

Effect of WC nanoparticles addition on optical properties of CMC for photo-detectors devices

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World Journal of Advanced Research and Reviews, 2023, 17(01), 1194–1201

Publication history: Received on 12 December 2022; revised on 24 January 2023; accepted on 26 January 2023

Article DOI: <https://doi.org/10.30574/wjarr.2023.17.1.0147>

Abstract

In this paper, nanostructures from carboxymethyl cellulose (CMC) /tungsten carbide nanoparticles (WC NPs) were fabricated. The WC NPs was added to polymer by various weight ratios are (1.5, 3 and 4.5) wt. %. "The optical characteristics" of CMC/WC nanostructures were tested. The optical results exhibited the absorbance of CMC is raised with rising of the content of WCNPs. The gap of energy of CMC polymer reduces with a rise of the content of WCNPs. The optical constants such as "coefficient of absorption, coefficient of extinction, index of refractive", dielectric "constants for real and imaginary part"and conductivity of CMC varied with a rise of the weight ratios of WC NPs.

Keywords: CMC; Nanocomposites; Optical properties; WC

1. Introduction

When combined with a polymer, organic/inorganic hybrid substances provide incredibly appealing and flexible fields. Because they combine the benefits of organic polymers' ductility, dielectric properties, and flexibility with those of inorganic materials increased thermal stability, rigidity, and strength as well as their higher refractive index and harder surface, nanocomposites of organic and inorganic materials have a wide range of applications [1]. There has to be more investigation into how nanoparticles affect the characteristics of a polymer matrix in order to more accurately predict the final properties of the composite. Recently, composites of polymer and ceramic filler have drawn attention because of their appealing electronic and electrical properties. Potential applications include sensores, window and packaging of electronic[2].Composites with polymer matrix display distinct characteristics and include found ever-increasing fields as engineering components and structures in land transportation, electricalandelectronics, aviation, aerospace,military, sensors, marine,UV resistance, sports and recreational industries [3-7].Carboxymethyl cellulose "(CMC) "is a linear polysaccharide of anhydro-glucose" that is "an anionic, water-soluble"cellulose derivative. 1,4-Glycosidic linkages link the repeating units together. Only a few anionic carboxymethyl groups (i.e., -CH₂COOH) in the CMC structure, which replace some of the "presentof hydroxyl groupsin the pure "infrastructureof cellulose ", are the primary molecular difference between CMC and cellulose [8, 9]. CMC and its composites, for instance, are frequently used in the biomedical fields of tissue engineering, bone-tissue engineering, wound dressing,creation of artificial organs or and diagnosis of various diseases[10].Due to its exceptional characteristics, including a "high melting point", excellent hardness, low friction coefficient, strong "resistanceof oxidation ", and "superior electrical conductivity", tungsten carbide (WC) has potential applications. The substance has been used with success in the ""hydrogen evolution reaction" (HER), solar cells, and as an efficient catalyst for the oxygen reduction reaction and electro-oxidation of methanol [11]. Because it is inexpensive, has a high catalytic activity, is selective, and has good thermal stability under testing. Additionally, WC is more resistant to acidic solutions and operates at greater temperatures. For direct alcohol fuel cells, it demonstrated resistance to CO poisoning, resulting in a prolonged catalytic life[12,13]. This paper aims to explain the effect of WC NPsadding on optical characteristics of CMC for photo-detectors devices.

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2. Material and methods

Films of carboxymethyl cellulose (CMC) doped with tungsten carbide (WC) were created via casting method. CMC film was created by dissolving 1gm of this polymer in 50 ml of deionized water at room temperature with magnetic stirrer for half an hour. The nanocomposites films were created by adding WC NPs to a CMC solution with concentrations of (1.5, 3 and 4.5) wt.%. The optical characteristics of nanocomposites films were tested using "spectrophotometer (UV-1800⁰A-Shimadzu)". The coefficient of absorption (α) is calculated by [14]:

$$\alpha = 2.303 \left(\frac{A}{d} \right) \quad \dots\dots\dots(1)$$

Which: "A is the absorbance and d is the thickness. The gap of energy is given by" [15]:

$$(ahv)^{1/m} = C(hv - E_g) \quad \dots\dots\dots(2)$$

Which: C is constant, hu is the photon energy, E_g is the gap of energy, $m = 2$ and 3 to indirect transition of allowed and forbidden". The index of refractive (n) is defined by [16]:

$$n = \frac{1 + \sqrt{R}}{1 - \sqrt{R}} \quad \dots\dots\dots (3)$$

which "R is the reflection. The coefficient of extinction (k) is determined by" [17]:

$$k = \frac{\alpha\lambda}{4\pi} \quad \dots\dots\dots (4)$$

which " λ is the wavelength. The dielectric constant of real and imaginary parts: real (ϵ_1), and imaginary (ϵ_2) are given by" [18]:

