Effect of Adding Neodymium Oxide (NdO) on Optical Properties of (PVA-PVP) Composites

Khansaa Saleem Sharba*

The general directorate of education in Babil, Ministry of Education in Iraq

*Corresponding author: E-Mail: khanhun_sl@yahoo.com

ABSTRACT

In the present research, effect of Neodymium Oxide (NdO) addition on the optical properties of Poly (vinyl alcohol)-poly (vinyl pyrrolidone) (PVA-PVP) hydrogels composites have been investigated. The blend samples have been obtained by adding NdO to (PVA-PVP) with various weight percentages by solution casting method. The absorption spectra has been registered at the wavelength scope 200-1100 nm. The experimental results show that the (absorption coefficient, extinction coefficient, refractive index, real and imaginary dielectric constants) increased with an increasing of the concentration of NdO, and the energy gap of the indirect transition (allowed and forbidden) has been determined, and their values were declined with an increasing of concentration of NdO.

KEY WORDS: Composite, Neodymium Oxide, Optical Properties.

1. INTRODUCTION

A polymer mixture is a member of a category of materials that is similar to metal alloys, in which at least two polymers are mixed with each other to make a new material with various physical properties (Gert, 1996). Polymer composites have unique properties such as light weight, high flexibility, and ability to be fabricated at low temperature and cost (Asogwa, 2011). In early works Polymers have been used as insulators because of their high resistivity and dielectric properties and it are widely used in electrical and electronic applications (Alias, 2013). Polyvinyl alcohol has an exceptional film forming, emulsifying, adhesive properties beside opposition to oil, grease and solvent. PVA is odorless and nontoxic, also has high oxygen and aroma barrier properties (Sedlarik, 2007). The insert of (PVP) into (PVA) is expected to significantly decrease degradation and stabilize the polymer network and the mechanical properties of pure PVA hydrogels through hydrogen bonding interactions between the carbonyl group on PVP and the hydroxyl group along PVA chain (Abd El-Mohdy, 2009). In this work, we spot light on the optical properties of (PVA-PVP) with various condensation of NdO to use the final product in some technical applications.

2. EXPERIMENTAL WORK

The materials used in this research are (PVA) and (PVP) as a matrix and Neodymium Oxide (NdO) powder as filler. The PVA (80 wt.%) and PVP (20wt.%) were dissolved in distilled water by using magnetic stirrer for the blending process of 60 minutes to get more homogeneous solution with temperature (65°C). The neodymium oxide was add to the polymer matrix by various weight percentages (2, 4 and 6 wt.%) and wait for 10 minutes to obtain mixture more homogenous. The casting technique had been used to prepare the films from this mixture and casting each one of these percentages in the template (Petri dish) and then left for (6 days) to dry mixture at room temperature. The optical properties of PVA-PVP-NdO composites can be measured by using UV/1800/Shimadzu spectrophotometer in the wavelength range (200-1100) nm.

3. RESULTS AND DISCUSSION

The absorbance (A): Absorbance is defined as the ratio between absorbed light intensity (I_A) by material and the incident intensity of light (I_o) (Mott, 1979):

$$A = \frac{I_A}{I_o} \quad (1)$$

The optical properties are computed by recorded the absorbance spectra of (PVA-PVP-NdO) composites with wavelength range (200-1100) nm was registered at room temperature. The absorption at any wavelength depends on the number of particles along the way of the incident light (concentration) and the length of the optical path passing through the form as well as the temperature (Omed, 2015). Figure.1, illustrates the relationship between optical absorbance with wavelength of (PVA-PVP-NdO) composites. The absorbance of composites are decreased with the increasing of wavelength and increases with the increase of weight percentages of NdO, this is according to the absorbed light by free electrons (Mwolfe, 2011).

Figure.1. The absorbance versus wavelength for (PVA-PVP-NdO) composites

The absorption coefficient and energy gap: Absorption coefficient can be defined as a ratio decrement in flux of incident rays energy relative to the distance unit in the trend of incident wave diffusion and its computed by using the (Abutu, 2015):

$$\alpha = 2.303A/t \quad (2)$$

Where, (A) absorbance and (t) is thickness.

Figure.2, illustrates the link between the absorption coefficients versus the wavelength for PVA-PVP-NdO composites. The absorption coefficient increased with the increasing of the NdO contain. The values of α are small at low energies because the probability of electrons transition are small, energy of the incident photon is not enough to move the electrons from the valence to the conduction band, whereas at high energies, the values of α are great, which lead to that probability of electrons transition are great because the energies of the incident photons are enough to move the electrons from the valence to the conduction band (Kramadhathi, 2013). The absorption coefficient increased with the increasing of NdO contain in the PVA-PVP-NdO composites.

Figure.2. The absorption coefficient versus photon energy for (PVA-PVP-NdO) composites

The absorption coefficient help to know the nature of electron transition. If the values of the absorption coefficient are high ($\alpha > 10^4 \text{ cm}^{-1}$) lead to that transition of electrons are direct, and when the values of absorption coefficient are low ($\alpha < 10^4 \text{ cm}^{-1}$) lead to transition of electrons are indirect (Kasap, 2002). The obtained results showed that the absorption coefficient are lower than 10^4 cm^{-1} , which mean PVA-PVP-NdO composites have indirect energy gap.

