Preparation of (PVA/Y_2O_3) Nanocomposite and Study the Optical Properties for Optoelectronic Device

Ali Jabbar Louis
Physical department, College of Education for Pure Science, Babylon university, 51001, Hilla, Iraq, ali.gabbaer.pure306@student.uobabylon.edu.iq

Ali Razzaq Abdulridha
Physical department, College of Education for Pure Science, Babylon university, 51001, Hilla, Iraq.

Abstract

The casting method was used to investigated the (PVA) polymer and its doped with variant of weight percent of Y_2O_3 NPs. The morphological and optical properties was examined. The optical microscope (OM) denotes a good distribution of Y_2O_3 NPs, as well as charge transfer and form a network of paths within the polymeric matrix. The absorbance of (PVA/Y_2O_3) nanocomposite increases as the concentrations of (Y_2O_3) nanoparticles increase, whereas the transmittance and energy gap of (PVA/Y_2O_3) nanocomposite reduce with rise concentrations of (Y_2O_3) nanoparticles. The coefficient of absorption, coefficient of extinction, index of refractive, real and imaginary parts of dielectric constants and conductivity of optical are rising with the rise of the weight percentages of Y_2O_3 nanoparticles. the result indicate that this nanocomposite can be used for optoelectronic device.

Keywords: *PVA, Y_2O_3, optical properties, nanocomposite, optoelectronic.*

1- Introduction

Due to their numerous uses in fields like optoelectronics, biotechnology, and photonics, polymers have become more and more alluring [1]. There are a number of reasons why the characteristics can be improved by adding the right dopant, but one of the most crucial ones is decent interaction between the nanoparticles and the matrix with good particle dispersal inside the matrix [2]. Polymer nanocomposites (PNCs) have emerged as a significant research field in recent years. They participate in a variation of present industry and industrial requests. Due to they are inexpensive, have a reduced density, are flexible, light, easy to manufacture, have a fast industrial processing speed, and have superior electrical qualities [3]. In addition, if PNCs possess good optical transparency, a in height index of refractive and gap of band reasonableness, they might be applied to optoelectronic devices. prepared by solution casting in PNCs [4].

Because of the high regard that polyvinyl alcohol (PVA) has received for both its chemical and physical characteristics over time, research interest in this area has grown [5]. Because of its semi-crystalline structure and many properties, including adsorption, biocompatibility, and high-water solubility, PVA is frequently utilized in medical devices. Moreover, it is a non-toxic and inexpensive polymer utilized in controlled drug delivery systems, tissue engineering scaffolding, and wound dressing [6]. Due to the function of the OH group and hydrogen bonding, PVA has several crucial uses. Additionally, due to its compatibility with the living organism, it can be employed as a medical material [7]. Furthermore, PVA has the ability to selectively adsorb metal ions like mercury, palladium, and copper. PVA has a melting point of 230°C, a density of between 1.19 and 1.31 g/cm3, and a molecular formula of $(C_2H_4O)_n$. It breaks down quickly at 200°C [8]. Due to its superior material qualities and appropriateness as a waveguide and a laser host, yttrium oxide (Y_2O_3) has attracted a lot of attention lately. Its material characteristics include a high index of refractive (1.7-1.9), a wide transparency range, a big gap of band, exceptional conductivity of thermal and a low dominating phonon energy.

The aims of study, preparation of the (PVA-Y_2O_3) nanocomposite and investigation the optical properties for optoelectronic device.

2- Materials and method

The solution casting method to prepare the (PVA-Y_2O_3) nanocomposites in different Y_2O_3 NPs . PVA pure film was created by dissolving 1 gm of this polymer in 50 ml of distilled water at room temperature with magnetic stirrer for half an hour. The nanocomposites films were created by adding Y_2O_3 NPs to a PVA solution with concentrations of (1.5, 3, 4.5 and 6) % wt. The optical microscope (OM) provided by Olympus (Top View, type Nikon-73346). The optical characteristics of PVA/Y_2O_3nanocompsite were tested using spectrophotometer (UV-18000A-Shimadzu).

The coefficient of absorption (α) is calculated by [10]

$$\alpha = 2.303\frac{A}{d} \qquad (1)$$

where: absorbance is A and thickness is d.