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

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

The conductivity of optical (σ_{op}) is defined by [19].

$$\sigma_{op} = \frac{\alpha mc}{4\pi} \quad \dots\dots\dots (7)$$

3. Results and discussion

Fig. (1) display the absorbance of a CMC/WC nanocomposites with a wavelength range of 200-1100 nm. The absorption of CMC rises with rise the WC NPs content which due to the free electron absorb the light of incident hence the transmittance will decrease as shown in Fig.2. This result is agreement with" [20-22].

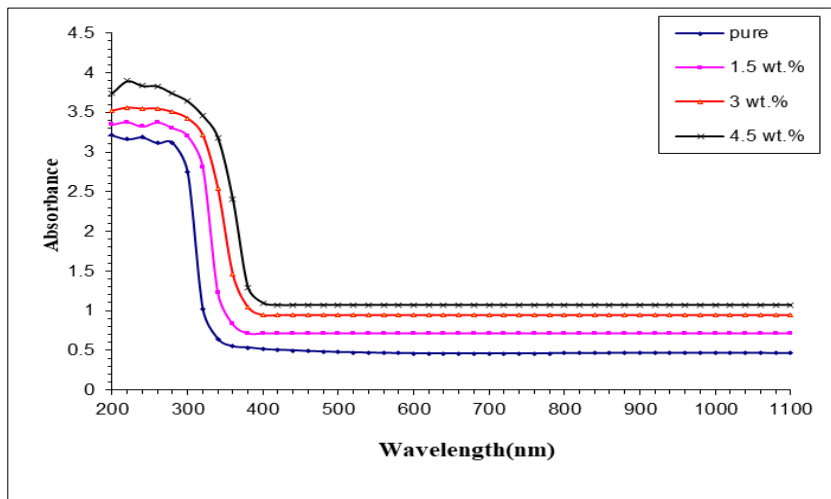


Figure 1 Influence of WC NPs on the absorbance of CMC

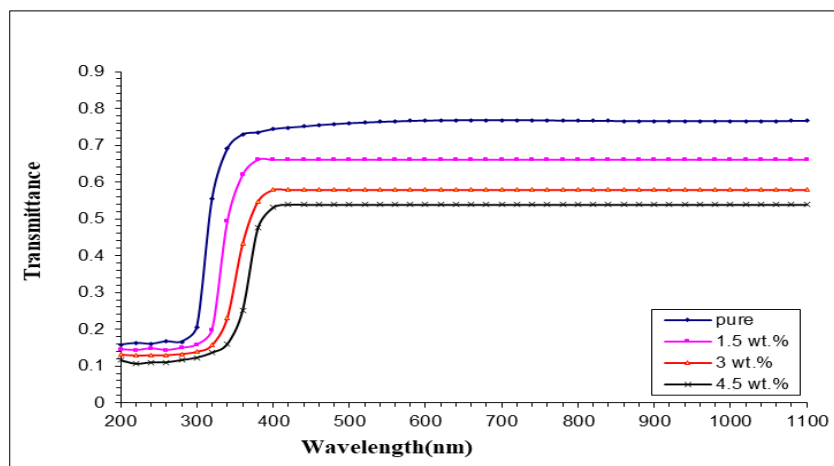


Figure 2 Optical transmittance of CMC/WC nanocomposites

The coefficient of absorption of CMC/WC nanostructures with energy of photon are demonstrate in fig.(3). When the WC NPs content rises, the α rise. The improve of α is indicate a rise in light absorbance [23]. The nanostructures have an indirect gap of energy when the value of α is less than 10^4 cm^{-1} .

