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# Influence of Silicon Carbide (Sic) on Optical Properties of Polyacrylamide (PAAm)

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## Abstract

In this work, nanocomposite films based on polyacrylamide (PAAm)and SiCwith differentcontentsare(2, 4 and 6) wt.% were prepared by solution casting technique. The prepared samples were characterized by UV–Vis analytical techniques. The absorbance increase as the additives of SiC NPs increases while transmittance and both allowed and forbidden energy gap decreased as the additives of SiC NPs increased. The coefficients of absorption and extinction, index of refractive, real and imaginary dielectric constants and optical conductivity increasedas the additives of SiC NPs increased.

Keywords: PAAm, SiC NPs, nanocomposite and optical properties.

## 1- Introduction

The blending of polymers with inorganic nanoparticles in nanocomposites has attracted considerable attention because to the expected outstanding thermal, optical, electrical, and antibacterial properties.The adoption of inorganic materials is motivated by their noteworthy properties, such as enhanced thermal stability, good electrical properties, and a high refractive index. Nevertheless, previous studies indicate that inorganic nanoparticles possess some drawbacks and are insufficient in meeting the diverse requirements of modern device applications [1]. Polymer nanocomposites effectively include a wide variety of fillers, so enhancing the functionalities and applicability of polymers, while also preserving the intrinsic flexibility in manufacturing and processing that is typically associated with plastics, thermosets, and resins. The application of polymer nanocomposites has demonstrated efficacy in resolving the inherent difficulties connected with the combination of properties that are conventionally deemed incompatible. The terminology "polymer nanocomposite" may be employed synonymously with "inorganic-organic hybrids" and "molecular composites." Additionally, this category encompasses widely recognized commercial items, such as polymers that integrate carbon black or fumed silica. The main focus of this study revolves around polymer nanocomposites that integrate nanoscale clays with various carbon nanotubes[2]. Polyacrylamide (PAAm) is a synthetic polymer that possesses favorable properties such as high adhesive strength, suitable moisture absorption capacity, substantial water affinity, and absence of toxicity. Polyacrylamide (PAAm) is a polymer consisting of a carbon chain that is covalently bonded to an amide functional group. Polyacrylamide (PAAm) molecules are characterized by the presence of amino (-NH2) and carbonyl (-C=O) functional groups [3]. The conformation of a polyacrylamide (PAAm) molecule is dependent on the pH of its surrounding environment. The polymer molecule demonstrates an extended structure when exposed to basic pH settings, but it assumes a coiled conformation when subjected to acidic pH conditions [4]. Silicon carbide (SiC) is categorized as a non-oxide chemical. The semiconductor ceramic material has a number of notable properties, including as high thermal conductivity, resistance to acid and melting reactions, extraordinary resistance to oxidation, and thermal stability. The material's remarkable shock resistance and high hardness make it very ideal for use in microwave dielectrics and power energy storage materials, both of which widely employ this material. However, the process of producing SiC nanoparticles is quite uncomplicated. The process of agglomeration exerts a notable influence on the physicochemical characteristics of composites, hence facilitating the achievement of desirable results. The research conducted by [5] demonstrated that the utilization of surface-modified nanoparticles resulted in improvements in the performance of composites. The primary aim of this study is to examine the influence of silicon carbide (SiC) on the optical properties of polyacrylamide (PAAm).

## 2- Preparation of (PAAm/SiC) nanocomposite

The polyacrylamide (PAAm) with a mass of 0.5 grams was initially dissolved in 50 milliliters of deionized water at room temperature for a duration of one hour. Subsequently, the dissolution process was continued for an additional hour under a temperature range of 75-80 degrees Celsius, employing a magnetic stirrer. The resultant solution was applied onto pristine glass surfaces and thereafter exposed to ambient air at room temperature for a duration of 240 hours to facilitate the drying process until complete evaporation of the solvent occurred. Polyacrylamide (PAAm) containing silicon carbide nanoparticles (SiC NPs) was prepared using a standardized technique to fabricate nanocomposite films with varying weight ratios of 2, 4, and 6 wt.%. The thickness of the films that were created measured around 0.11mm.The development of NCs was examined using a UV-visible spectrophotometer (Shimadzu UV-1650 PC, Phillips, a Japanese manufacturer) within the wavelength range of 300 to 1100 nm.

