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Dielectric and Optical Properties of (PVAc-PEG-Ber) Biocomposites

Majeed Ali Habeeb
Department of Physics, College of Education for Pure Science, Babylon University, Iraq

Abstract: In this study, the dielectric and optical properties of (PVAc-PEG-Ber) biocomposites. The effect of berry paper mulberry on dielectric and optical properties of polyvinyl acetate and polyethylene-glycol has been studied. The optical properties of biocomposites were measured in the wavelength range 190-790 nm. The experimental results showed that the absorbance, absorption coefficient, extinction coefficient, refractive index and real and imaginary dielectric constants of polymer composites are increasing with increasing of berry paper mulberry concentrations. The energy gap of polymer is decreased with increasing of the berry paper mulberry concentrations. The dielectric properties are measured in frequency range 100-5 MHz. The dielectric parameters are increasing with increases of the berry paper mulberry percentages and change with increase of the berry paper mulberry concentration.

Key words: Berry paper mulberry, optical properties, biocomposites, dielectric parameters, Iraq

INTRODUCTION

The choice of the polymers is usually guided mainly by their mechanical, thermal, electrical, optical and magnetic behaviors. However other properties, such as hydrophobic/hydrophilic balance, chemical stability, bio-compatibility, optoelectronic properties and chemical functionalities (i.e., solvation, wettability, templating effect, etc.) have to be considered in the choice of the polymers. The polymers in many cases can also allow easier shaping and better processing of the composite materials. The composites have been widely used in the various fields, such as military equipments, safety, protective garments, automotive, aerospace, electronics and optical devices. However, these application areas continuously demand additional properties and functions, such as high mechanical properties, flame retardation, chemical resistance, UV resistance, electrical conductivity, environmental stability, water repellency, magnetic field resistance, radar absorption, etc. (Jeon and Baek, 2010). The studies on optical properties of polymers have attracted much attention in view of their application in electronic and optical devices. The optical properties are studied to achieve better reflection, antireflection, interference and polarization properties (Ahmad *et al*., 2012). The development of polymer systems with high ionic conductivity is one of the main objectives in polymer research. This is because of their potential applications as electrolytes in solid-state batteries, fuel cells, electrochemical display devices/smart windows, photo electrochemical cells, etc., due to their high conductivity, high energy density, wide electrochemical stability and easy process ability. The main advantages of polymer electrolytes are their mechanical properties, ease of fabrication of thin films of desirable sizes and their ability to form proper electrode/electrolyte contact in electrochemical devices (Ismail *et al*., 2012). The doped polymers may present useful applications in integrated optics or in real time holography. In order to tailor materials with improved properties within the doped polymer class, it is necessary to understand and control the electronic mechanisms involved in the optical behavior (Jeon and Baek, 2010). The studies on optical properties of polymers have attracted much attention in view of their application in electronic and optical devices (Mahsan *et al*., 2009).

Theoretical: The absorption coefficient (α) is defined:

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

Where:
A = The absorbance of the material
t = The sample thickness

The energy band gap given by Tauc (1972):

$$\alpha h\upsilon = B\left(h\upsilon - E_g\right)^r \quad (2)$$

Where:
$h\upsilon$ = The photon energy
B = Constant
E_g = The optical energy band gap
r = 2 or 3 for indirect allowed and indirect forbidden transition

The refractive index (n) of the specimens is defined:

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

The extinction coefficient (k) calculate by using the following equation:

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

The real and imaginary parts of dielectric constants (ε_1 and ε_2) was calculated by using Eq. 5 and 6:

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

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

The optical conductivity is given by Mullis and Tagushi:

$$\sigma = \left[\alpha^2 c \varepsilon_0 \lambda / 4\pi\right] \quad (7)$$

Where:
c = The velocity of light
ε_0 = The permittivity of free space

The absorption coefficient in low energy is:

$$\alpha(f) = \alpha_n \exp\left(hf / E_e\right) \quad (8)$$

Where, E_e is the width of local states in the band gap. The skin depth (X) is given by:

$$X = 1 / \alpha \quad (9)$$

Also, the absorption coefficient is given by:

$$\alpha = k\lambda^P \quad (10)$$

The dielectric constant, $\acute{\varepsilon}$ (w) using the following expression:

$$\varepsilon'(w) = C(w)\frac{d}{\varepsilon_0 A} \quad (11)$$

Where:
C (w) = The capacitance
d = The sample thickness
A = The surface area of the sample