The gap of energy given by[11]

$$(\alpha h\upsilon)^{1/m} = C(h\upsilon - E_g) \qquad (2)$$

Where: constant is C, the photon energy is hυ, Eg is the gap of energy, m = 2 and 3 to indirect transitions of permitted and prohibited. The extinction coefficient (k) is determined by[12]

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

where: wavelength is

The index of refractive (n) is defined by[13]

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

where: reflectance is R

The real (ε_1) and imaginary (ε_2) of dielectric constant parts are given by[14]

$$\varepsilon_1 = n^2 - k^2 \qquad (5)$$

$$\varepsilon_2 = 2nk \qquad (6)$$

The optical conductivity (σ_{op}) is defined by[15]

$$\sigma_{opt.} = \frac{\alpha n C}{4\pi} \qquad (7)$$

where C: is light velocity

3- Result and discussion

Fig. (1) demonstrate the photomicrographs of the surface of (PVA) polymer and the nanocomposites with different ratios of Y_2O_3 NPs at magnification power (10x). The surface image of polymer film demonstrations a regular phase without phase separation. According to the images in Fig.(1,B-E), it is possible to observe that the NPs are aggregates as a cluster at lower concentration, hence the charge carriers are permitted to permit through the routes. As the concentration of Y_2O_3 NPs is increased, its form a network of paths within the polymeric matrix.

Figure (1): Photomicrographs (x10) for PVA/Y2O3 nanocomposites A. PVA, B. 1.5 wt.% Y2O3, C. 3wt.% Y2O3, D. 4.5wt.% Y2O3 and E. 6wt.% Y2O3

