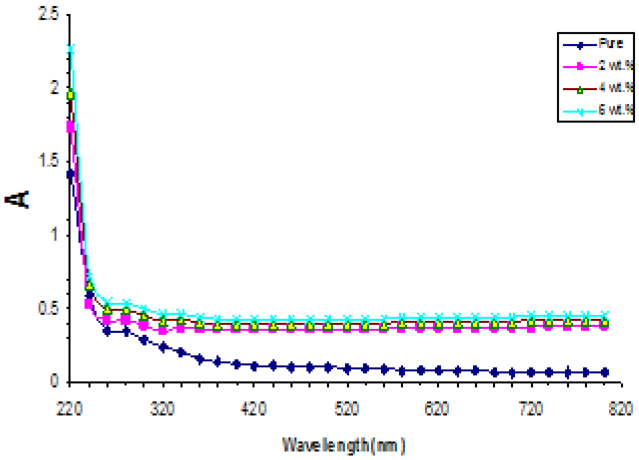

Figure 1: The UV spectra of (PVA-PAA-Ag) nanocomposites with wavelength

The relationship between absorption coefficients of nano composites with photon energy is shown in Fig. 2. From this figure, the absorption coefficient is increased with increase of the nano particles concentrations which attributed to increase the absorption of the light [10].

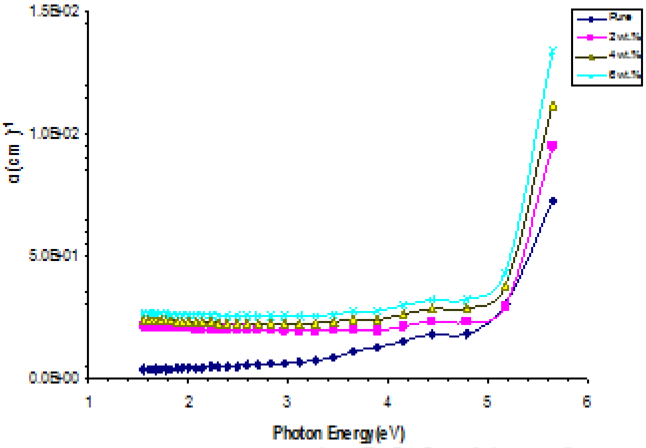

Figure 2: The relationship between absorption coefficient of (PVA-PAA-Ag) nanocomposites with photon energy

The Fig. 3 and Fig. 4 show the effect of Ag-nanoparticles concentrations on energy band gap of the nanocomposites. The energy band gap decreases with increase of the concentrations of nanoparticles which due to increase the localized levels in forbidden energy band gap[11].

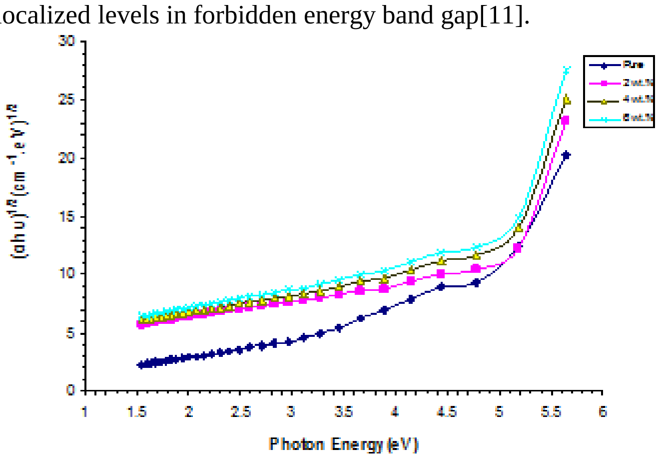

Figure 3: The relationship between $(\alpha h\upsilon)^{1/2}(cm^{-1}.eV)^{1/2}$ and photon energy of (PVA-PAA-Ag) nanocomposites.

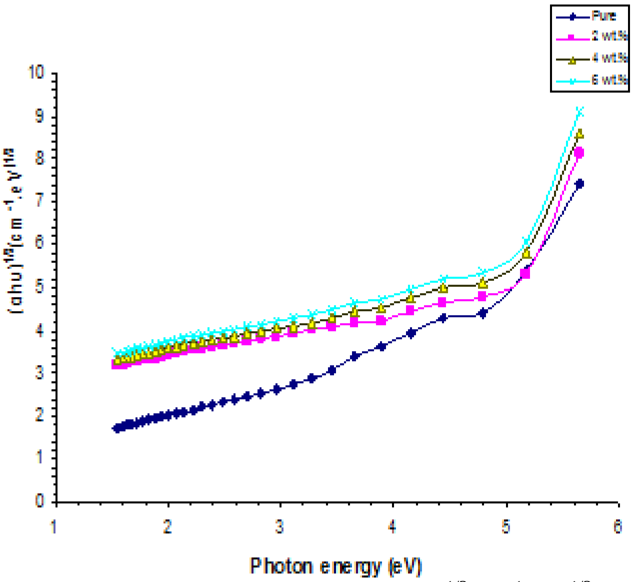

Figure 4: The relationship between $(\alpha h\upsilon)^{1/3}(cm^{-1}.eV)^{1/3}$ and photon energy of (PVA-PAA-Ag) nanocomposites

The variation of the extinction coefficient nanocomposites of different concentration of Ag- nanoparticles with the wavelength is shown in Fig. 5. From the figure we can see the extinction coefficient increases with the increase of the Ag-nanoparticles concentrations, this behavior attributed to loss of energy because the reaction between the light and the molecules of the medium [12].