## 3- Result and discussion

The optical absorbance of PAAm/SiC nanocomposites within the wavelength range of 300-1100 nm is depicted in Figure 1. This figure demonstrates that the absorbance value exhibits a positive correlation with the SiC NPs content. This relationship indicates that an increased SiC NPs content results in a higher absorption of photons, enabling sufficient energy for atom interaction. Consequently, the absorbance value increases while the transmittance value decreases, as depicted in Figure (2). These findings are consistent with the existing literature [6].

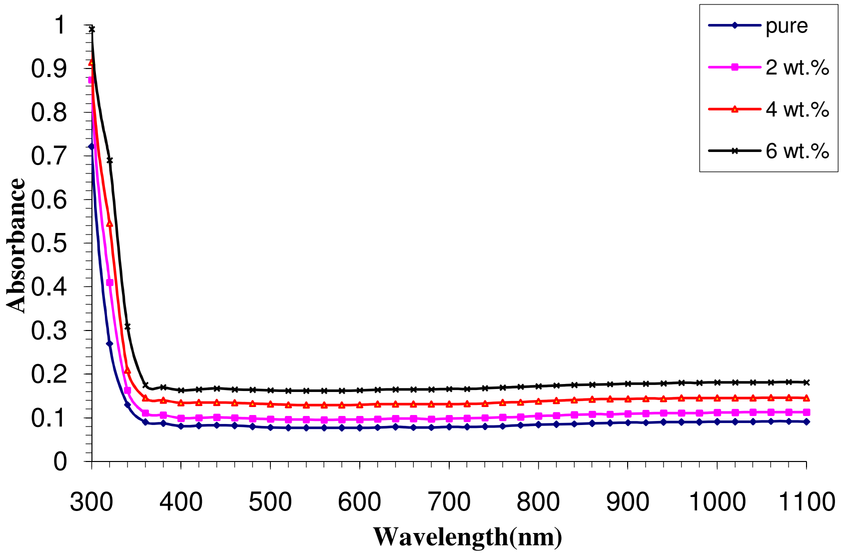

**Fig.(1). The absorbance spectra with the wavelength of PAAm/SiCnanocomposite**

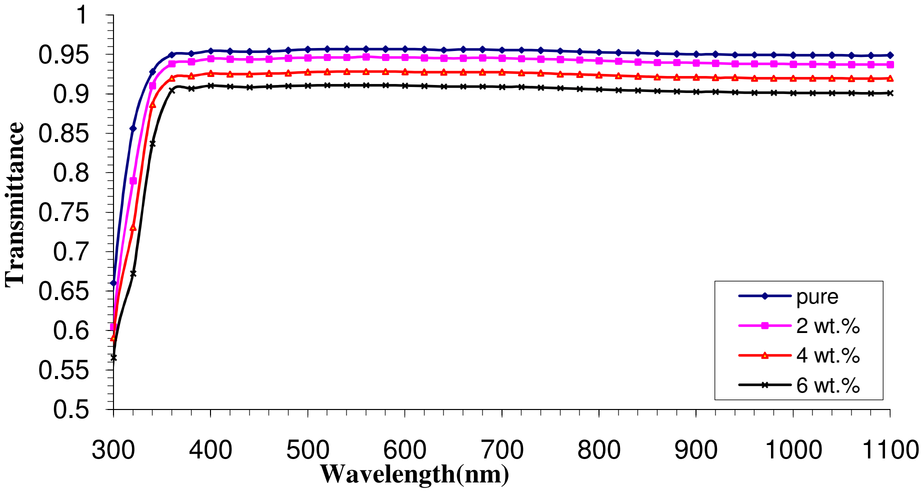

**Fig.2.Transmittance spectra of the PAAm/SiC nanocomposite with wavelength.**

The determination of the absorption coefficient (α) in (PAAm/SiC) nanocomposite films serves as a valuable physical technique for obtaining pertinent insights into the nature of charge carriers within a band and the magnitude of the band gap energy. This analysis is contingent upon the energy of the incident light. The absorption coefficient is often determined through the utilization of the equation relationship[7] .

