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## Enhancement of Optical Parameters for PVA/PEG/Cr<sub>2</sub>O<sub>3</sub> Nanocomposites for Photonics Fields

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### ABSTRACT

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#### Keywords:

Cr<sub>2</sub>O<sub>3</sub>, nanocomposites, optical properties, blend, nanoparticles

In this study, many samples have been synthesized by using solution casting technique with different additive content of Chromium oxide nanoparticle (Cr<sub>2</sub>O<sub>3</sub>NPs), poly vinylalcohol (PVA) and polyethylene glycol (PEG). The UV-Vis. spectrophotometer used to record the absorbance spectrum in the range of (200-800) nm. The absorption of UV waves is improved while the transmittance is reduced when Cr<sub>2</sub>O<sub>3</sub> NPs were added to the polymeric system which are useful for a number of applications including low-cost UV protection and solar radiation shield. When Cr<sub>2</sub>O<sub>3</sub> NPs concentrations increased, the optical energy gap for indirect transition (allowed and forbidden) was decreased. Furthermore, all the optical constant has been improved.

## 1. INTRODUCTION

Polymer nanocomposites have recently gained popularity due to the unique properties that these materials can achieve. Metal [1-3] and semiconductor [4-6] nanoparticles exhibit extraordinary optical and electrical properties, and polymers are regarded to be a good host material for these nanoparticles. Similarly, Because of their high surface-to-bulk ratio, nanoparticles have a considerable impact on the matrix, producing in some exceptional properties that aren't available formed at one of the pure materials. More research into theto better predict the composite's final properties therefore, the impact of nanoparticles on the properties of a polymer matrix is required [7-9]. Lately, composites of polymer/ceramic filler obtain raised consideration related their attractive electronic and electrical characters, angular acceleration accelerometers, integrated decoupling capacitors, electronic packaging and acoustic emission sensors are several potential fields [10]. PVA is a semi crystalline polymer, offers a wide range of uses owing to the role of the OH collection and hydrogen bonding [11]. Because of its compatibility with the living body, it can also be used as a medical substance [12]. In addition, PVA can selectively absorb metallic ions like as copper, palladium, and mercury. PVA is made up of the chemical formulation (C<sub>2</sub>H<sub>4</sub>O)<sub>x</sub>, which has a density of (1.19-1.31)g/cm<sup>3</sup> and a melting temperature of 230°C. Over 200°C, it degrades rapidly [13]. is a form of thermoplastic polymer with a flexibility of C–O–C bonding. It also possesses solubility in organic solvents, hydrophilicity, crystallinity  $\gamma$ , and self-lubricating properties. As a result, PEG is one of the most widely used polymers for the creation and growth of a wide range of vital applications [14]. There are several studies on PEG and PVA nanocomposites for various applications like energy storage [15-17], antibacterial [18] and humidity sensors [19-21]. This

paper aims to prepare the PVA-PEG-Cr<sub>2</sub>O<sub>3</sub> nanocomposites and investigating its optical properties.

## 2. EXPERIMENTAL WORK

Nanocomposites films of polyvinyl alcohol (PVA)/ polyethylene glycol (PEG) with different contents of chromium oxide (Cr<sub>2</sub>O<sub>3</sub>) nanoparticles were prepared by casting process. The PVA/PEG blend was prepared with ratio(70%PVA/30%PEG) by dissolving of 1 gm in distilled water (30 ml). The Cr<sub>2</sub>O<sub>3</sub> NPs were added to the (PVA/PEG) blend with ratios 1%, 2%, and 3%. The optical characteristics of PVA/PEG/Cr<sub>2</sub>O<sub>3</sub> nanocomposites were tested using spectrophotometer (UV-1800<sup>0</sup>A-Shimadzu).

## 3. RESULT AND DISCUSSION

Figure 1 displays the influence of Cr<sub>2</sub>O<sub>3</sub> NPs on the absorbance of PVA-PEG blend with wavelength range (200-800) nm. Because free electrons absorb incident light, the absorbance of nanocomposite increases as the concentration increases [22]. This result is agreement with previous studied [23, 24]. The high absorbance of nanocomposites at UV region due to the photon energy enough to interact with atoms lead to the high absorbance [25].

