RESEARCH PAPER

# Preparation and Study of Some Physical Properties of CMC:PVA–AgO Nanocomposites

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## ABSTRACT

This study investigates the effect of incorporating silver oxide (AgO) nanoparticles into a polymer composite made of polyvinyl alcohol (PVA) and carboxymethyl cellulose (CMC) were mixed in a 1:1 ratio. Nanocomposite films were prepared using casting method process with adding different concentrations of AgO nanoparticles (0.3, 0.5 and 0.7 wt%). Structural properties, Fourier-transform infrared (FTIR) and scanning electron microscope (SEM) analyzes were used to evaluate the effect of AgO incorporation on the properties of the polymer blend. Samples' optical properties were tested by measuring their UV-Visible spectra. The findings show that the addition of AgO nanoparticles significantly improves the structural and optical properties of the mixture. For the nanocomposites containing 0.3, 0.5, and 0.7 wt% AgO, the optical band gap gradually decreased from 5.35 eV (pure mixture) to 5.25, 5.20, and 5.16 eV, respectively.

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## INTRODUCTION

Nanomaterials have attracted large attention because of their remarkable physicochemical properties, which allow programs throughout various commercial, electric, and biomedical fields [1,2]. Among the ones, steel nanoparticles represent the cornerstone of nanostructured materials, imparting specific benefits along with decreased melting factors, large surface-to-quantity ratios, special optical features, improved mechanical electricity, and tunable magnetic houses [3]. In parallel, solid polymers have verified exquisite progress in advanced technologies, which include sensors, high-energy-density batteries, electrochromic gadgets, and sun cells. This is commonly attributed to their flexibility, electrochemical stability, sturdiness, and safety [4,5]. Polyvinyl alcohol (PVA), mainly reveals intriguing traits along with excessive elasticity, wonderful movie-forming capacity thru solution casting, considerable dielectric energy, and high rate garage capability. Its hydroxyl companies in addition facilitate chemical and physical interactions with numerous dopants [6,7]. In a similar way via creating sturdy hydrogen-bonding contacts and crosslinking networks with PVA, carboxymethyl cellulose (CMC), a biodegradable and non-toxic by-product of cellulose with an

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abundance of carboxyl (-COOH) corporations, improves polymer performance [8,9]. The incorporation of CMC into PVA matrices has been shown to markedly enhance mechanical, structural, and useful homes of the ensuing polymer blends [10]. Another promising material in organic and bioelectronics is poly(styrenesulfonate):poly(3,4-ethylenedioxythiophene) (PEDOT:PSS), valued for its superior conductivity, high optical transparency, and ability to form stable aqueous dispersions. It is widely utilized as a conducting ink to fabricate flexible thin films and electrodes, with recent studies reporting conductivity enhancement through the addition of crosslinking agents such as 3-methyl-3-oxetanemethanol [11]. The distribution of CMC inside the matrix formed by PVA has a major impact on the mechanical characteristics of nanocomposite films. Recently, polymer films doped with silver oxide (AgO) nanoparticles have emerged as a focal point in research due to the multifunctional nature of AgO, including outstanding antibacterial activity, as well as superior electrical and thermal conductivity. Embedding AgO nanoparticles into polymeric matrices not only provides enhanced antibacterial and anticorrosive performance but also tailors optical and electrical characteristics for advanced technological applications [12-15]. The present study investigates the influence of AgO nanoparticles' influence on the structural and optical properties of a polymeric blend consisting of (PVA) and CMC.

## MATERIALS AND METHODS

*Preparation of (CMC/PVA:AgO)*

The casting method used to create nanocomposite films primarily based on (CMC/PVA) and AgO-doped (CMC/PVA) blends. In the initial step, 0.2 g of PVA and 0.2 g of CMC were separately dissolved in 10 mL of distilled water at 80 °C and room temperature, respectively. After one hour of individual dissolution, both solutions were mixed and further stirred for 3 hours to ensure a fully homogeneous (CMC/PVA) blend.