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

Within this particular case, the variable A is utilized to indicate the absorbance of the film, while the variable t is employed to denote the thickness of this film. Figure 3 depicts the correlation between the absorption coefficient (α) and photon energy in the (PAAm/SiC) nanocomposite. The data presented in Figure 3 demonstrates a clear trend of the absorption edge shifting towards lower energy with increasing concentration of SiC NPs additive. The results obtained from the experiment demonstrate a decrease in the optical energy gap as the quantity of the additive increases [8].

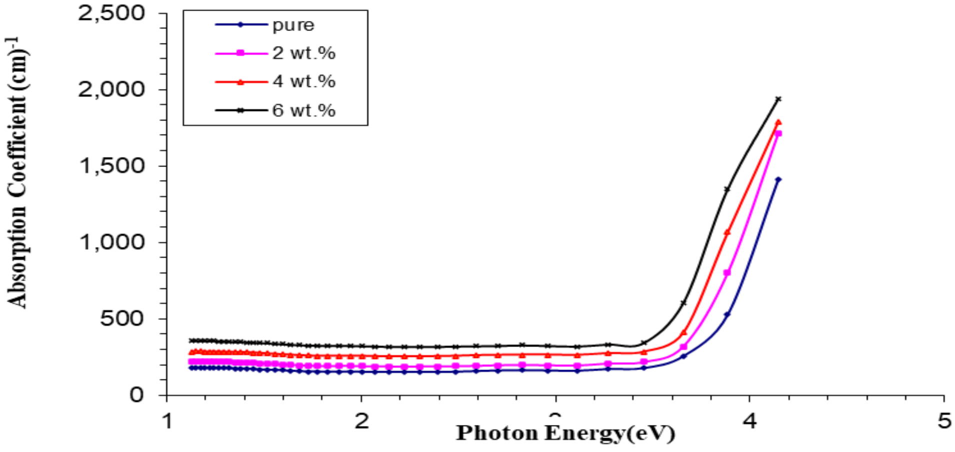

**Fig.3: The spectra of absorption coefficient of PAAm/SiC nanocomposite with wavelength**

The relationship between the indirect optical energy gap (Egopt), photon energy (hυ), and absorption coefficient can be expressed by the following equation[9]:

$(\alpha h\nu)= B\ (h\nu - E_g^{opt} \pm E_{ph})^r$ (2)

The parameter B is utilized to characterize band tailing, whereas the parameter r is employed to indicate the nature of optical transitions in the materials under investigation. Specifically, a value of n=2 corresponds to authorized indirect transitions, whilst a value of n=3 corresponds to forbidden indirect transitions. The determination of the optical band gap energy can be achieved by analyzing the relationship between the exponentiated product of the absorption coefficient and the photon energy, as depicted in Figures 4 and 5. These figures are accompanied by a corresponding nomenclature, as presented in Table 1.

The determination of the indirect band gaps in PAAm/SiC nanocomposite films can be achieved by projecting the linear segment of the curve onto the hv axis. There is a clear observation that the presence of SiC NPs has a significant impact on the lowering of both permissible and banned indirect Egopt values. The reduction in the optical energy gap can potentially be attributed to the generation of faults and disorders within the materials that are in close proximity to the conduction band. These findings are consistent with the findings described in reference [10].