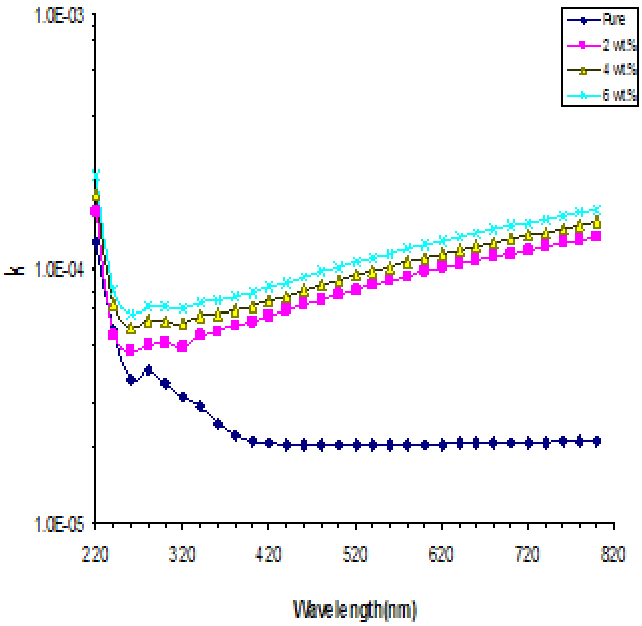

Figure 5: variation of the extinction coefficient for nanocomposites with the wavelength

Fig. 6 shows the effect of Ag- nanoparticles concentrations on refractive index of (PVA-PAA-Ag) nanocomposites. The figure show that the refractive index of nanocomposites increases with increase of the Ag- nanoparticles concentrations which attributed to increase the scattering of the incident light [13].

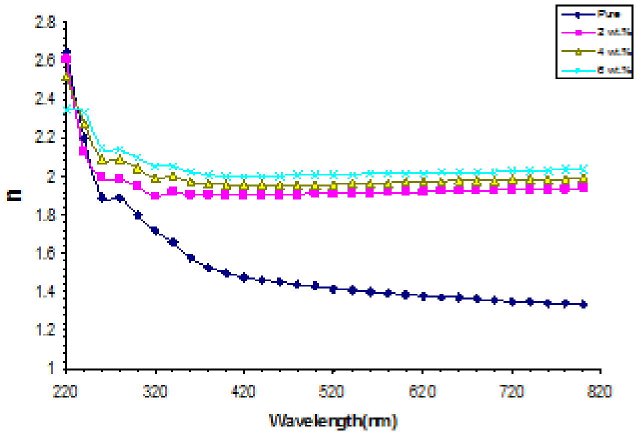

Figure 6: effect of Ag- nanoparticles concentrations on refractive index of (PVA-PAA-Ag) nanocomposites

The Fig.7 and Fig.8 show the relationship between the real, imaginary parts of dielectric constant with wavelength

of different concentrations of Ag-nanoparticles. From these figures, we can see that the real and imaginary parts of dielectric constant are increasing with the increase of the Ag-nanoparticles concentrations which attributed to increase the absorption coefficient and scattering[14].

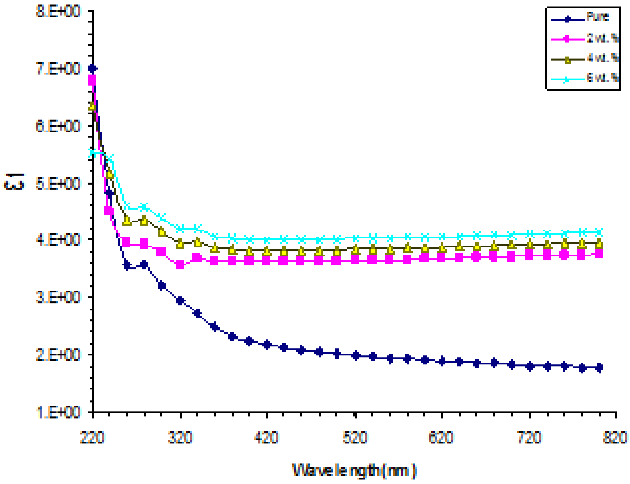

Figure 7: variation of real part of dielectric constant with wavelength of different concentrations of Ag-nanoparticles

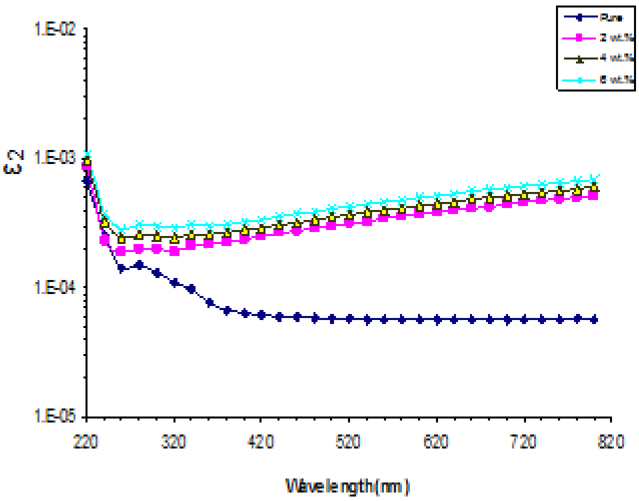

Figure 8: variation of imaginary part of dielectric constant with wavelength of different concentrations of Ag-nanoparticles

4. Conclusions

1) The absorbance of (PVA-PAA) composites increases with the increase of the silver nanoparticles concentrations.
2) The optical constants of (PVA-PAA) composites (absorption coefficient, extinction coefficient, refractive index and real and imaginary dielectric constants) are increasing with the increase of the silver nanoparticles concentrations.
3) The energy band gap (E_g) of (PVA-PAA) composites decreases with the increase of the silver nanoparticles concentrations.

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