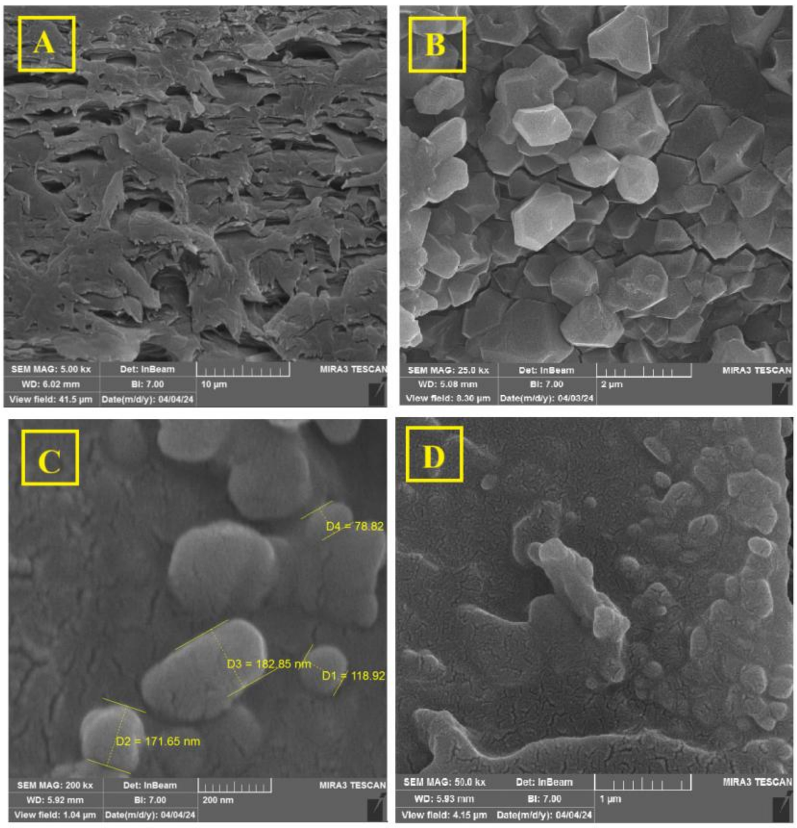


Fig. 1. FE-SEM images of nano composites films: (A) (CMC/PVA Pure, (B) AgO nanoparticles, and (C&D) (CMC/PVA:5% AgO.

All stirring procedures were conducted using a magnetic stirrer to maintain consistent uniformity.

In the initial step, 0.2 g of PVA was dissolved in 10 mL of distilled water at 80 °C, while 0.2 g of CMC was separately dissolved in 10 mL of distilled water at room temperature. Both processes were carried out under continuous magnetic stirring for one hour. Subsequently, the two solutions were mixed and stirred for an additional 3 hours using a magnetic stirrer at room temperature to obtain a homogeneous (CMC/PVA) blend. AgO NPs with 3, 5, and 7 wt% ratios were regularly added into the polymer combination. The process was under stirring until a uniform dispersion was accomplished. The products were then cast into Petri dishes and left to dry forming flexible nanocomposite films.

A UV-Visible spectrophotometer supplied by the Japanese company Shimadzu (UV-1900i) used for measure optical properties, while the chemical bonds and functional groups were characterized using a Shimadzu FTIR spectrophotometer (IRAffinity-1)

## RESULTS AND DISCUSSION

*Surface Analysis*

The surface morphology of the synthesized (CMC/PVA) films was investigated using FSEM before and after the incorporation of (AgO NPs) at a concentration of 5 wt%. As shown in Fig. 1a, (CMC/PVA) film exhibits a relatively homogeneous, indicating good miscibility between the polymer components. Upon the addition of AgO NPs, the micrographs reveal the presence of numerous nanoparticle clusters distributed across the polymers film. Such agglomeration is commonly attributed to the elevated surface energy and strong interparticle interactions of nanoparticles. The resulting morphology indicates that while the polymer matrix provides adequate encapsulation, nanoparticle dispersion remains a key factor influencing the structural and functional properties of the nanocomposite films [14-16]. The nanocomposite particles size is in the range 86.54 nm to 182.85 nm.