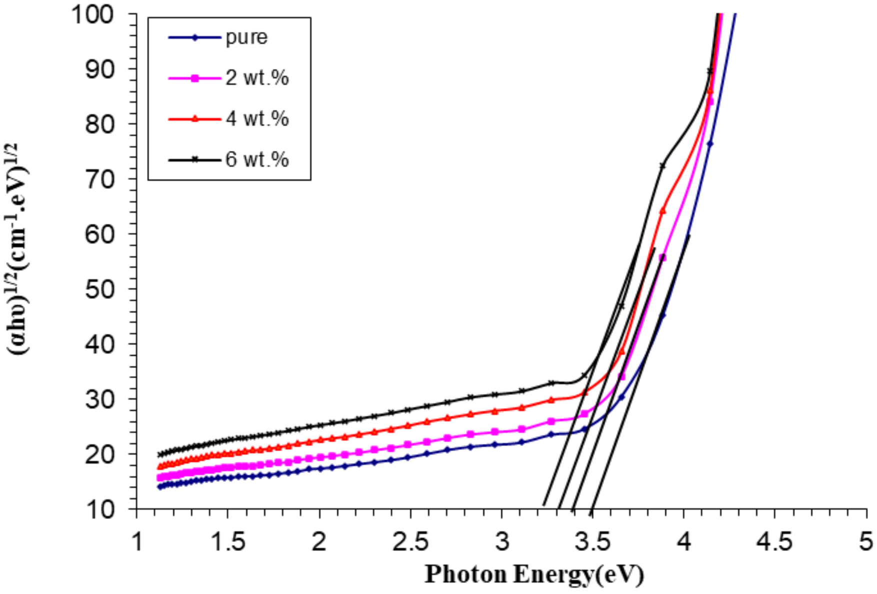

**Fig. 4. A plot of $(\alpha h\nu)^{1/2}$versus (hν) of (PAAm/SiC) nanocomposite.**

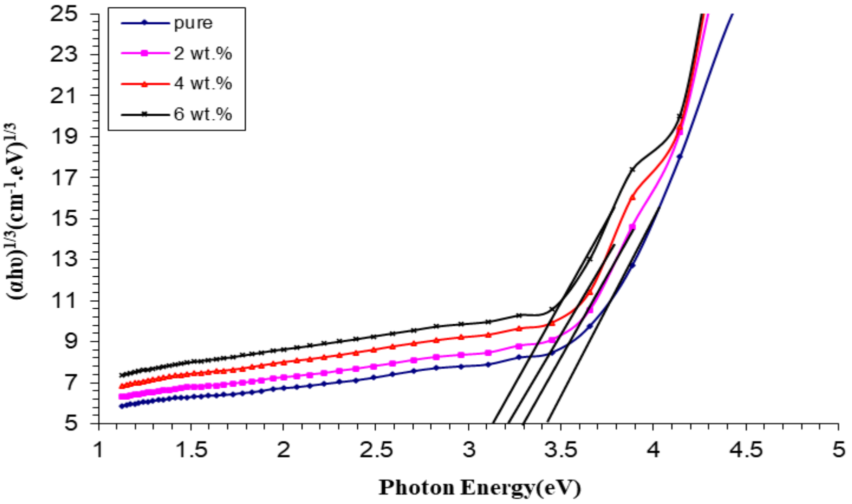

**Fig. 5. A plot of $(\alpha h\nu)^{1/3}$ versus (hν) of (PAAm/SiC) nanocomposite**

**Table 1: $E_g^{opt}$ values for the allowed and forbidden indirecttransition of (PAAm/SiC) nanocomposite**

| Sample | Allowed (eV) | Forbidden (eV) |
|---|---|---|
| PAAm | 3.5 | 3.4 |
| 2wt% SiC | 3.4 | 3.3 |
| 4wt% SiC | 3.3 | 3.2 |
| 6 wt% SiC | 3.2 | 3.12 |

The index of refractive (n)and extinction coefficient ($K_o$) of PAAm/SiC nanocomposite films were considered from the equations [11] .

$$n = \frac{1+R}{1-R} + \left[\frac{4R}{(1-R)^2} - K_O{}^2\right]^{1/2} \qquad (3)$$

$$K_O = \frac{\alpha\lambda}{4\pi} (4)$$

Where R means the reflectance.