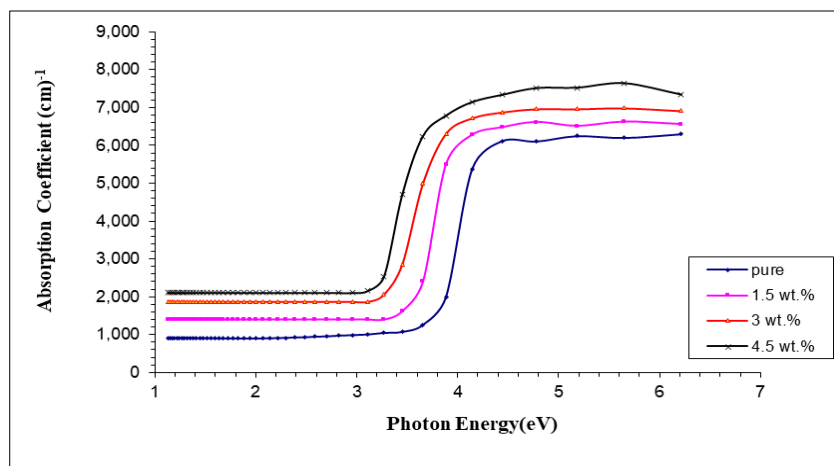


Figure 3 Absorption coefficient of CMC/WCnanocomposites versus photon energy

By plotting $(\alpha h\nu)^{1/2}$ and $(\alpha h\nu)^{1/3}$ against $h\nu$ as shown in figs.(4,5), the energy of gap was calculated. The gap of energy for the allowed reduced from 3.6 eV for the CMC to 2.9 eV for the for 4.5 wt.% WC NPs and from 3.4 eV for the CMC to 2.6 eV for CMC 4.5 wt.% WC NPs gap of for the forbidden. The creation of local states in the band gap cause to reduce the gap of energy [24]. The value gap of energy is demonstrated in Table (1)."

Table 1 Gap of energy values of CMC/WCnanocomposites

WC NPs wt. %	Eg (eV)	
	allowed	forbidden
0	3.6	3.4
1.5	3.4	3.1
3	3.1	2.8
4.5	2.9	2.6

The extinction coefficient for CMC/WC nanostructure is demonstrate in Fig.(6). The Krises as the content of WC NPs rises. This result attributed to the improvement of the coefficient of absorption when the added of WCNPs. This result agrees with [25].

