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RESEARCH ARTICLE

PREPARATION AND STUDY OF SOME OPTICAL PROPERTIES OF ($PVA-Ni(CH_3COO)_2$) COMPOSITES

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ABSTRACT

Pure polymer (polyvinyl alcohol (PVA)) films were prepared by using casting technique. The films were doped with $Ni(CH_3COO)_2$ salt at different concentrations (2, 4, 6, 8 and 10) wt% to investigate the effect of doping on some optical properties of the prepared films. The absorption and transmission spectra have been recorded in the wavelength range (190-1100) nm. The experimental results for ($PVA-Ni(CH_3COO)_2$) films show that the electronic transition is allowed indirect transition, and the energy gap decreases within increasing the filler content. The absorption coefficient, refractive index, extinction coefficient and real and imaginary parts of dielectric constant are calculated and it is found that all these optical parameters are increased with increasing the filler content.

INTRODUCTION

Generally, the use of most polymers was limited to the manufacture of cheap products which were used for simple purposes. However, the rapid technical development has required the replacement of some materials being used in industry with others having better specifications. Consequently, polymers have replaced Aluminum and Iron for some purposes that require stress and high temperature (Kontos *et al.,* 2007; Mustafa, 2008). Later, the development of polymer science has started to increase by leaps and bounds. Nowadays, scientists seek to produce, cheap, flexible and multi-purpose polymers. They are used in housing, automobiles and they can be used for different industrial applications. Plastics are the most versatile materials used in different industries such as aircraft, packaging, electrical equipment and as electrical insulators. They have increasingly an important role in the manufacture of satellites, space researches and thermal barriers (Kontos *et al.,* 2007; Mustafa, 2008). Plastics have replaced metals in many applications. They have superseded steel and many other metals in being erosion resistant and chemically inert. Having higher temperature extension and specific heat than metals, plastics have been used for constructing and lining of reactors, absorption towers and the manufacture of pipes and valves. Most of plastics are currently manufactured as light, rigid and foamy materials and used as insulators due to their low thermal and electrical conductivity. Plastics have almost no free electrons but recent scientific and technical break throughs have succeeded in making some modifications on regular plastics and brought in to existence of a new generation of plastics that combine the electrical features of the conductive and semi-conductive materials and the mechanical and chemical features of plastics (Mustafa, 2008; El-Dahshan 2002).

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MATERIALS AND METHODS

The materials used in this work were as a powder of polymer (polyvinyl alcohol (PVA)) doped by Nickel Acetate ($Ni(CH_3COO)_2$) salt with weight percent (0, 2, 4, 6,8 and 10) wt %. It was dissolved in glass beaker by distilled water (15 ml) using magnetic stirrer about (45 minutes) and placed in Petri dish (5 cm diameter) using casting technique to prepare the films. The thickness of the dried films is (45 μm) measured by digital micrometer. The absorption and transmission spectra for ($PVA-Ni(CH_3COO)_2$) films have been recorded in the wavelength range (190-1100) nm by using double-beam spectrophotometer (Shimadzu, UV-Visible 1800) provided by optima (300) plus company.

RESULTS AND DISCUSSION

Figure (1) shows the absorption spectrum for ($PVA-Ni(CH_3COO)_2$) films with different concentrations of $Ni(CH_3COO)_2$ salt as a function of the wavelength. It is shown that the adding of the filler $Ni(CH_3COO)_2$ salt to the polymer (PVA) leads to increase the intensity of the absorbance peak.

So, there is shift in the position of the peaks for all amounts of filler adding to the polymer towards red wavelengths. The increase of absorbance with the increase of the weight percentage of the added $Ni(CH_3COO)_2$ salt can be explained by the fact that $Ni(CH_3COO)_2$ ions absorbed the incident light on them (El-Dahshan, 2002; Gabur, 2010; Abdul Munaim and A. Hashim, 2010).

Figure (2) shows the transmission spectrum for (PVA-$Ni(CH_3COO)_2$) films with different concentrations of $Ni(CH_3COO)_2$ salt as a function of the wavelength. The figure shows that the transmittance decreases with the increase of the weight percentage of the added $Ni(CH_3COO)_2$ salt. This is caused by the added $Ni(CH_3COO)_2$ salt which contains electrons in its outer orbits which can absorb the electromagnetic energy of the incident light and then the electrons travel to higher energy levels.