Figure 6 illustrates the relationship between the spectral refractive index and various ratios of SiC nanoparticles in the polymer PAAm. The figure clearly demonstrates that the refractive index exhibits an increase as the concentration of SiC NPs is augmented. The observed fluctuation in the refractive index, denoted as "n" in this context, can be attributed to a criterion related to structural alterations[12].

Figure 7 illustrates the relationship between the behavior extinction coefficient and wavelength. It is evident that the extinction coefficient values of the nanocomposite films are significantly higher than those of the polymer PAAm across all locations. This behavior is associated with an increase in the absorption of incoming light[13]

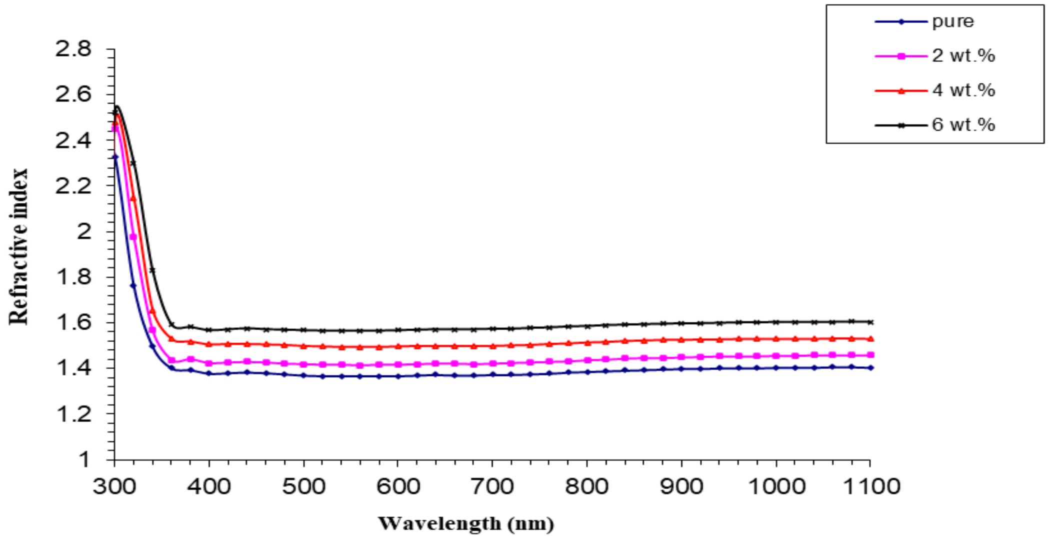

**Fig. 6:Refractive index of (PAAm/SiC) nanocomposite**

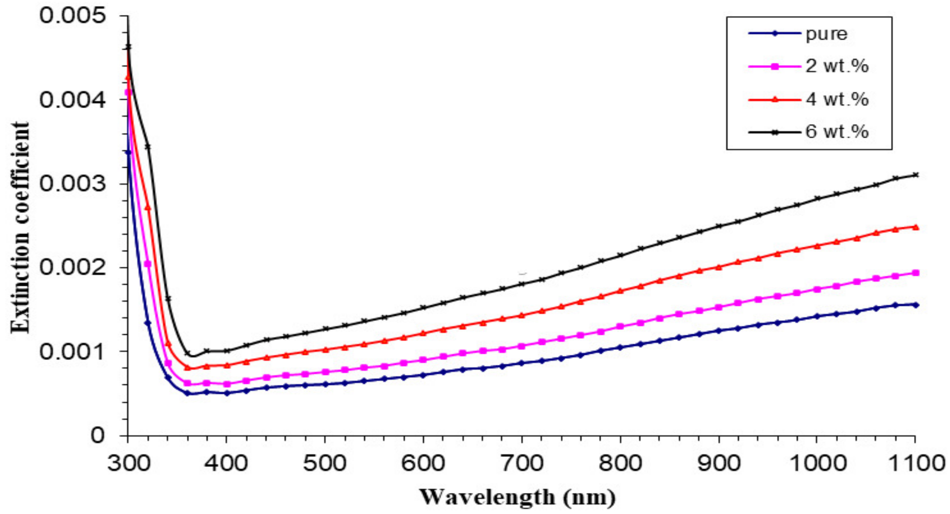

**Fig. 7: Extinction coefficient of PAAm/SiC) nanocomposite.**

The components of the dielectric constant, namely the real part (ε1) and the imaginary part (ε2), are provided as follows[14]:

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

$\varepsilon_2 = 2nk$ (6)

Figures 8 and 9 depict the relationship between the wavelength and the real and imaginary dielectric constants of the PAAm/SiC nanocomposite, showcasing the observed variance. The presented data indicates that the real and imaginary dielectric constants of both components were enhanced when the concentration ratio of SiC NPs increased. The observed phenomenon can be attributed to the heightened level of electrical polarization within the nanocomposites [15].