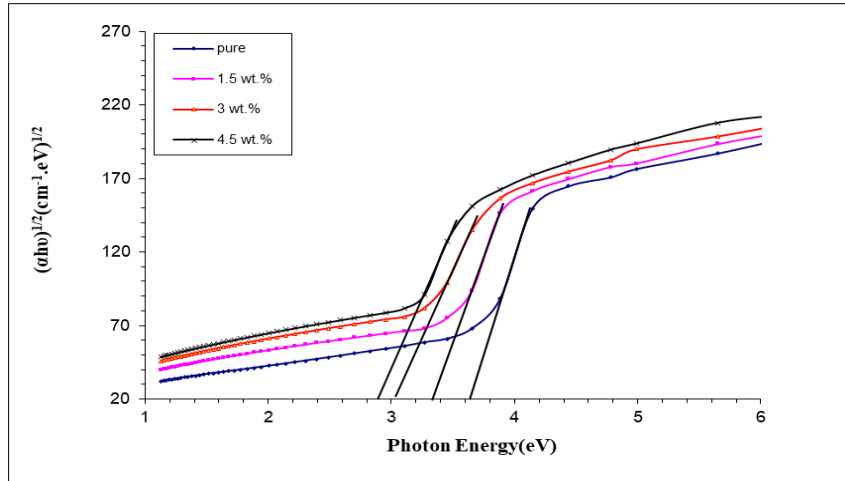


Figure 4 $(\alpha h\nu)^{1/2}$ versus $h\nu$ of CMC/WC nanocomposites

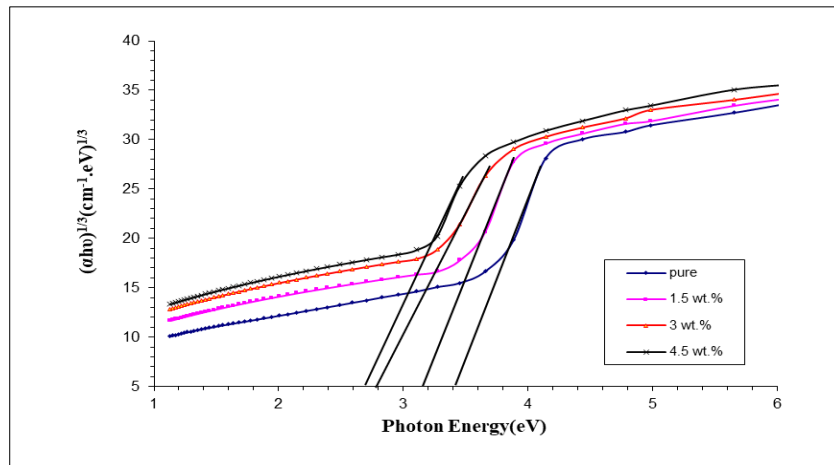


Figure 5 $(\alpha h\nu)^{1/3}$ versus $h\nu$ of CMC/WC nanocomposites

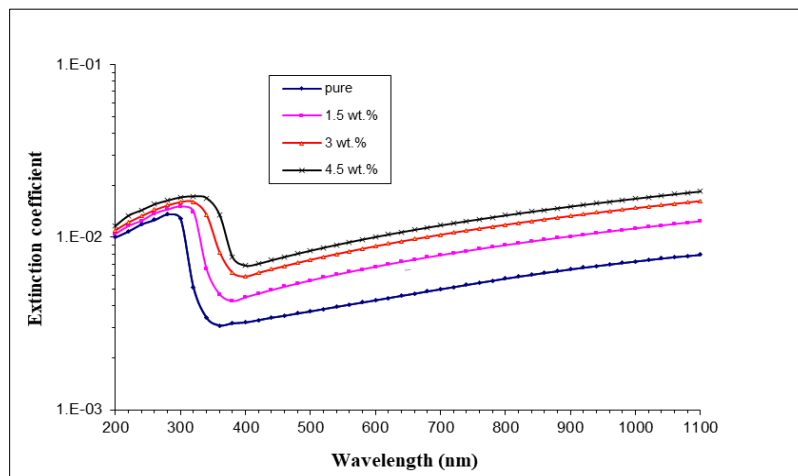


Figure 6 Extinction coefficient for (CMC/WC) nanocomposites

The refraction index of (CMC/WC) nanostructure with wavelength is demonstrate in Fig. (7). The index of refractive inclines to rise as the rises of WC NPs content in the CMC polymer. This result due to rise of WC NPs content, the density of the nanostructure rises [26].