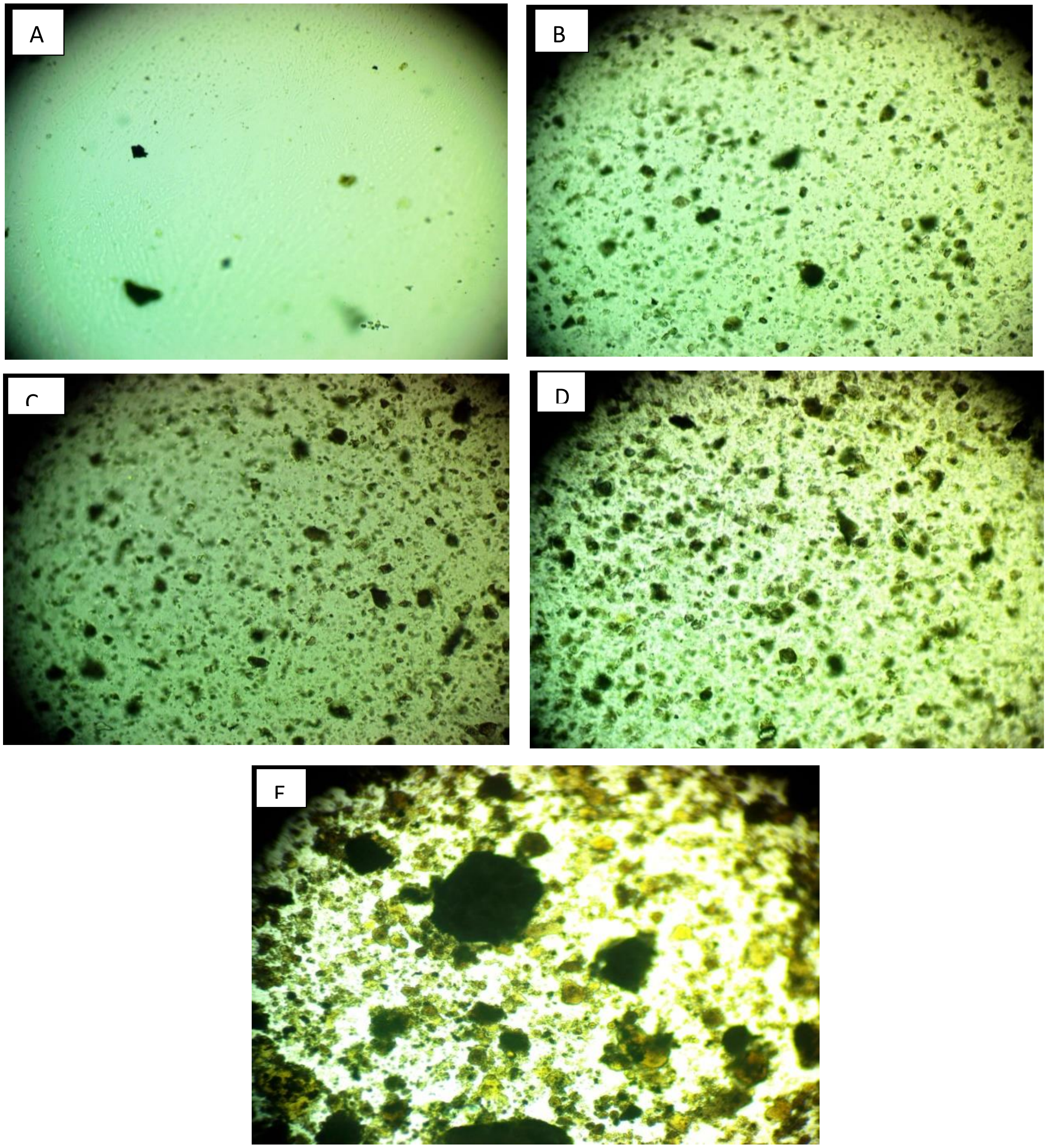


Figure (2) illustrates the disparity of absorbance for (PVA-Y_2O_3) nanocomposites with wavelength. It can be noted that the absorption of (PVA-Y_2O_3) nanocomposites rising with rise content of Y_2O_3 NPs, which, at high energies, results from donor levels electron excitations to the conduction band. Moreover, the electron excites from a lower to a higher energy level by absorbing a known energy photon, which is related to photon energy sufficient to react with atoms therefore, the transmittance reduced as proved in figure (3). This action is matched with research findings. [16-19].

Fig (2): Optical absorbance performance of PVA-Y2O3 nanostructures films with photon wavelength

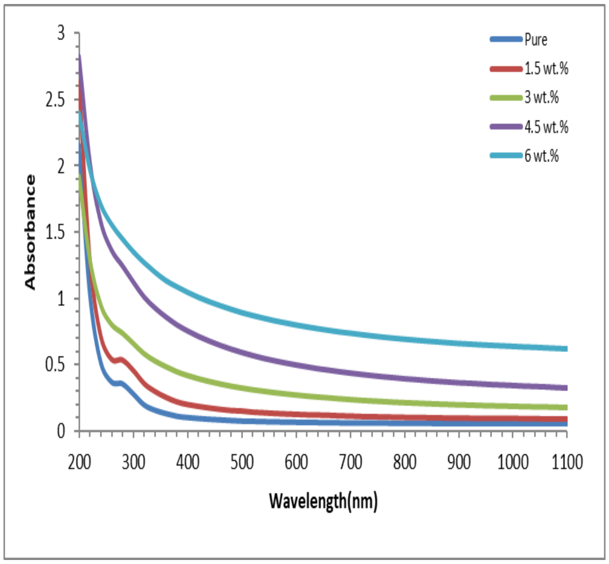
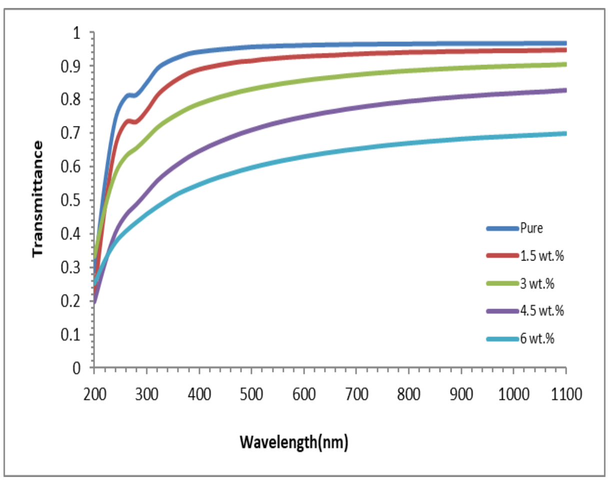


Fig (3). Behaviour of Optical transmittance for PVA-Y2O3 nanostructures films with photon wavelength