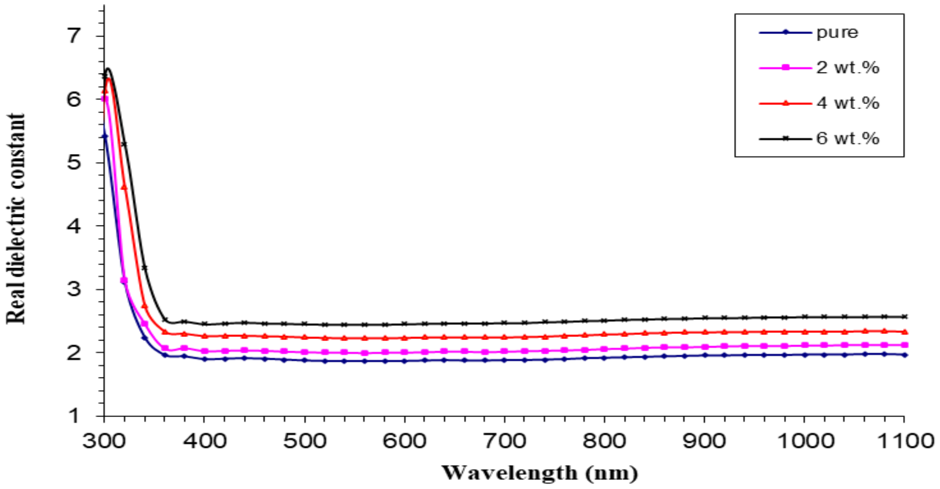

**Fig.(8). The real dielectric constant with the wavelength of PAAm/SiCnanocomposite**

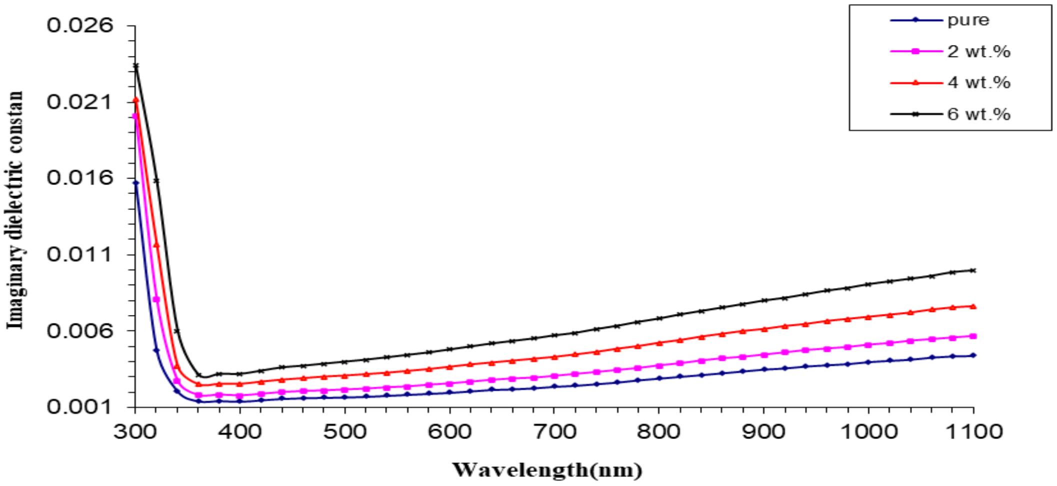

**Figure (9). Imaginary dielectric constant with the wavelength forPAAm/SiCnanocomposite.**

The optical conductivity ($\sigma_{op}$) is defined by[16].

$\sigma_{op} = \alpha nc/4\pi$ (7)

The variable c represents the speed of light. The optical properties of (polyacrylamide/silicon carbide) nanocomposites, specifically the spectral optical response, are elucidated in Figure 10. According to the data presented in the figure, it can be observed that the electrical conductivity (σop) increases as the content of SiC nanoparticles (NPs) increases. This phenomenon can be attributed to the formation of localized energy levels within the energy gap. As the nanoparticle content increases, the density of these localized phases in the band structure also increases. Consequently, the absorption coefficient increases, indicating an increase in the electrical conductivity (σop) of the nanocomposite [17].