Whereas for dielectric loss ε'' (w):

$$\varepsilon''(w) = \varepsilon'(w) \times \tan\delta(w) \quad (12)$$

Where, tan δ (w) is dissipation factor. The AC conductivity σ_{ac} can be calculated by the following equation:

$$\sigma_{ac}(w) = \varepsilon_0 w \varepsilon'' \quad (13)$$

MATERIALS AND METHODS

The biocomposites were prepared by using casting technique. The materials used in this research are PVAc-PEG, as matrix and berry paper mulberry, as filler. The polymers were dissolved in distill water by using magnetic stirrer in mixing process to get homogeneous solution. The concentrations of berry paper mulberry are (0, 3, 6 and 9) wt.% were added and mixed for 20 min to get more homogenous solution, after which solution was transferred to clean glass. The optical properties of biocomposites are measured by using UV-1800 Shimadzu spectrophotometer. The dielectric properties of biocomposites were measured using LCR meter in the frequency (f) range 100-5 MHz at room temperature.

RESULTS AND DISCUSSION

Figure 1 shows the variation of the optical absorbance of (PVAc-PEG-Ber) biocomposites with the wavelength of the incident light of different concentrations. Figure 1 indicate that the absorbance of polymers increases with increasing of berry paper mulberry concentration, this attributed to the absorbance of berry paper mulberry (USDA, 1999).

The variation of the absorption coefficient (α), as a function photon energy are presented in Fig. 2. The values of the absorption coefficient of (PVAc-PEG-Ber) biocomposites are <10^4 cm^{-1} in the investigation spectral range. The fundamental absorption which corresponds to electron excitation from the valence band to conduction band can be used to determine the nature and value of the optical band gap, E_g. The value of E_g will be given by intercept on the hυ-axis, the optical energy gap has been determined from the intercepts of extrapolations to zero with the photon energy axis $(\alpha h\upsilon)^r \rightarrow 0$, as shown in Fig. 3 and 4.

From Fig. 3 and 4, researchers can see that the increase of concentration of berry paper mulberry in the polymers leads to decrease in the optical band gap. The decrease in band gap with increase in concentration of the berry paper mulberry can be due to the decrease of the distant between the valance band and conduction band. The extinction coefficient is directly proportional to the absorption coefficient. The decrease in the extinction coefficient with an increase in wavelength shows that the fraction of light lost due to scattering (Kurt, 2010; Rashid *et al.*, 2013), as shown in Fig. 5.

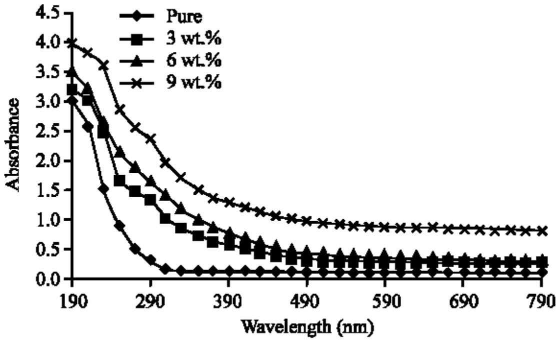

Fig. 1: The variation of the optical absorbance of biocomposites with the wavelength

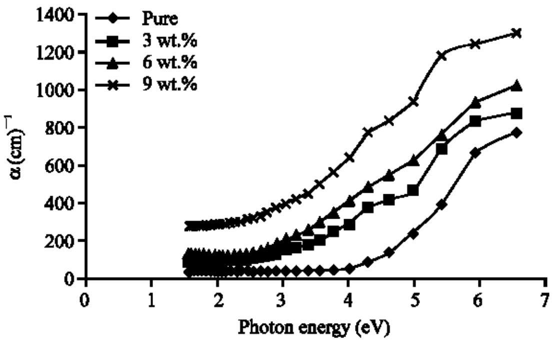

Fig. 2: The variation of the absorption coefficient of (PVAc-PEG-Ber) biocomposites with the photon energy