The coefficient of absorption (α) is a sensitive physical method to provides us with useful information about the types of electron transition, depending on the incident light's energy. Equation (1) was used to determine the (α). Figure (4) explain the coefficient of absorption of (PVA-Y_2O_3) nanocomposite versus photon energy of the incident light. It is assumed that direct electron transitions occur when the α is large ($>10^4$) cm^{-1}. When the α is low (10^4 cm^{-1}), an indirect transition of electrons is assumed. The values coefficient of absorption of (PVA-Y_2O_3) nanocomposite, the transition of electron is indirect. The coefficient of absorption of nanocomposites rises with the rises of the content of Y_2O_3 NPs, this is due to the rise of amount of charge carriers and therefore rising the absorbance and absorption coefficient for (PVA-Y_2O_3) nanocomposites [20].

Fig (4): Absorption coefficient behavior of PVA-Y2O3 nanostructures with photon energy

Equation (2) is used to determine the (PVA-Y_2O_3) nanocomposites' energy band gap. Figure (5) displays the energy gaps for the permitted indirect transitions of (PVA- Y_2O_3) nanocomposites. Figure (6) displays the energy gaps for prohibited indirect transitions of (PVA- Y_2O_3) nanocomposites. Because to the generation of stages in the gap of energy, the E_g for permitted and prohibited indirect transitions of (PVA- Y_2O_3) nanocomposites are reduced as the concentration of (Y_2O_3) nanoparticles increases. These findings concur with earlier research [21-23]. The Table (1) displays the energy gaps for permitted and prohibited indirect transformations.

Fig (5): Energy gap values of allowed indirect transition of PVA-Y2O3 nanostructures

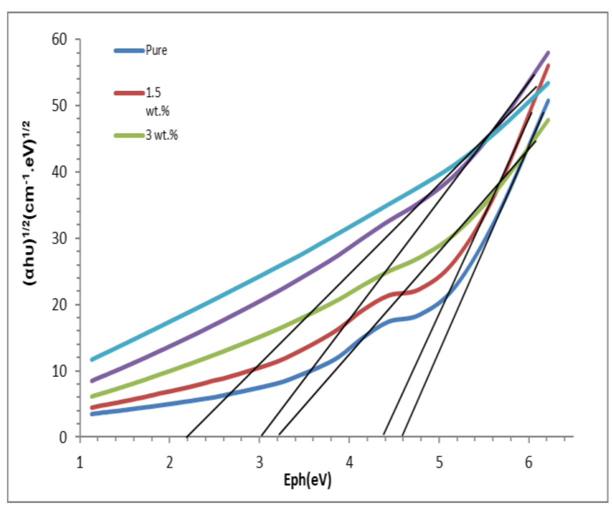


Fig (6): Energy gap values of forbidden indirect transition of PVA-Y2O3 nanostructures

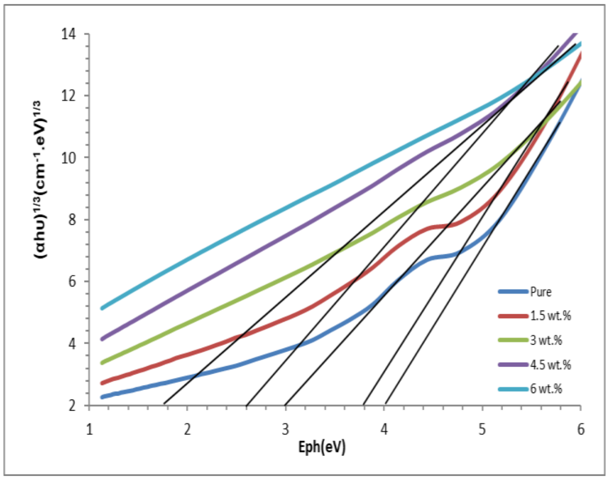
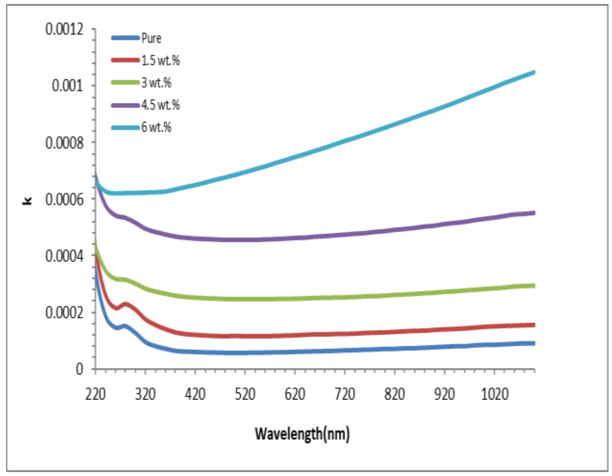