*FTIR analysis*

Fig. 2 illustrates the FTIR spectra, the stretching at 500-600 $cm^{-1}$ was reported for the spectra of CMC: PVA\Ag-Nps (pure-black) [17]. The FTIR spectrum of the CMC/PVA/Ag-red (3%) nanoparticles exhibited characteristic peaks for O-H stretching in the range of 3500–3700 $cm^{-1}$, and C-H stretching at 2830 $cm^{-1}$. Furthermore, the

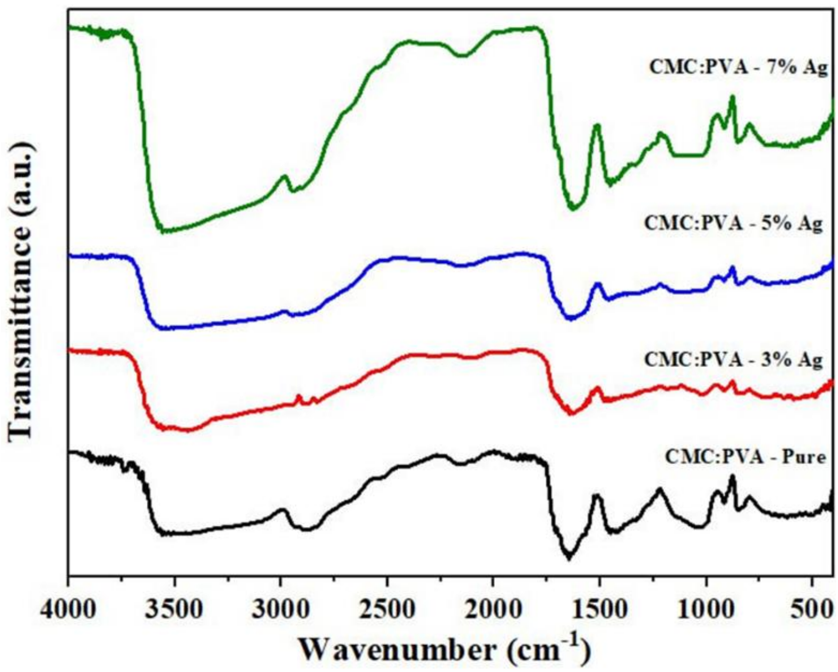


Fig. 2. (a) FTIR spectra of Nano Composites Films: (a) CMC/PVA: pure, (b) CMC/PVA:3% AgO (c), CMC/PVA:5% AgO; (d), and (CMC/PVA:7% AgO.

absorption bands at 1740 $cm^{-1}$ and 1430 $cm^{-1}$ were attributed to the C=O and symmetric carboxylate stretching vibrations, respectively [18, 19]

The FTIR spectra of the CMC/PVA nanocomposites loaded with different silver concentrations (Ag-red, Ag-blue, and Ag-green) revealed significant vibrational shifts, indicating strong intermolecular interactions. For the 3% Ag-red sample, characteristic absorption bands were observed at 3500–3700 $cm^{-1}$ and 2830 $cm^{-1}$, corresponding to O-H and C-H stretching vibrations, respectively. The peaks at 1740 $cm^{-1}$ and 1430 $cm^{-1}$ are attributed to the carbonyl (C=O) and symmetric carboxylate stretching, consistent with previous reports [18, 19].

In the 5% Ag-blue films, a broader O-H stretching band appeared at 3200–3800 $cm^{-1}$, while the C-H stretching shifted to 2930 $cm^{-1}$. The peaks at 1420 $cm^{-1}$ and 925 $cm^{-1}$ are associated with the C-H bending modes of the PVA backbone [20]. The interaction between CMC and PVA is further evidenced by the shifting of C-O stretching and bending vibrations to 1685 $cm^{-1}$ and 1560 $cm^{-1}$, compared to the sharp C-O stretch at 1082 $cm^{-1}$ in the pure components. Furthermore, the 7% Ag-green nanocomposite exhibited distinct peaks in the 480–550 $cm^{-1}$ range, which are assigned to Ag-O vibrations, confirming the successful incorporation of silver nanoparticles within the polymer matrix.