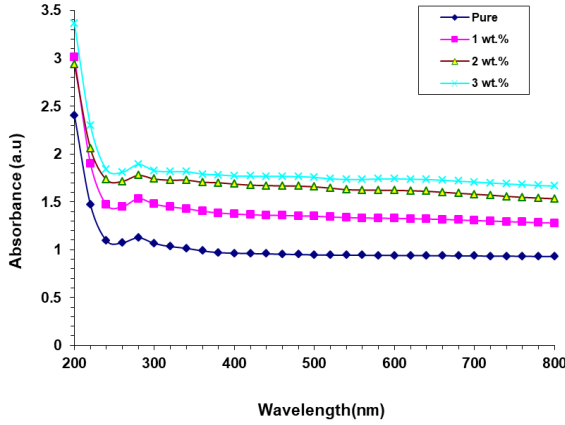
The optical transmittance of PVA-PEG-Cr<sub>2</sub>O<sub>3</sub> nanocomposites is shown in Figure 2. The transmittance decreases when the Cr<sub>2</sub>O<sub>3</sub> concentration in the PVA-PEG nanocomposite increasing from 1% to 3%, as shown in this figure.

The absorption coefficient ( $\alpha$ )calculated by the equation [26]:

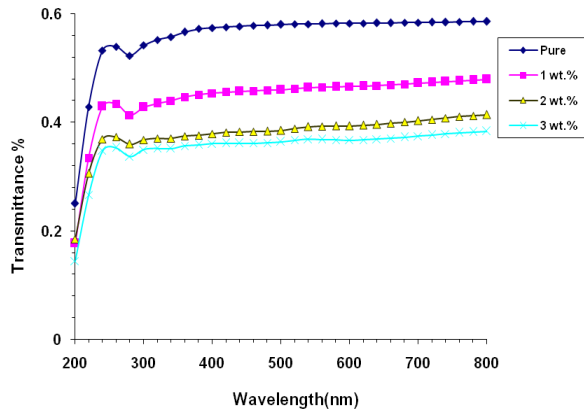
$$\alpha = 2.303 \frac{A}{t} \quad (1)$$

where, (A) is the absorbance and (t) is the specimen thickness.

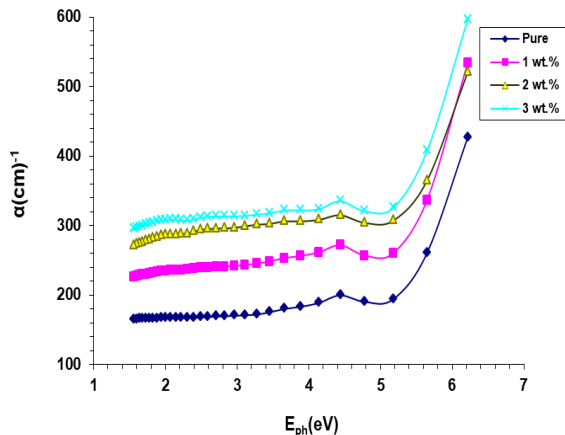
The absorption coefficient versus photon energy are shown in Figure 3. When the increasing of the Cr<sub>2</sub>O<sub>3</sub>NPs concentration, the  $\alpha$  increase. The increase of  $\alpha$  is due to an increase in light absorption [27]. The nanocomposites are said to have an indirect energy gap if the value of  $\alpha$  is less than 10<sup>4</sup> cm<sup>-1</sup>. The polymer blend had low  $\alpha$  this may be as a result of low crystallinity [28, 29].