The optical energy gap (allowed and forbidden) can be computed by using this formula (Mishjil, 2016):

$$\alpha h\nu = B(h\nu - E_g)^r \quad (3)$$

Where, (E_g) is optical Energy gap, ($h\nu$) is the photon energy, (B) is a constant depending on the transition probability, and (r) is a number that characterizes the optical absorption process, and can take the values; $r = 1/2$ for the allowed direct transition, $r = 1/3$ for the forbidden direct transition, whereas $r = 2$ for allowed indirect transition, $r = 3$ for the forbidden indirect transition.

The usual method to calculate the energy band gap for indirect allowed and indirect forbidden transition is by drawing upright line from the upper part of the curve toward the x-axis at the value $(\alpha h\nu)^{1/2} = 0$. It can be seen that the values of allowed and forbidden indirect transition band optical energy gap declines with increasing the concentration of NdO due to creation of new levels in the band gap, which lead to smooth the transition of electrons from the valence band to these local levels to the conduction band, thus the band gap declines (Sabah, 2016; Khalid, 2016), as shown in figures.3 and 4.

Figure.3. The plot of $(\alpha h\nu)^{1/2}$ with photon energy for (PVA-PVP-NdO) composites

The values of optical energy gap for indirect transition (allowed, forbidden) for the prepared films are shown in Table.1.

Table.1. The values of optical energy gap for the allowed and forbidden indirect transition for (PVA-PVP-NdO) composites

Neodymium oxide (wt. %)	Optical energy gap for indirect transition	
	Allowed	Forbidden
0	4.9	4.82
2	4.8	4.70
4	4.5	4.40
6	3.7	3.80

Transmittance (T): The transmittance (T) is computed by using formula 4 (Streetman, 2000). Figure.5, illustrates the transmittance spectra (T) with incident wavelength for (PVA-PVP-NdO) composites.

$$T = 10^{-A} \quad (4)$$

Where, (T) is transmittance and (A) is absorption. From this figure we can see that the transmittance declines with increasing of NdO concentration in the PVA-PVP-NdO composites.

Figure.5. The transmittance versus wavelength for (PVA-PVP-NdO) composites

Extinction coefficient (k_o): The extinction coefficient (k_o) is directly proportional to the absorption coefficient (α) and its computed by using formula 5 (Frohlich, 1958):

$$k_o = \frac{\alpha \lambda}{4\pi} \quad (5)$$

Where, λ is wavelength of incident photon rays. Figure.6, illustrates the diversity of extinction coefficient with photon energy for (PVA-PVP-NdO) composites. From the figure, It can be noticed that k_o is increase with the increasing of NdO concentration which related to the increase of absorb part of the incident light.

Figure.6. The Extinction coefficient versus wavelength for (PVA-PVP-NdO) composites

Refractive index (n): The refractive index (n) can be computed of (PVA-PVP-NdO) composites from the formula (Zaky, 1970):

$$n = (1 + R^{1/2}) / (1 - R^{1/2}) \quad (6)$$

Where (R) is the reflectance.

The figure.7, illustrates the link between refractive index and photon energy of the (PVA-PVP-NdO) composites with various content of NdO. From this figure, it can be noticed that the refractive index is increase with the increasing of the NdO content according to the increase of packing density as a result of neodymium oxide content (Adnan, 2010).

Figure.7. The refractive index versus wavelength for (PVA-PVP-NdO) composites

The real and imaginary dielectric constants (ϵ_1 , ϵ_2): The real dielectric constant (ϵ_1) and imaginary dielectric constant (ϵ_2) are determined by using the formulas (Khalid, 2015):

$$\epsilon_1 = n^2 - k^2 \quad (7),$$

$$\epsilon_2 = 2nk \quad (8)$$

Figures.7 and 8, illustrates the variation of real and imaginary parts of dielectric constant with wavelength for PVA-PVP-NdO composites. It can be seen that ϵ_1 and ϵ_2 increased with the increasing of NdO content which attributed to increase the absorption of incident light of (PVA-PVP-NdO) composites.

Figure.8. The real part of dielectric constant versus wavelength for (PVA-PVP-NdO) composites

Figure.9. The imaginary part of dielectric constant versus wavelength for (PVA-PVP-NdO) composites

4. CONCLUSIONS

The absorbance and the absorption coefficient of (PVA-PVP-NdO) composite films increases trend as the increasing of neodymium oxide content as well as the absorption coefficient is less than (10^4 cm^{-1}), this indicates to forbidden and allowed indirect electronic transitions, while the transmittance decreased.

The energy band gap of (PVA-PVP-NdO) composite films declines trend as the increasing of neodymium oxide content, while refractive index, extinction coefficient and real and imaginary parts of dielectric constant values are increased as a result of increasing of neodymium oxide content.

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