Hydrogen bonding among the hydroxyl groups of CMC-PVA and AgO -Nps in the films caused the O-H peaks to change in slope and shift, showing that CMC-PVA and AgO were successfully incorporated [21].

*Optical properties*

One of the most fruitful ways to develop and comprehend the structure and optical properties of polymers is to investigate their Spectra of

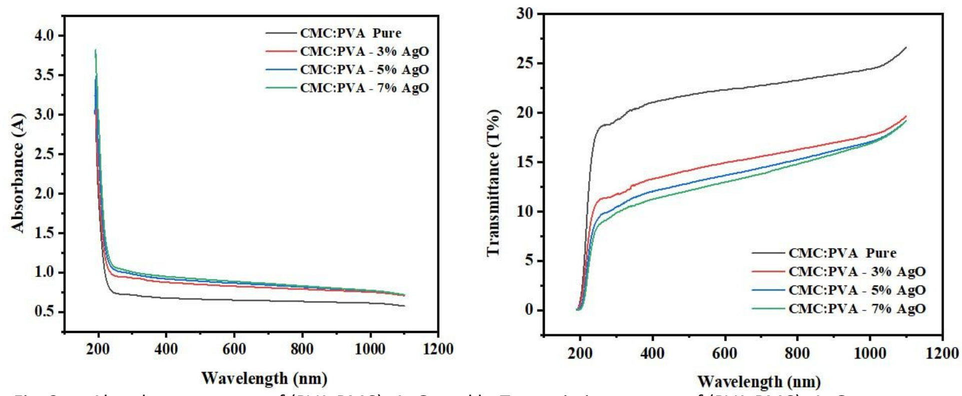

Fig. 3. a- Absorbance spectra of (PVA:PMC): AgO, and b- Transmission spectra of (PVA:PMC): AgO.

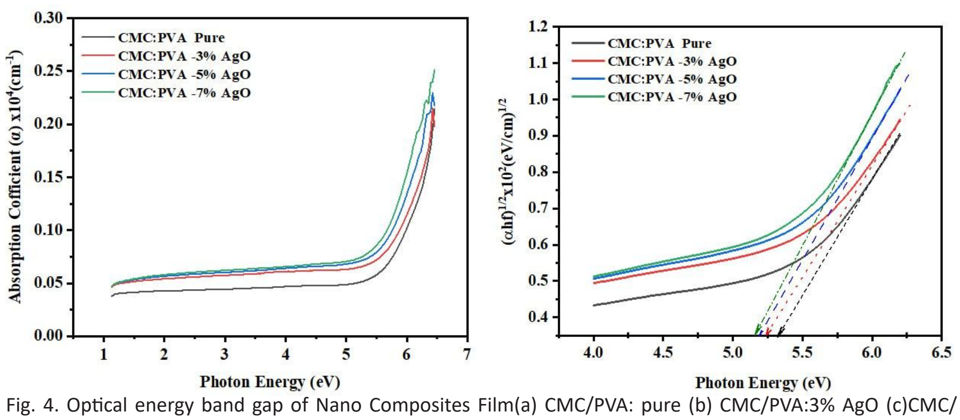

Fig. 4. Optical energy band gap of Nano Composites Film(a) CMC/PVA: pure (b) CMC/PVA:3% AgO (c)CMC/PVA:5% AgO; (d) (CMC/PVA:7% AgO.

optical absorption. Fig. 3a shows the UV-VI-NIR absorption spectra of both pure PVA:PMC and PVA:PMC doped with silver oxide (AgO). Fig. 3b also shows that doping with silver oxide (AgO) reduced the transmittance. The decrease in transmittance observed in Fig. 3b upon AgO doping is a direct consequence of increased photon scattering and absorption by the silver nanoparticles. These results suggest that AgO acts as an effective filler, modifying the optical density and the refractive index of the composite films.

Plotting the absorption coefficient and photon energy $(\alpha hf)^{1/2}$ against the energy of the photons at room temperature in Fig. 4 reveals a linear behavior [22]. The following formula [23] can be used to determine the optical energy gap:

$$\alpha h\nu = A(h\nu - E_g)^n \quad (1)$$

Where (A) is proportionality constant, (hυ) the photon's energy, and (n) determines the type of transition. Based on the value of the absorption coefficient α, (n) was 1/2.