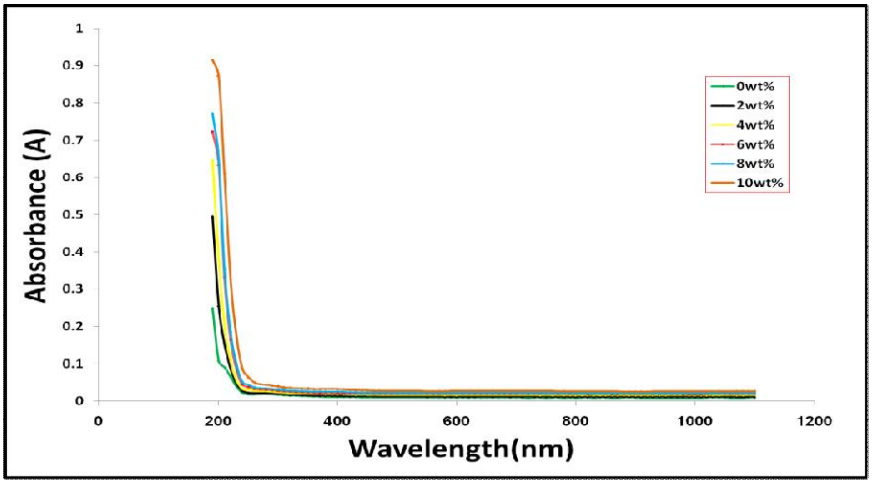

Figure 1. The absorbance for (PVA-$Ni(CH_3COO)_2$) films with different concentrations of $Ni(CH_3COO)_2$ salt as a function of the wavelength

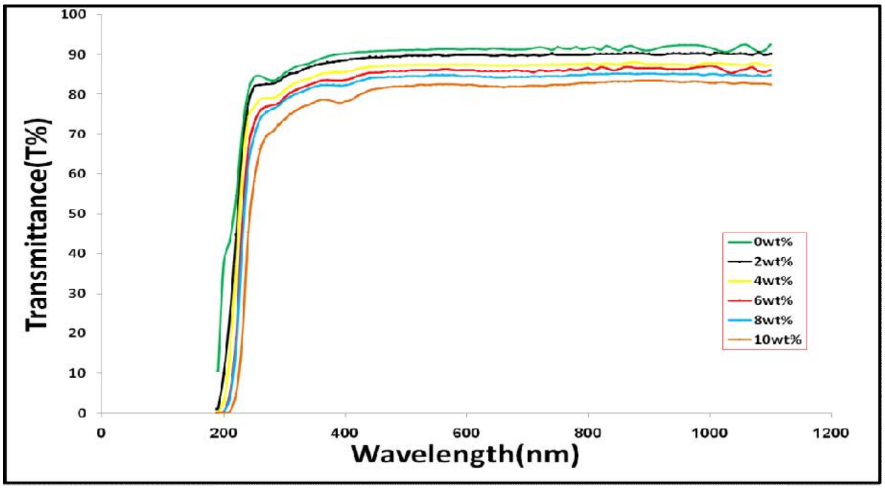

Figure 2. The transmittance for (PVA-$Ni(CH_3COO)_2$) films with different concentrations of $Ni(CH_3COO)_2$ salt as a function of the wavelength

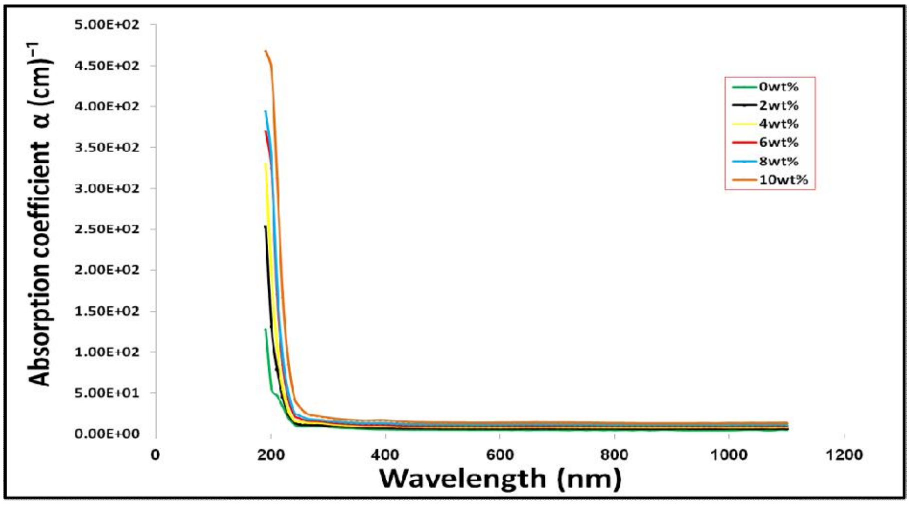

Figure 3. The absorption coefficient for (PVA-$Ni(CH_3COO)_2$) films with different concentrations of $Ni(CH_3COO)_2$ salt as a function of the wavelength

This process is not accompanied by emission of radiation because the traveled electrons to higher levels have occupied vacant positions of energy bands, thus part of the incident light is absorbed by the substance and does not penetrate through it (El-Dahshan, 2002).