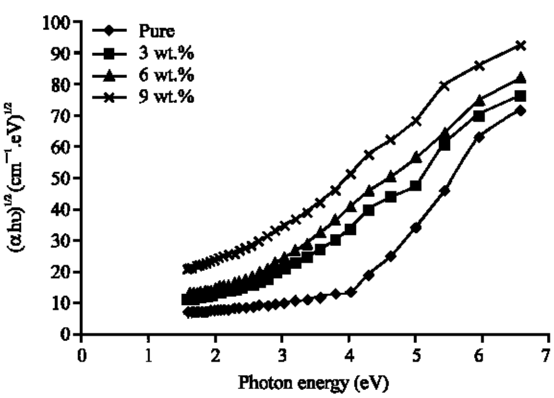

Fig. 3: The relationship between $(\alpha h\upsilon)^{1/2}$ $(cm^{-1}.eV)^{1/2}$ and photon energy of biocomposites

Figure 6 shows the variation of the refractive index of biocomposites a function of photon energy. It has been found that the value of refractive index of (PVAc-PEG-Ber) biocomposites increases with the increasing of concentration of berry paper mulberry which is a result of increasing the number of atomic refractions (Tsoumis, 1986).

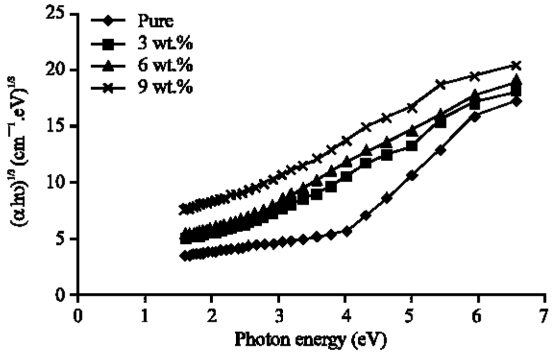

Fig. 4: The relationship between $(\alpha h\upsilon)^{1/3}$ $(cm^{-1}.eV)^{1/3}$ and photon energy of biocomposites

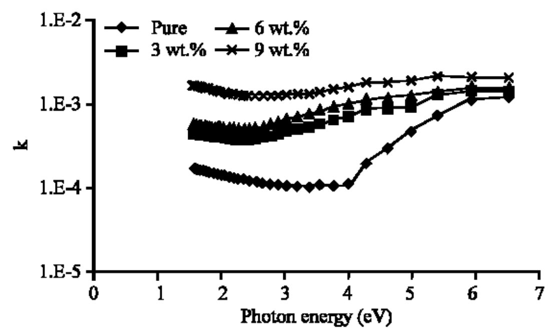

Fig. 5: The variation of the extinction coefficient of (PVAc-PEG-Ber) biocomposites with the photon energy

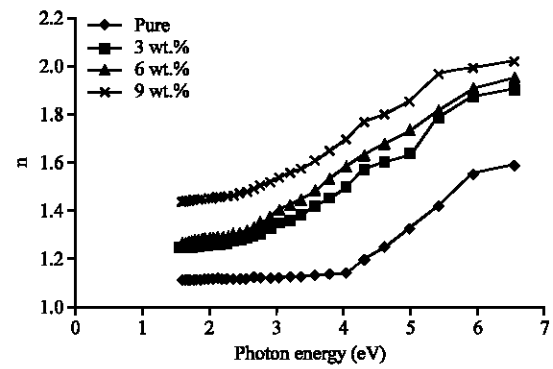

Fig. 6: The variation of the refractive index of biocomposites a function of photon energy

Figure 7 and 8 show the variation of real and imaginary parts of dielectric constants of (PVAc-PEG-Ber) biocomposites with the photon energy. The variation of ε_1 mainly depends on (n^2) because of small values of (k^2) while ε_2 mainly depends on the (k) values which are related to the variation of absorption coefficients. The real part of the dielectric constant is associated with the term