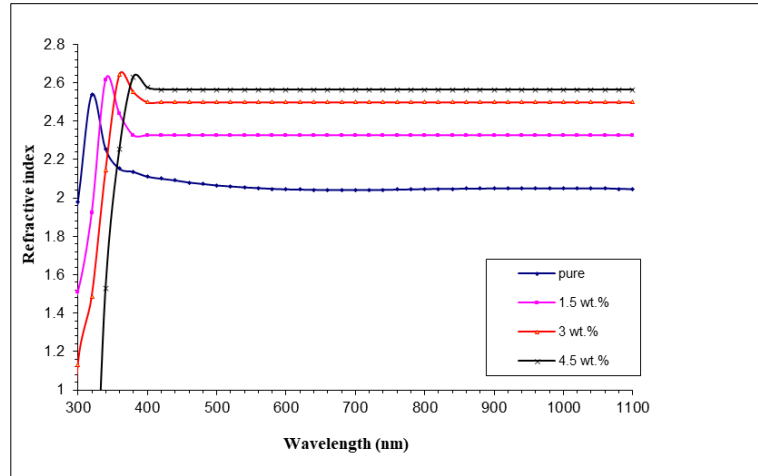


Figure 7 Refraction index of (CMC/WC) nanocomposites versus wavelength

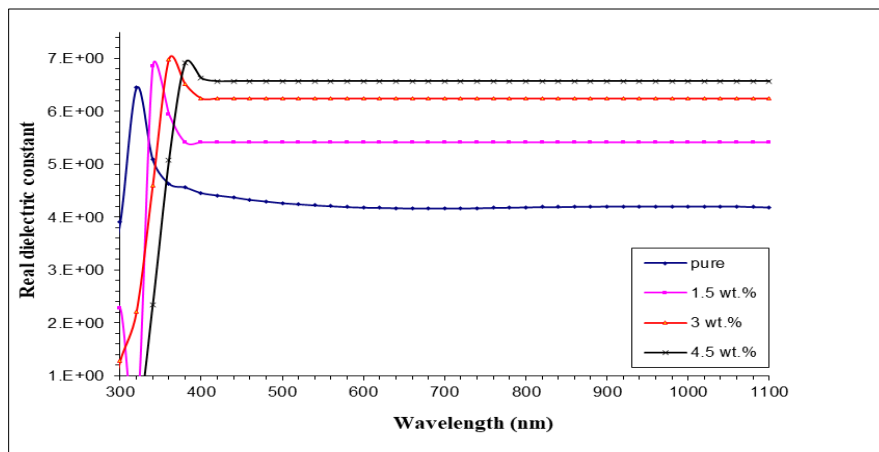


Figure 8 Variation of (ϵ_1) versus wavelength

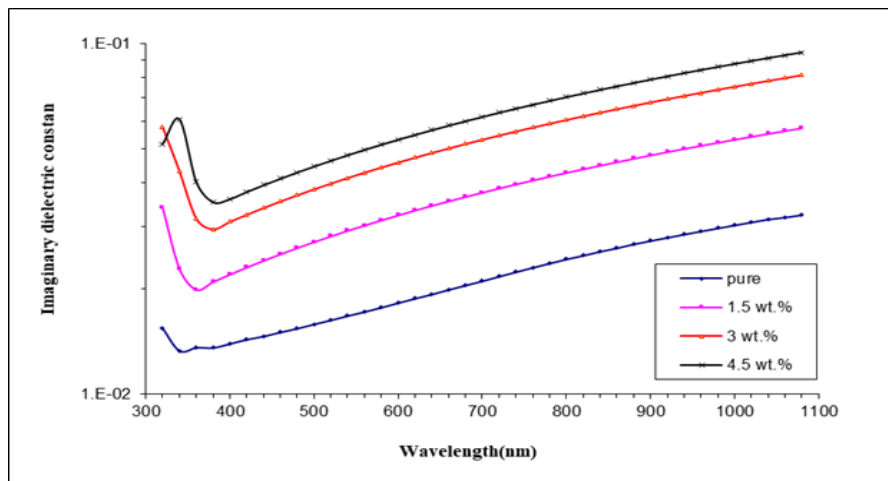


Figure 9 Variation of (ϵ_2) versus wavelength

The variance of (ϵ_1) with wavelength is demonstrate in fig.(8). Since of the low value of K^2 , the dielectric constant of real rises as the n values rise when the content of WC NPs rises. The variation in (ϵ_2) with wavelength is demonstrate in Fig.(9). Since the relation between α and K , it is clear that ϵ_2 is dependent on K values that differ with the coefficient of absorption. This result is agreeing with [27].

Fig. (10) Demonstrate the conductivity of optical of CMC/WC nanostructure versus of wavelength. The conductivity of optical of CMC increases as the WC content increases which indicate to create of local states in the E_g [28].

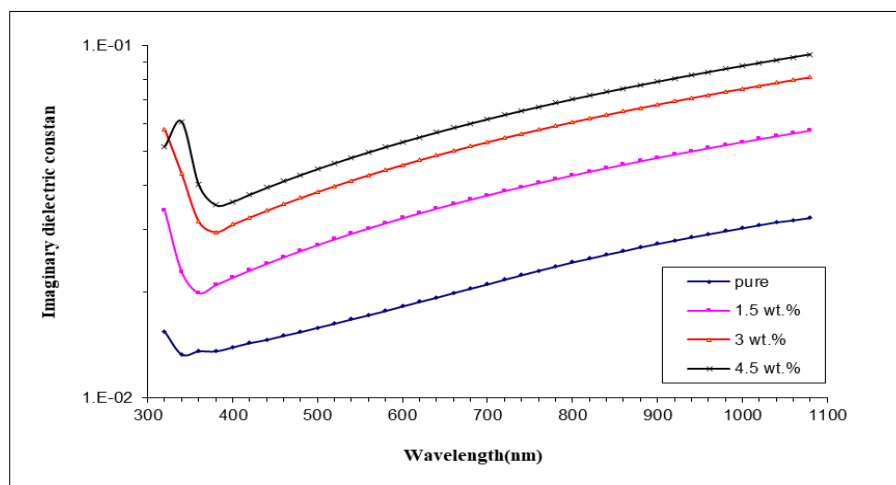


Figure 10 Optical conductivity of CMC/WC nanocomposites versus wavelength

4. Conclusion

The results demonstrated that adding various content of WC NPs improved the optical characteristics of CMC. The absorbance and optical constants (coefficient of absorption, coefficient of extinction, index of refractive, dielectric constants for real and imaginary and conductivity) of CMC increased with a rise in weight percentages of WC NPs. The gap of energy (E_g) of CMC decreases with the increase of the content of WC NPs. The optical results demonstrated that the CMC/WC nanocomposites might be utilized for a variety of optoelectronic applications.

Compliance with ethical standards

Acknowledgments

Acknowledgment to University of Babylon.

Disclosure of conflict of interest

No conflict of interest.

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