α is absorption coefficient which can be calculated directly from the Eq. 2[24]:

$$\alpha = \ln(1/T)/d \quad (2)$$

where: (T) the transmittance, (d) film thickness.

The analysis revealed that the incorporation of silver oxide (AgO) led to a noticeable reduction in the direct band gap. This narrowing of the energy gap is attributed to the formation of sub-bandgap states or 'tails' created by the AgO nanoparticles within the polymer matrix, which facilitate electronic excitations at lower energies.

The red shift indicates that the absorption edge moves towards lower energies as a result of doping. It may be regarded as proof of a straight allowed transfer. Optical energy band gaps were (5.35, 5.25, 5.2, 5.16) eV, respectively, as the concentration of AgO escalated (pure, 3%, 5%, and 7%). The presence and fluctuation of the optical energy band gap ($E_g$) in relation to photon energy can be ascertained by the emergence of local cross-linking inside the polymer's amorphous phase [25]. Doping ratios generally result in a decrease in the optical energy band gap.

Fig. 5 represents the relationship between the incident photon energy and both the refractive index and extinction coefficient. The Eq. 3 can be used to calculate both refractive index ($n_o$) and extinction coefficient ($k_o$) [26]:

$$n_o = \left[\frac{(1+R)^2}{(1-R)^2} - (k_o^2 - 1)\right]^{1/2} + \frac{(1+R)}{(1-R)} \quad (3)$$

Where R reflectance.

The refractive index is correlated with reflectance. As can be notice from the refractive index diagram a significant increase in the refractive index values with increasing impurity percentage, as is observed at a doping percentage of 7% with silver oxide at photon energy from 1 to 6 electron volts. However, in the energy region of (6-7) eV, a sharp decrease in the refractive index curve is observed, which is attributed to the short wavelength in that region.

In the extinction coefficient ($k_o$) diagram, the Eq. 4 can be employed to determine the extinction

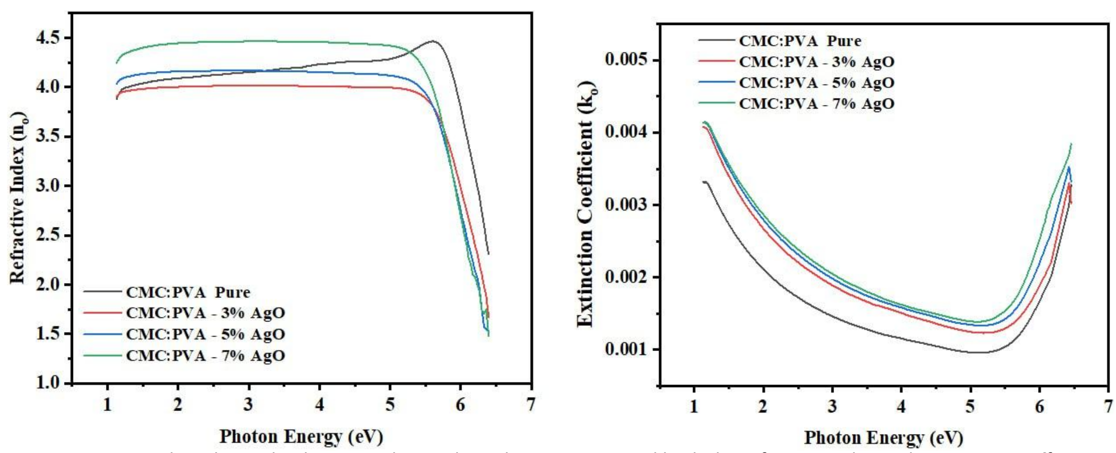

Fig. 5 represents the relationship between the incident photon energy and both the refractive index and extinction coefficient.