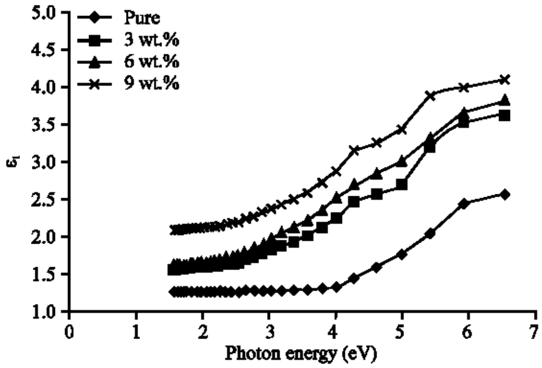

Fig. 7: Variation of the real part of dielectric constant of biocomposites with the photon energy

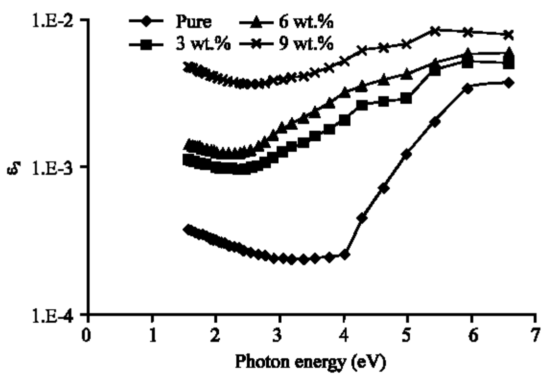

Fig. 8: Variation of the imaginary part of dielectric constant of biocomposites with the photon energy

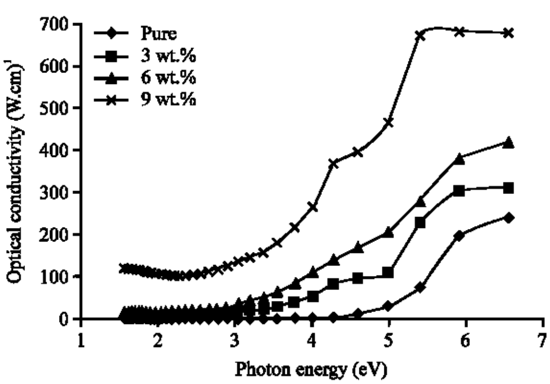

Fig. 9: Variation of the optical conductivity of biocomposites with photon energy

that shows how much it will slow down the speed of light in the material and the imaginary part shows how a dielectric absorbs energy from an electric field due to dipole motion (Keam Holdem Associated, 1999).

Figuer 9 shows the variation of the optical conductivity of biocomposites a function of photon

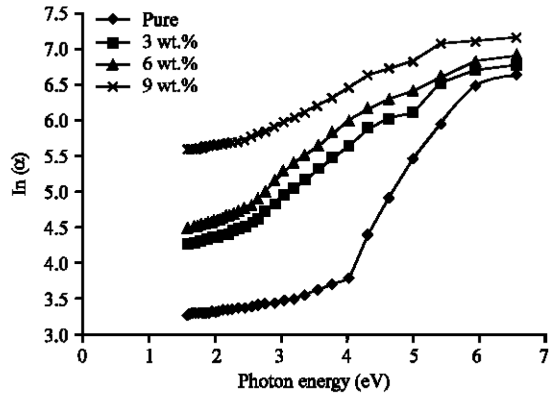

Fig. 10: The width of local states of biocomposites

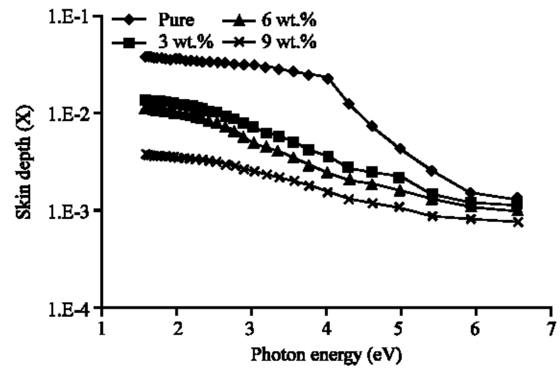

Fig. 11: Variation of skin depth with the photon energy of biocomposites

energy. The optical conductivity depends directly on the absorption coefficient, so the optical conductivity is increased with the increase of the concentration of the berry paper mulberry.

