P-ISSN 1991-8941
E-ISSN 2706-6703
Vol. 19, No. 2 (2025)

Journal of University of Anbar for Pure Science
(JUAPS)

journal homepage: juaps.uoanbar.edu.iq

Open Access

Original Paper

Preparation and study of PVA/PANI nanocomposite films properties doped with metal oxides using spectroscopic analysis techniques

Bothaina M. Abed[1], **Mohammed G. Hammed**[2*]

[1]Basic science Department, College of Medicine, University of Anbar, Ramadi, Iraq
[2]Physics Department, College of Science, University of Anbar, Ramadi, Iraq

ARTICLE INFO

Received: 01/02/2025
Accepted: 19/03/2025
Available online: 14/11/2025
December Issue
10.37652/juaps.2025.157078.1354

CITE @ JUAPS

Corresponding author
Mohammed G. Hammed
sc.moh72_gh@uoanbar.edu.iq

ABSTRACT

This current study investigates the optical properties of polyvinyl alcohol (PVA), polyaniline (PANI), their 50:50 blend, and nanocomposite films doped with CuO and Fe_2O_3 nanoparticles. They were prepared using the casting method and the prepared films were tested using UV-Vis absorption spectra. The results revealed that pure PVA showed low absorbance, reflecting its transparent nature. PANI results demonstrated higher absorbance due to its conjugated π-electron system. The prepared PVA: PANI blend showed synergistic effects with enhanced absorbance in the UV region due to $\pi \rightarrow \pi^*$ transitions and the formation of polarons from protonated PANI. Our results indicated that doping with nanoparticles further increased the absorbance through localized surface plasmon resonance effects. Moreover, transmission decreased with doping, especially in the UV region, due to enhanced scattering and absorption. The absorption coefficient was higher in the PVA: PANI blend, with doping introducing localized energy states and reducing the optical band gap. Our results highlight the potential of synthesized nanocomposites to use in different optoelectronic applications.

Keywords: *Fe_2O_3 nanoparticles, nanocomposite, Polymers blend, UV*

1 INTRODUCTION

Polymer-based nanocomposites have garnered significant attention in recent years due to their unique characteristics and their diverse applications in industries, including electronics, energy storage, and sensing devices [1]. The high capacity of Polymer nanocomposite films (integrating conductive and non-conductive polymers), which offer a combination of flexibility, conductivity, and durability, has become very significant [2]. Polyvinyl alcohol (PVA), a water-soluble and biocompatible polymer, is commonly used in the fabrication of composite films. The semicrystalline structure accounts for its superior film-forming properties, substantial mechanical strength, and thermal stability, all of which enhance its attractiveness [3,4]. It possesses elevated dielectric strength, excellent thermal and mechanical stability, and substantial charge storage capacity [5]. Conversely, polyaniline (PANI) is recognized as one of the most extensively researched conducting polymers. It is distinguished by its exceptional electrical characteristics, environmental resilience, and straightforward synthesis. The integration of PVA and PANI into a nanocomposite structure can synergistically improve the mechanical, thermal, and electrical properties of the resultant films [6,7].

Integration of metal oxides as dopants in these polymer nanocomposites is essential for altering their structural, optical, and electrical properties. Metal oxides have the capability to interact with the polymer matrix and modify the nanocomposite morphology, electrical structure, and charge transport pathways. Metal oxide-doped PVA/PANI nanocomposites are promising candidates for advanced technological applications, including energy storage devices, electromagnetic shielding, and gas sensors [8,9]. The optical properties of polymers significantly influence our understanding of their internal structure and bond characteristics, elucidating the

December 2025 issue – published 1 December 2025.

mechanisms of electron transfer between energy beams during the assessment of absorption and permeability of these materials. Optical constants such as absorption (A), absorption coefficient (α), and transmittance (T) have been widely used to analyze the optical properties of polymer mixtures to determine the optical characteristics across various wavelengths. Analysis using the ultraviolet (UV) radiation spectrum enables inferences regarding the quality of bonds, orbitals, and energy levels [10].

The creation of flexible nanocomposite films was widely studied for different optoelectronic applications [9]. They employed a solution cast process, combining polyvinyl alcohol (PVA), polyaniline (PANI), and silver (Ag). The successful production of these nanocomposite films, featuring evenly dispersed Ag nanoparticles inserted in the PVA/PANI blend, was confirmed through transmission electron microscopy (TEM), ultraviolet absorbance, and X-ray diffraction (XRD) techniques. When compared to pure PVA film, the UV absorbance measurements of PVA/PANI blends and PVA/PANI/Ag nanocomposites demonstrated a decrease in optical bandgap. The results clearly demonstrate that the optical properties of the PVA polymer were modified by the addition of PANI and Ag NPs. Based on that, the fabricated PVA/PANI/Ag nanocomposite films can be used in optoelectronic devices [9].

The aim of this study was to synthesize and characterize PVA/PANI nanocomposite films, incorporating specific metal oxides, and to study the effect of metal oxide doping on the optical properties of the synthesized films. The insights gained from this study will enhance our understanding of polymer-metal interactions and their implications for future applications in advanced technologies.