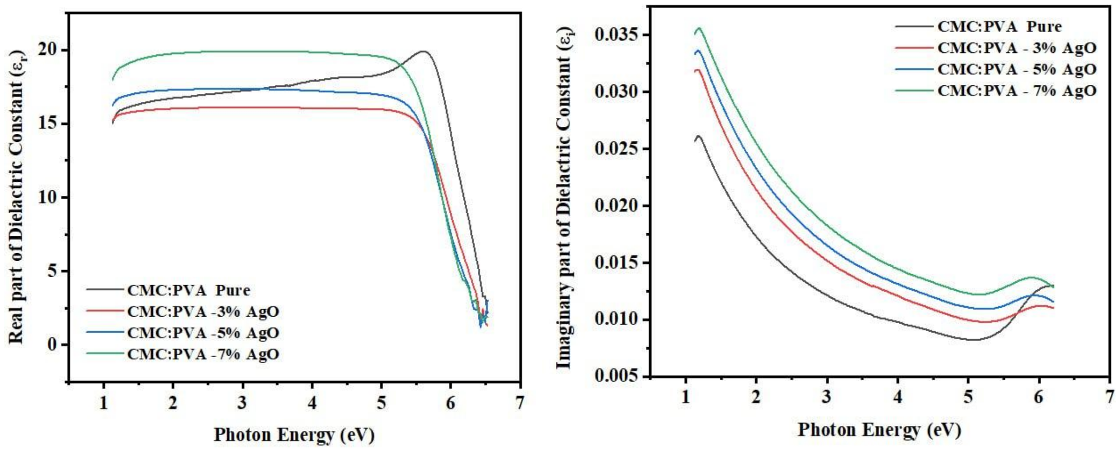

Fig. 6 represents both the real and imaginary dielectric constants.

coefficient (ko) from [27]:

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

*Where λ is wavelength*

It is noted that the attenuation of the incident beam on the prepared films escalates with the augmentation of the doping of silver oxide, as it is noted that the extinction coefficient decreases with the increase in the frequency of the incident beam to reach the maximum at the photon energy of 5.5 eV, and it is noted that the attenuation of the rays inside the films increases during the region of (5.5-7) eV, with the extinction coefficient value increasing with the increase in the percentage of impurity[28].

Fig. 6 represents both the real ( $\varepsilon_r$) and imaginary ($\varepsilon_i$) dielectric constants, it is represented by the Eqs. 5 and 6 respectively [29].

$$\varepsilon_r = n_o^2 - k_o^2 \quad (5)$$

$$\varepsilon_i = 2n_o k_o \quad (6)$$

The real dielectric constant ($\varepsilon_r$) ,which represents the energy storage capacity of the films, exhibited an upward trend with increasing silver oxide (AgO) content within the 1.0–5.5 eV range. However, a sharp decline in ($\varepsilon_r$) values was observed at photon energies exceeding 5.5 eV, indicating rapid energy dissipation. The real dielectric constant component is related to the behavior of the refractive index. Regarding the imaginary part of the dielectric constant, we note a decrease in the energy lost in the film in the region of (1-5.5) eV due to absorption and interaction of photons with the bonds of the film material. The imaginary dielectric constant value increases for the impurity-doped films with increasing silver oxide content [30].

## CONCLUSION

CMC:PVA nanocomposite films, incorporated with AgO nanoparticles, were successfully synthesized via the casting technique. Microscopic imaging SEM confirmed the high miscibility of the CMC/PVA matrix and the successful distribution of AgO nanoparticles, noting localized aggregation at higher dopant concentrations. FTIR analysis verified strong interfacial interactions through hydrogen bonding between the polymers' functional groups and the nanoparticles. The optical performance was significantly enhanced, as evidenced by a controlled reduction in the direct band gap from 5.35 eV to 5.16 eV at 7 wt.% AgO, alongside increased refractive index and extinction coefficient values. Furthermore, dielectric studies indicated that AgO integration improved the films' charge storage and energy dissipation capacities, as reflected by the rise in real and imaginary dielectric constants. Overall, The addition of AgO nanoparticles improved the polymeric blend's structural, optical, and electrical characteristics, demonstrating their potential use in biomedical technologies, optoelectronic devices, and sensors.

## CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this manuscript.

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