Figure 10 shows the calculation of width of local states in the band gap. From Fig. 10, researchers can see that the width of local states is decreased with the increase of the berry paper mulberry concentration, this attributed to decrease the dangling bands, defects and the trapping of the generated carriers (Singh, 2006).

Figure 11 shows the variation of skin depth with the photon energy. Figure 11 shows that the skin depth increases with the decreasing of the concentration of the berry paper mulberry, this attributed to decrease the probability of absorption.

Figure 12 shows the variation of (lnα) with (lnλ) to calculate (p) in Eq. 10. From Fig. 12, researchers can conclude that the scattering mechanism is photon scattering because the value of p~1.5.

Figure 13 shows the variation of the dielectric constant of (PVAc-PEG-Ber) biocomposites with the frequency. The increase of frequency results in

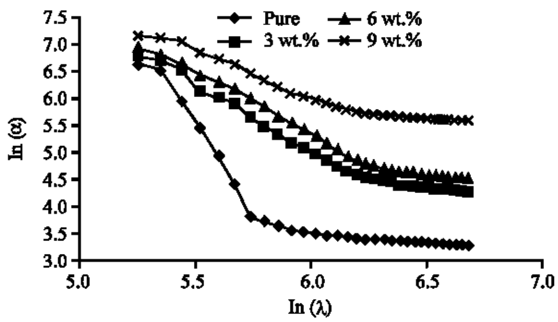

Fig. 12: Photon scattering with biocomposites

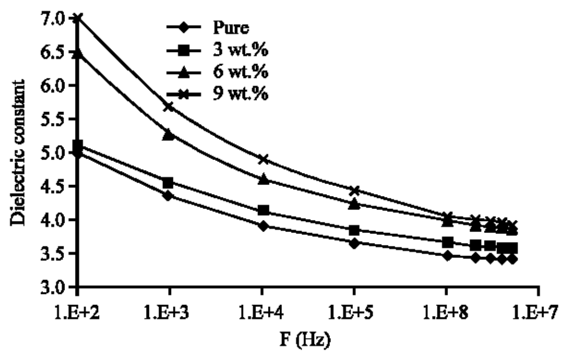

Fig. 13: The variation of the dielectric constant of biocomposites with the frequency

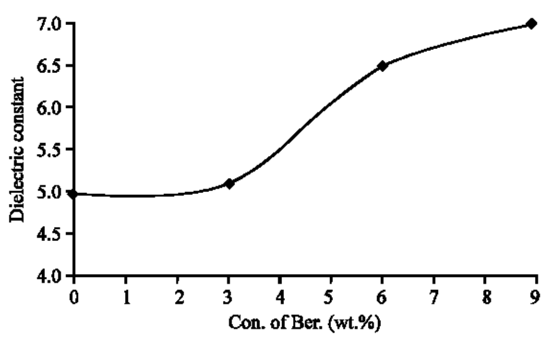

Fig. 14: The variation of the dielectric constant of biocomposites with the the concentration of berry paper mulberry

decreasing of space charge polarization to the total polarization. The space charge polarization becomes the more contributing type of polarization at low frequencies and less contributing with the increase of frequency, this would result in the decrease of dielectric constant values. The dielectric constant of biocomposites increases with the increasing of concentration of the berry paper mulberry, this attributed to increase the dipoles charge (Siau, 1995), as shown in Fig. 14.

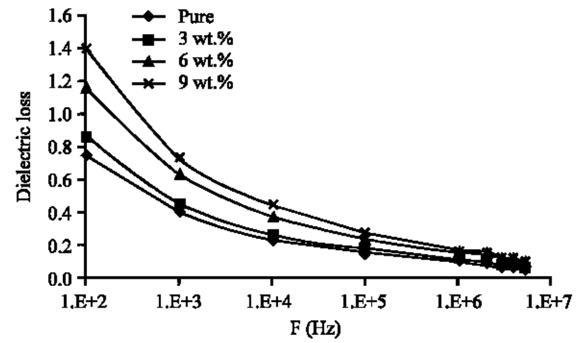

Fig. 15: The variation of the dielectric loss of biocomposites with the frequency