**Figure 1.** Influence of Cr<sub>2</sub>O<sub>3</sub> NPs on the absorbance of PVA-PEG blend



**Figure 2.** Optical transmittance of PVA-PEG-Cr<sub>2</sub>O<sub>3</sub> nanocomposites



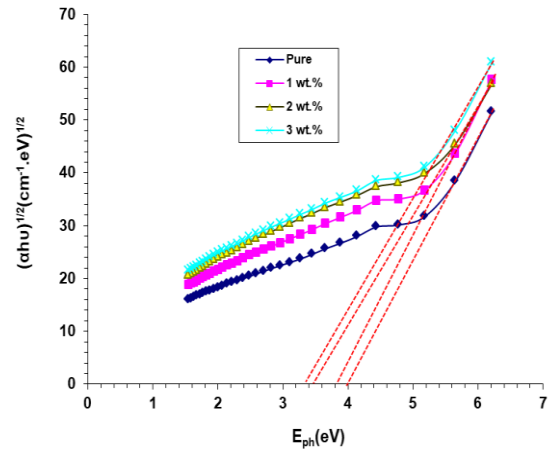
**Figure 3.** Absorption coefficient of PVA-PEG-Cr<sub>2</sub>O<sub>3</sub> nanocomposites versus photon energy

The energy gap is calculated using the Tauc relation [24]:

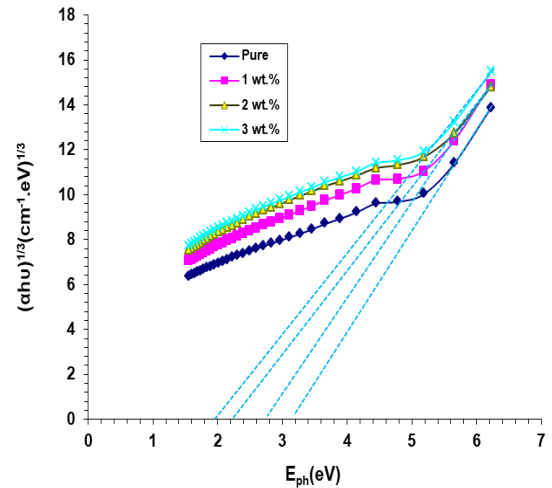
$$\alpha hv = B(hv - E_g)^r \quad (2)$$

where, E<sub>g</sub> denotes the optical energy gap, r=2 or 3 denotes the allowed or forbidden indirect transition, hv denotes electromagnetic energy, and B is a constant.

By graphing  $(\alpha hv)^{1/2}$  and  $(\alpha hv)^{1/3}$  versus hv in Figures 4, 5, the band gap was calculated. The allowed energy gap decreased from 4eV for the pure PVA-PEG to 3.4 eV for the PVA-PEG- 3% Cr<sub>2</sub>O<sub>3</sub>nanocomposite and 3.2eV for the pure PVA-PEG to 2 eV for the PVA-PEG-3% Cr<sub>2</sub>O<sub>3</sub> nanocomposite for the forbidden energy gap. The energy gap reduces with rise in the Cr<sub>2</sub>O<sub>3</sub> NPs content which is due to the create of localized levels in the band gap [30, 31]. The value of energy gap are shown in Table 1.



**Figure 4.**  $(\alpha hv)^{1/2}$  versus hv of PVA-PEG-Cr<sub>2</sub>O<sub>3</sub> nanocomposites



**Figure 5.**  $(\alpha hv)^{1/3}$  versus hv of PVA-PEG-Cr<sub>2</sub>O<sub>3</sub> nanocomposites

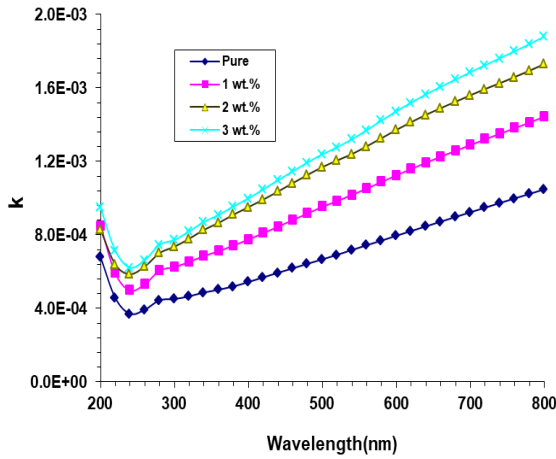
**Table 1.** Energy gap values of PVA-PEG-Cr<sub>2</sub>O<sub>3</sub> nanocomposites