Figure (3) shows the absorption coefficient for (PVA-$Ni(CH_3COO)_2$ films with different concentrations of $Ni(CH_3COO)_2$ salt as a function of the wavelength. The absorption coefficient $\alpha(cm)^{-1}$ is calculate using the equation $\alpha = 2.303(A/t)$ (Wolfe *et al.,* 1989), where (A) is the absorbance and (t) is the thickness of the film. At high energies, absorption coefficient is high. This means that there is a high possibility for electron transition. Consequently, the energy of incident photon is enough to move the electron from the valence band to the conduction band, i.e. the energy of the incident photon is greater than the energy gap (El-Dahshan, 2002). This shows that the absorption coefficient assists in figuring out the nature of electron transition, when the values of the absorption coefficient are high enough ($\alpha>10^4$) cm^{-1}, it is expected that direct transition of electron occurs where the energy and momentum are maintained by the electrons and photons. While, when the values of the absorption coefficient are low ($\alpha<10^4$) cm^{-1}, it is expected that indirect transition of electron occurs where the electronic momentum is maintained with the assistance of the phonon (Chiad, 2005). Among other results, the absorption coefficient for the (PVA-$Ni(CH_3COO)_2$) films is less than (10^4 cm^{-1}), this explains that the electron transition is indirect. We can also see from Figure (3) that the absorption coefficient increases with increasing the weight percentage of the added $Ni(CH_3COO)_2$ salt.

Figure (4) shows the relation between $(\alpha h\nu)^{1/2}$ for (PVA-$Ni(CH_3COO)_2$) films with different concentrations of $Ni(CH_3COO)_2$ salt as a function of the photon energy. The energy gap (E_g) for allowed indirect transition has been calculated by using equation (Sze and Ng. Kwok 2007):

$$\alpha h\nu = B(h\nu - E_g)^2 \qquad \text{.....................} (2)$$

Where B is inversely proportional to amorphousity and ($h\upsilon$) is the photon energy.

On drawing a straight line from the upper part of the curve toward the (x-axis) at the value $(\alpha h\nu)^{1/2}=0$ we get the energy gap (E_g) for the allowed indirect transition. The obtained values are shown in Table (1).

We can see that the values of energy gap (E_g) decrease with the increase of the weight percentage of the added $Ni(CH_3COO)_2$ salt. This is attributed to the creation of onsite levels in the energy gap (E_g); the transition in this case is conducted in two stages that involve the transition of electron from the valence band to the local levels and to the conduction band as a result of increasing the added weight percentage. This behavior is attributed to the fact that composites are of heterogeneous type (i.e. the electronic conduction depends on added impurities). The increase of the added rate provides electronic paths in the polymer which facilitate the crossing of electron from the valance band to the conduction band (El-Dahshan 2002; Gabur 2010).

Table 1. Values of energy gap (E_g) for the allowed indirect transition for (PVA- $Ni(CH_3COO)_2$) films with different concentrations of $Ni(CH_3COO)_2$ salt

$Ni(CH_3COO)_2$ (wt%)	E_g (eV)
	Allowed indirect
Pure (PVA)	5.65
2	5.35
4	5.20
6	5.125
8	5.05
10	5.00

Figure (5) shows the change of refractive index for (PVA-$Ni(CH_3COO)_2$) films with different concentrations of $Ni(CH_3COO)_2$ salt as a function of the wavelength. The refractive index (n) is calculated from equation (Chopra and Kaur, 1983):

$$n = \sqrt{\frac{4R - k^2}{(R-1)^2} - \frac{(R+1)}{(R-1)}} \qquad \text{..................}(3)$$

Where (R) is the reflectance and (k) is the extinction coefficient.

From the figure we can see that the refractive index increases with increasing the weight percentage of the added $Ni(CH_3COO)_2$ salt.