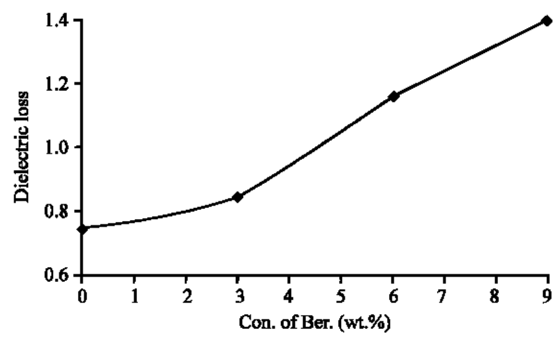

Fig. 16: The variation of the dielectric loss of biocomposites with the the concentration of berry paper mulberry at 100 Hz

Figure 15 shows the variation of dielectric loss with the frequency biocomposites. The dielectric loss of biocomposites decreases with the increasing the frequency, this is attributed to the decrease of the space charge polarization contribution when increasing the frequency (Lu *et al*., 2006). The dielectric loss increases with the increase of the concentration of berry paper mulberry, this is due to the increase of the ionic charge carriers (Guskos *et al*., 2005), as shown in Fig. 16.

The variation of AC electrical conductivity of (PVAc-PEG-Ber) biocomposites, as a function of the frequency at room temperature is shown in Fig. 17. The electrical conductivity is increased with the increasing of the frequency. This behavior can be explained in terms of polarization effect and hopping, i.e., a polarization effect since the berry paper mulberry concentration is insufficient to form an infinite network, i.e., the polarization effect between these finite network (cluster), as well as hopping of the electron between adjacent states, randomly distributed within these finite network.

Figure 18 indicates that AC electrical conductivity is increased with the increasing of concentration of the

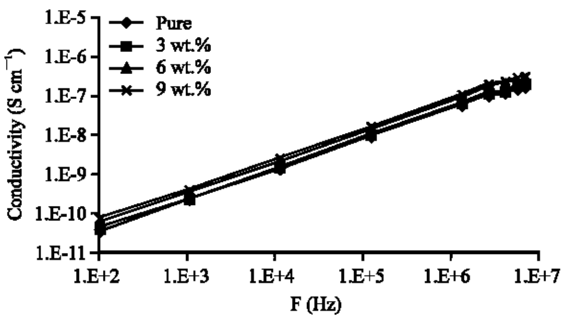

Fig. 17: The variation of the electrical conductivity of biocomposites with the frequency

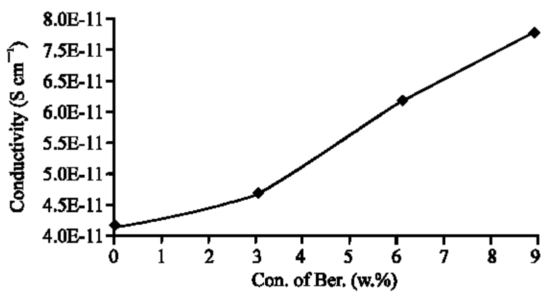

Fig. 18: The variation of the conductivity of biocomposites with the concentration of berry paper mulberry at 100 Hz

berry paper mulberry, a result which supports the suggestion of hopping of charge carrier conduction mechanism (James, 1974).

CONCLUSION

- The absorbance of polymers increases with increasing of the berry paper mulberry concentration
- The optical constants (absorption coefficient, extinction coefficient, refractive index and real and imaginary dielectric constants) are increasing with increasing of the concentration of the berry paper mulberry
- The energy band gap of polymer decreased with the increasing of the berry paper mulberry concentration
- The optical conductivity of (PVAc-PEG) composite increases with increasing of the berry paper mulberry
- The width of local states and skin depth are decreased with the increasing of the berry paper mulberry concentration
- The scattering mechanism is photon scattering
- The dielectric constant bioocomposites decreases with the increasing of the frequency and increases with the increase of the concentration of berry paper mulberry
- The dielectric loss of (PVAc-PEG-Ber) biocomposites decreases with the increasing of the frequency and increases with the increase of the concentration of berry paper mulberry
- The AC electrical conductivity of (PVAc-PEG-Ber) biocomposites increases with increases of the frequency and concentration of berry paper mulberry

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