Table (1) The values of the energies gaps for allowed and forbidden indirect transformations of (PVA-Y2O3) nanocomposites

Concentration percentage wt.% of Y_2O_3	Allowable energy gap (eV)	forbidden energy gap (eV)
0	4.6	4
1.5	4.4	3.8
3	3.2	3
4.5	3	2.6
6	2.2	0.8

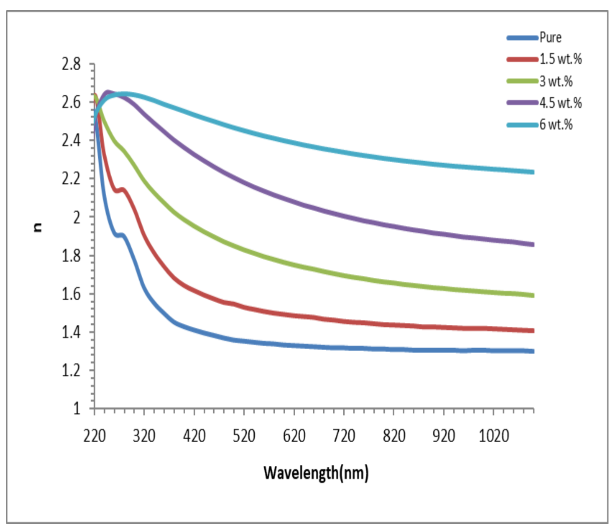
The extinction coefficient (k) of ($PVA\text{-}Y_2O_3$) nanocomposite is determined via the equation (3). Figure (7) illustrates the difference of the coefficient of extinction with the wavelength. The figure demonstrate that the coefficient of extinction rises as the content of (Y_2O_3) NPs rises, which is caused by a rise in optical absorption and photon dispersal in the polymer matrix. These findings are consistent with the findings of the researches [24].

Fig (7): Extinction coefficient variation of PVA-Y2O3 nanostructures with photon wavelength



The index of refractive (n) of ($PVA\text{-}Y_2O_3$) nanocomposite is planned by using equation (5). Figure (8) demonstrate the change of the refractive index with wavelength. As revealed in figure the index of refractive of ($PVA\text{-}Y_2O_3$) nanocomposites rises with increasing concentrations of Y_2O_3 NPs, also it is reduced with the increases of the wavelength, due to the rise in the density of nanocomposites [24].

Fig (8): Refractive index variation of PVA-Y2O3 nanostructures with photon wavelength



By using the equations (5,6) to calculated the real and imaginary parts of dielectric constant.

The real (ε_1) and imaginary (ε_2) parts of dielectric for ($PVA-Y_2O_3$) nanocomposites with wavelength are explain in Figs. (9,10). From this figures, the real and imaginary parts of dielectric constant of nanocomposite are rise with the rises of Y_2O_3 NPs content and reduce with rising wavelength, this result was brought about by an increase in electrical polarization that was a result of the sample's nanoparticle content. This is because the influence of extinction coefficient on the real components of the dielectric constant depends on refractive index while the imaginary components of the dielectric constant depend on extinction coefficient [25].