Figure (6) shows the change of extinction coefficient for (PVA-$Ni(CH_3COO)_2$) films with different concentrations of $Ni(CH_3COO)_2$ salt as a function of the wavelength. The extinction coefficient (k) is calculated from equation (Berglund *et al.,*1993):

$$k = \alpha\lambda/4\pi \qquad \text{...............................}(4)$$

Where (λ) is the wavelength of incident ray

It can be noted that the extinction coefficient is of lowering values at low concentrations, but it increases with increasing the weight percentage of the added $Ni(CH_3COO)_2$ salt. This is attributed to increased absorption coefficient with increased percentage of added $Ni(CH_3COO)_2$ salt.

Figures (7) and (8) shows the change of the real and imaginary parts of dielectric constant for (PVA- $Ni(CH_3COO)_2$) films with different concentrations of $Ni(CH_3COO)_2$ salt as a function of the wavelength. The real and imaginary parts of dielectric constant (ε_1,ε_2) can be expressed by the following equation (Klingshirn 1997):

$$\varepsilon_1 = n^2 - k^2 \qquad \text{...............................}(5)$$

$$\varepsilon_2 = 2nk \qquad \text{...............................}(6)$$

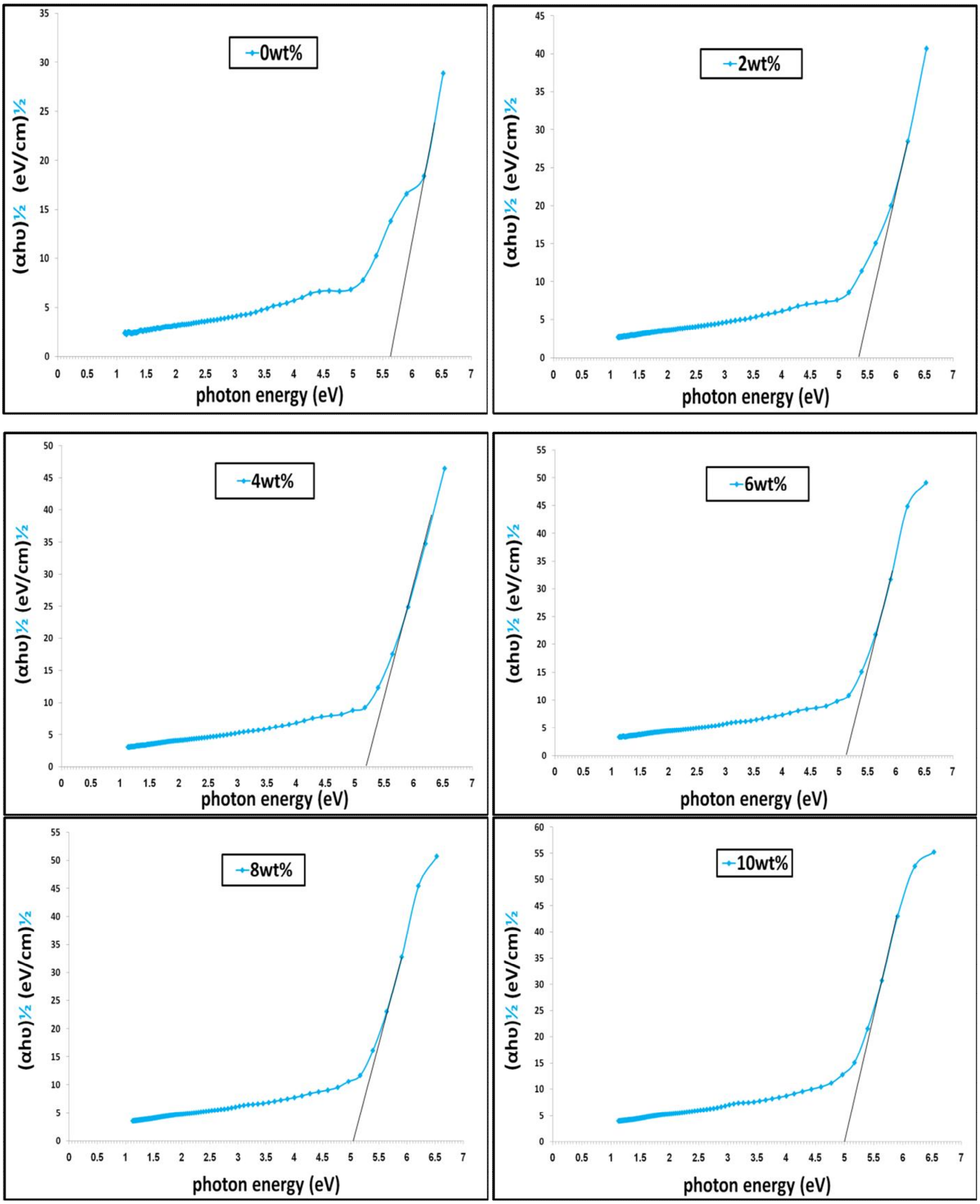

Figure 4. The energy gap for the allowed indirect transition for (PVA-Ni($CH_3COO)_2$) films with different concentrations of Ni($CH_3COO)_2$ salt