Cr <sub>2</sub> O <sub>3</sub> NPs wt. %	E <sub>g</sub> (eV)	
	allowed	forbidden
0	4	3.2
1	3.85	2.8
2	3.5	2.23
3	3.4	2

Using the following relation to determine the extinction coefficient (K) [32]:

$$K = \alpha\lambda / 4\pi \quad (3)$$

The extinction coefficient for (PVA-PEG-Cr<sub>2</sub>O<sub>3</sub>) nanocomposites is revealed in Figure 6 as a function of wavelength. It is worth noting that K increases as the concentration of Cr<sub>2</sub>O<sub>3</sub>NPs increases. This reason attribute to the enhancement of the absorption coefficient when the additive of Cr<sub>2</sub>O<sub>3</sub>NPs. This result agreement with the previous studied [33].

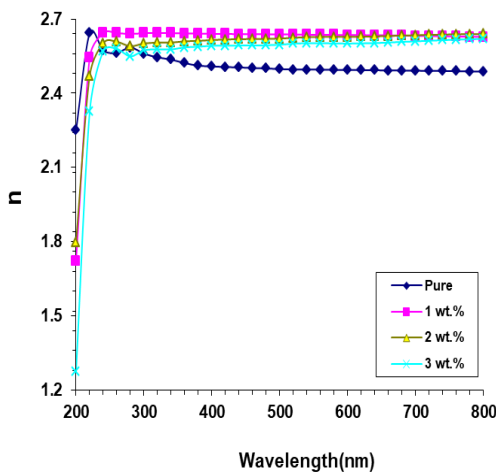


**Figure 6.** Extinction coefficient for (PVA-PEG-Cr<sub>2</sub>O<sub>3</sub>) nanocomposites

The refractive index (n) of (PVA-PEG-Cr<sub>2</sub>O<sub>3</sub>) nanocomposites was calculated by [34]:

$$n = (1 + R^{1/2}) / (1 - R^{1/2}) \quad (4)$$

The refraction index of (PVA-PEG-Cr<sub>2</sub>O<sub>3</sub>) nanocomposites versus of wavelength as shown in Figure 7. As revealed in the numeral, the refractive index tends to increase as the increase of Cr<sub>2</sub>O<sub>3</sub>NPs concentration in the PVA-PEG film. The reason for this is that as the increase of Cr<sub>2</sub>O<sub>3</sub> concentration, the density of the nanocomposites increases as well [35, 36].



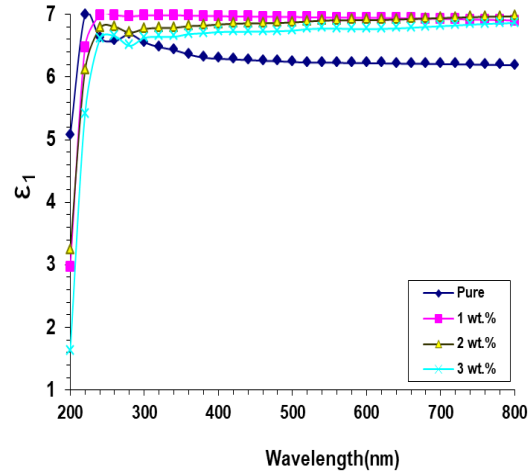
**Figure 7.** Refraction index of (PVA-PEG-Cr<sub>2</sub>O<sub>3</sub>) nanocomposites versus wavelength

The following equations were used to calculate the real and imaginary ( $\epsilon_1$  and  $\epsilon_2$ ) portions of dielectric constant [37]:

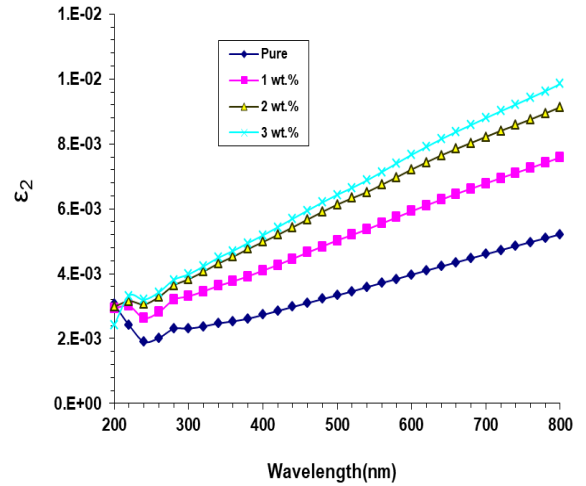
$$\epsilon_1 = n^2 - k^2 \quad (5)$$

$$\epsilon_2 = 2nk \quad (6)$$

The variation of ( $\epsilon_1$ ) versus of wavelength is indicated in Figure 8. Because of the low value of  $K^2$ , the real dielectric constant increases as the concentration of Cr<sub>2</sub>O<sub>3</sub> nanoparticles increases. The change in  $\epsilon_2$  versus of wavelength is shown in Figure 9. Due to the relationship between  $\alpha$  and K, it should be said that  $\epsilon_2$  is dependent on K values that vary with the absorption coefficient. This result is agreement with the previous studied [38].



**Figure 8.** Variation of ( $\epsilon_1$ ) versus wavelength

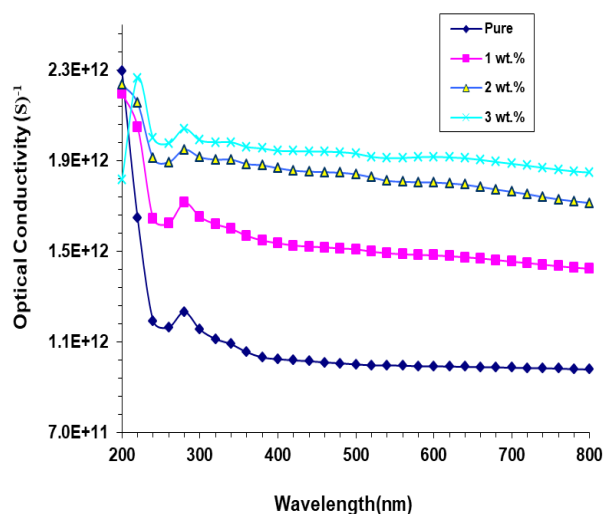


**Figure 9.** Variation of ( $\epsilon_2$ ) versus wavelength

Optical conductivity ( $\sigma$ ) was determined using the equation [39]:

$$\sigma = \alpha nc / 4\pi \quad (7)$$

In which c denotes the light speed, n the refractive index, and is the absorption coefficient. Figure 10 shows the optical conductivity of PVA-PEG-Cr<sub>2</sub>O<sub>3</sub> nanocomposites versus of wavelength. ( $\sigma$ ) of the PVA-PEG-Cr<sub>2</sub>O<sub>3</sub> nanocomposite increases as the Cr<sub>2</sub>O<sub>3</sub> content increases.



**Figure 10.** Optical conductivity of PVA-PEG-Cr<sub>2</sub>O<sub>3</sub> nanocomposites versus wavelength

#### 4. CONCLUSION

This paper includes the preparation of (PVA-PEG-Cr<sub>2</sub>O<sub>3</sub>) nanocomposites and studying its optical properties. The obtained results indicated that improvement in the optical properties of the (PVA-PEG-Cr<sub>2</sub>O<sub>3</sub>) nanocomposite when adding different percentages of Cr<sub>2</sub>O<sub>3</sub>NPs. Therefore, the nanocomposite (PVA-PEG-Cr<sub>2</sub>O<sub>3</sub>) can be used in different application such as photodetector and low-cost UV protection.

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