Fig (9): Behavior of real part of dielectric constant for PVA-Y2O3 nanostructures with photon wavelength

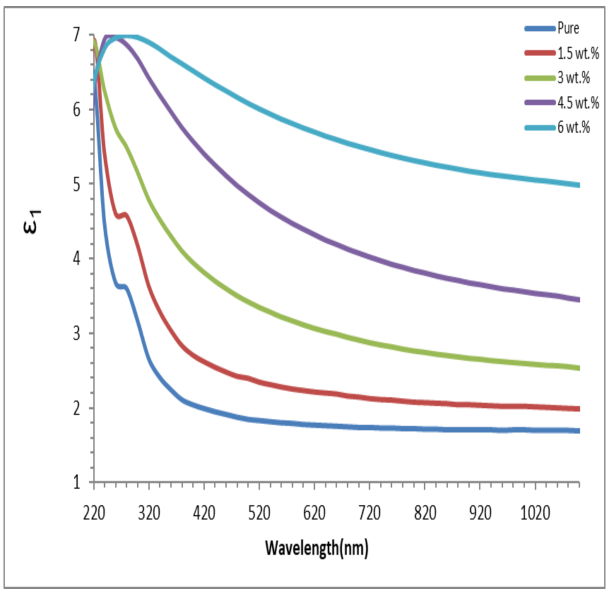
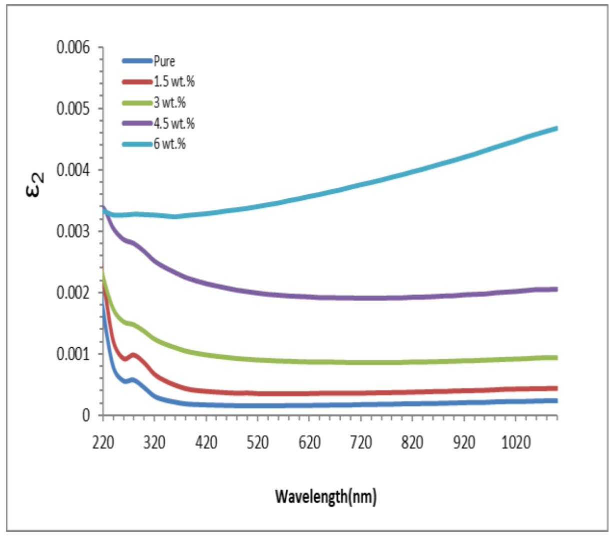
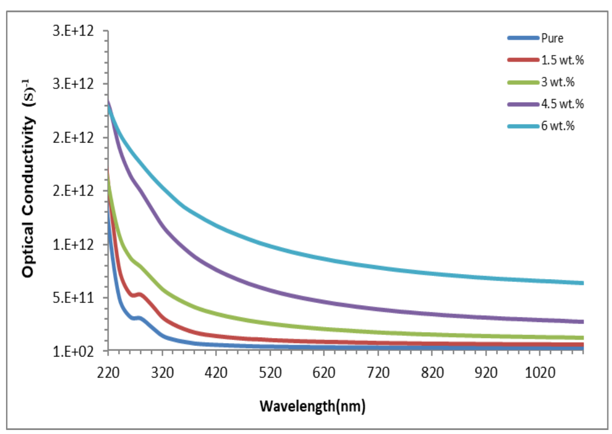


Fig (10): Behavior of imaginary part of dielectric constant for PVA-Y2O3 nanostructures with photon wavelength



The optical conductivity ($\sigma_{opt.}$) was calculated from the equation (7). The σ_{op} of ($PVA-Y_2O_3$) nanocomposites with a wavelength are explain in Fig. (11). From this figure, the optical conductivity rises with rises of content of Y_2O_3 NPs which is associated to the formation of local stages in the gap of energy, rising nanoparticle content induced a rise in the density of localized phases in the structure of band therefore, an rise in the coefficient of absorption suggests an rise in σ_{opt} of the nanocomposite [26].

Fig (11): Relationship between optical conductivity and wavelength of PVA-Y2O3 nanocomposites



4- Conclusion

This result can be summarized that good method for the prepared the (PVA/Y_2O_3) nanocomposites. The optical microscope (OM) denotes a good distribution of Y_2O_3 NPs, as well as charge transfer and form a network of paths within the polymeric matrix. The absorbance of (PVA-Y_2O_3) nanocomposite rises as the content of (Y_2O_3) NPs rise, while the transmittance and energy gap of (PVA-Y_2O_3) nanocomposite reduce with rise content of Y_2O_3 NPs. The coefficient of absorption, coefficient of extinction, index of refractive, real and imaginary parts of dielectric constants and optical conductivity are rising with the rise of the weight percentages of Y_2O_3 NPs. The result indicate that this nanocomposite can be used for optoelectronic device.

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