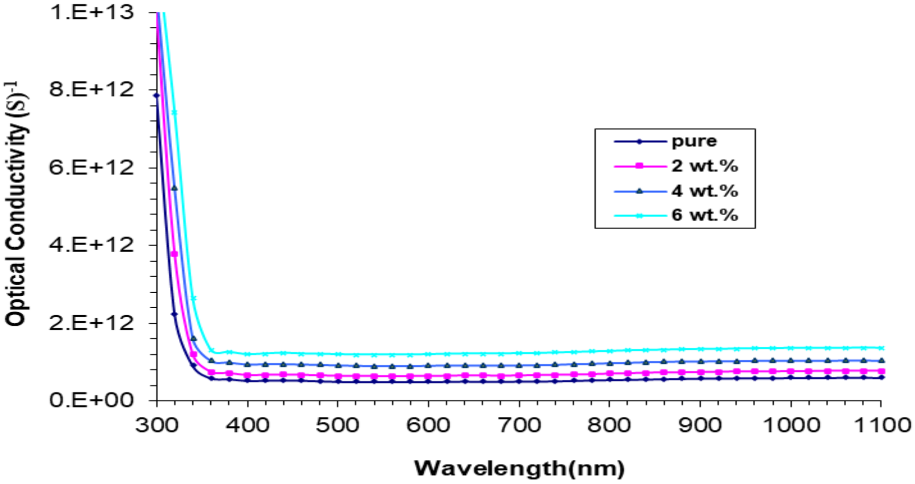

**Fig.(10): Variation $\sigma_{op}$ of (PAAm/SiC) nanocomposites with the wavelength.**

**Conclusions**:

The present study involved the fabrication of nanocomposite films composed of polyacrylamide (PAAm) and silicon carbide (SiC) nanoparticles (NPs) using the solution casting technique. The films were prepared with varying concentrations of SiC NPs. The samples that were created underwent characterization using UV-Vis analytical methods. The absorbance of the system exhibits an upward trend with increasing concentrations of SiC NPs, whereas the transmittance and energy gap associated with allowed and forbidden transitions show a decreasing trend with increasing concentrations of SiC NPs. The coefficients of absorption and extinction, index of refractive, real and imaginary dielectric constant exhibit an increase with the addition of SiC NPs. The conclusive findings indicate that the (PAAm/SiC) films exhibit favorable optical characteristics suitable for application in the field of optics.

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