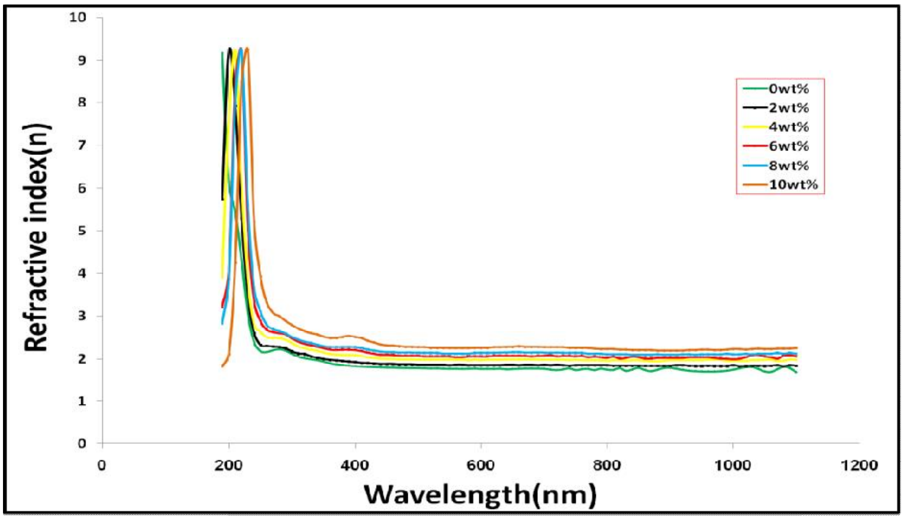

Figure 5. The refractive index for (PVA-Ni($CH_3COO)_2$) films with different concentrations of Ni($CH_3COO)_2$ salt as a function of the wavelength

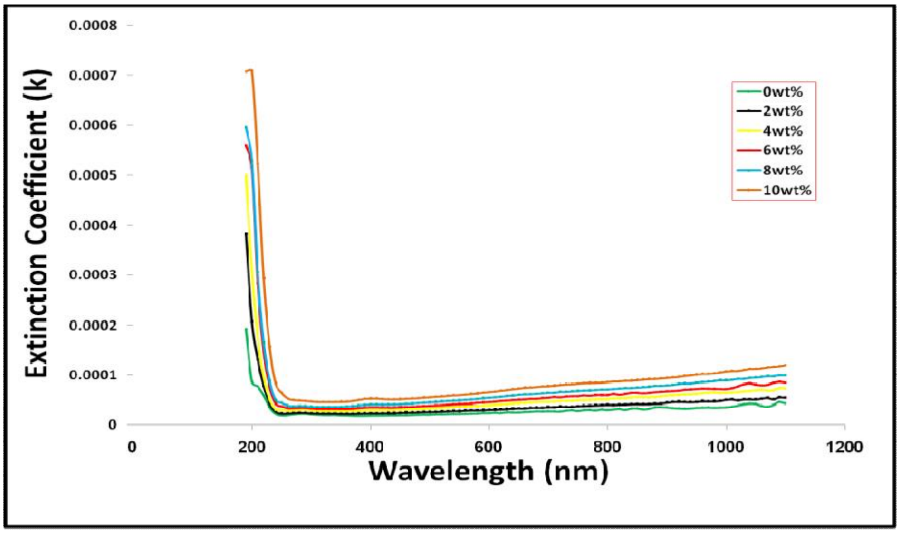

Figure 6. The extinction coefficient for (PVA-Ni($CH_3COO)_2$) films with different concentrations of Ni($CH_3COO)_2$ salt as a function of the wavelength

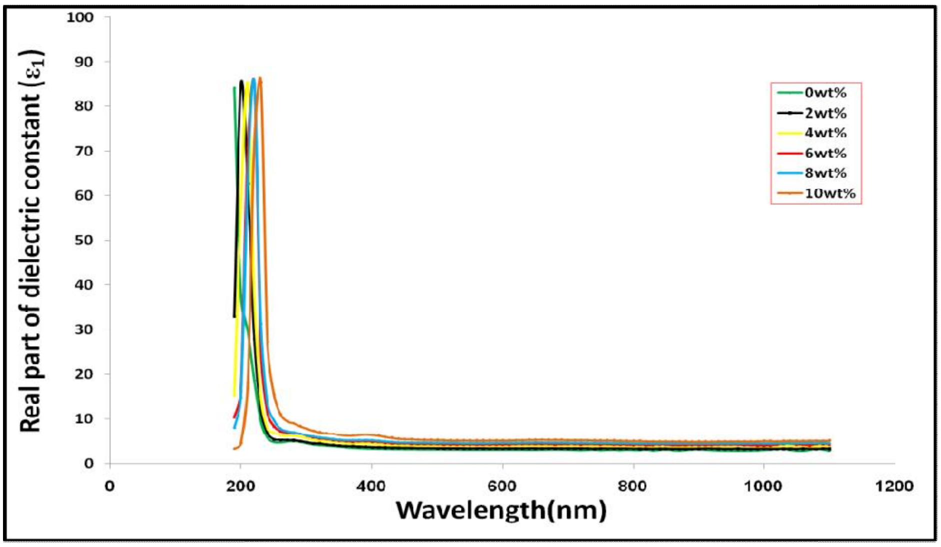

Figure 7. The real part of dielectric constant for (PVA-Ni($CH_3COO)_2$) films with different concentrations of Ni($CH_3COO)_2$ salt as a function of the wavelength

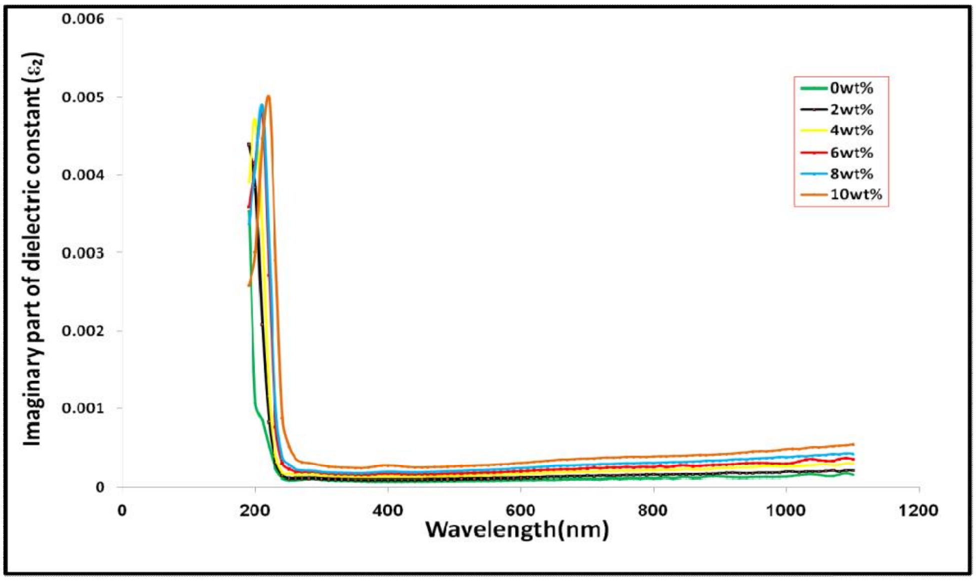

Figure 8. The imaginary part of dielectric constant for (PVA-Ni(CH_3COO)$_2$) films with different concentrations of Ni(CH_3COO)$_2$ salt as a function of the wavelength

It can be seen that the real and imaginary parts of dielectric constant increase with increasing the weight percentage of the added Ni(CH_3COO)$_2$ salt, and this behavior is similar to the behavior of refractive index and the extinction coefficient because (ε_1) depends on (n^2) due to low value of (k^2), while (ε_2) is dependent on (k) value that changes with the change of the absorption coefficient due to the relation between (α) and (k).

Conclusion

1. The absorbance and the absorption coefficient for (PVA-Ni(CH_3COO)$_2$) films increases with increasing of the filler content (wt%).
2. The absorption coefficient for (PVA-Ni(CH_3COO)$_2$) films is less than (10^4); this means that the electronic transition is indirect.
3. The energy gap of allowed indirect transition for (PVA-Ni(CH_3COO)$_2$) films decreases with increasing of filler content (wt%), while refractive index, extinction coefficient and real and imaginary parts of dielectric constant increase with increasing of filler content (wt%).

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