2 MATERIALS AND METHODS

Polyvinyl alcohol powder (1 g) (supplied by Alfa Chemistry Company, UK) was dissolved in 30 mL of distilled water with the chemical formula $[CH_2CH(OH)]n$ and molecular weight of 500 g/mole at a temperature of 60 °C using a magnetic stirrer for 6 hours to ensure homogeneity of the solution. Next, the same amount of polyaniline (Merck Company, with the chemical formula C6H7N and a molecular weight of 67.09 g/mol) was dissolved under the same conditions to obtain a homogeneous solution. After preparing the two solutions, they were mixed in a 50:50 ratio using a magnetic stirrer to obtain homogeneity of the polyvinyl alcohol solution with the polyaniline solution. In a subsequent step, 1 g of copper oxide (USA, with a molecular weight of 79.55 g/mole, characterized as a dark powder with 99.5% purity) and iron oxide (produced by USA Company, molecular weight 25 g, described as a red powder with 99% purity) nanoparticles were separately dispersed in 75 milliliters of distilled water. A high-energy ultrasound device was utilized to ensure prolonged suspension of these particles in the water. Subsequently, the suspended solutions of copper and iron oxide were incorporated into the previously prepared polymer blend at various concentrations (2, 4, 6, 8, and 10 wt%). The final stage was employed using casting technology to create composite films from these materials on glass slides, with thicknesses ranging from 0.15 to 0.2 μm. These films were then subjected to various tests to determine their optical properties.

3 RESULTS AND DISCUSSION

3.1 The absorbance (a)

The UV-Vis absorption spectra of the PANI pure, PVA pure, and (PVA: PANI) blend in aqueous solution are shown in Figure 1. The results indicated low absorption spectrum of pure PVA across all wavelengths, indicating the material's transparency in the UV and visible ranges. This suggests that the material does not have double bonds or components that are highly absorbed in this range [11]. The results indicated an increase in the absorption of PANI compared to PVA. According to the law of Beers, the absorption is proportional to the number of absorbing molecules [12]. This indicates the presence of double bonds and electronic properties that absorb light in the UV and visible range. Absorption peaks are attributed to electronic transitions ($\pi - \pi^*$ or $n - \pi^*$) within the polymer.

UV-vis spectra of the PVA: PANI blend had a greater absorption peak at shorter wavelengths (in the ultraviolet region), indicating that polyaniline is the primary factor contributing to the absorbance. This peak showed an increase in absorbency compared to the two compounds individually, indicating the synergistic effect of PVA and PANI in enhancing the absorbency of the mixture in the 300-350 nm region, attributed to the ($\pi - \pi^*$) transition of the benzenoid rings. Another peak greater than 400 nm is attributed to localized polarons, which is a characteristic of protonated PANI [13].

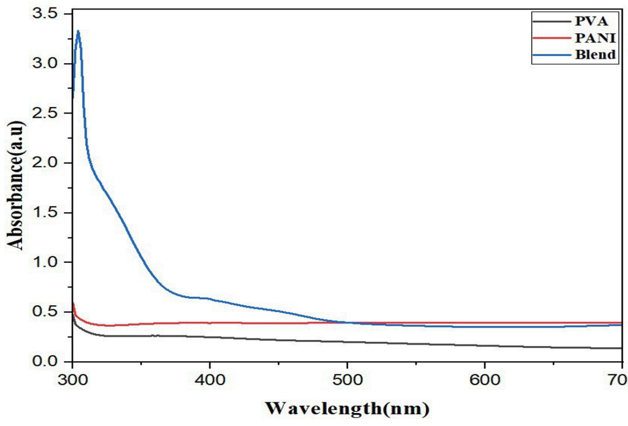

Fig. 1 Absorption spectra of PANI, PVA polymers and (PVA: PANI) blend

The results shown in Figure 2 indicate the UV-Vis absorption spectra of a blend composed of polyvinyl alcohol (PVA) and polyaniline (PANI) in a 50:50 ratio, doped with varying concentrations of copper oxide (CuO) and iron oxide (Fe_2O_3) hybrid nanoparticles within 300 – 1000 nm. The doping concentrations range from 2% to 10%. The analysis focuses on changes in optical properties as the nanoparticle concentration increases. The observed spectra offer valuable insights into the optical and electronic properties of the polymer-nanocomposite. The sudden increase in absorbance at shorter wavelengths is due to $\pi - \pi$ and $n - \pi$ involved electronic transitions in the PANI matrix, a characteristic of conjugation polymer systems. These changes are driven by the oxidation and doping states of PANI. Increased absorption in the UV region implies that both CuO and Fe_2O_3 nanoparticles add new electronic states, resulting in enhanced light absorption. This is in line with reports of metal oxide nanoparticles as active sites for charge generation and transfer in nanocomposite materials. These findings are consistent with conducted experiments on polymer nanocomposites [14].

In the Visible to Near-Infrared Region (400–1000 nm), the progressive reduction of absorbance is characteristic of semiconducting materials due to the preferential decline of photon absorption at longer wavelengths. A significant increase in overall absorbance values was observed with increasing nanoparticle concentration. Additionally, the incorporation of copper oxide (CuO) and iron oxide (Fe_2O_3) nanoparticles enhanced the optical density of the material. This improvement is likely a consequence of the local surface plasmon resonance (LSPR) by the nanoparticles, primarily CuO, and the quantum confinement effects of Fe_2O_3 nanoparticles [15]. With the increasing concentration of nanoparticles, the number of scattering centers and light absorption sites increases, resulting in a higher absorbance across the entire spectrum. Fe_2O_3 nanoparticles are well-known for intensive absorption in the UV-Vis spectral region due to their intrinsic bandgap $\sim$ 2.2 eV), whereas the other CuO $\sim$ 1.2 – 1.9 eV) contributes to deep absorption in the visible and near-infrared regions.

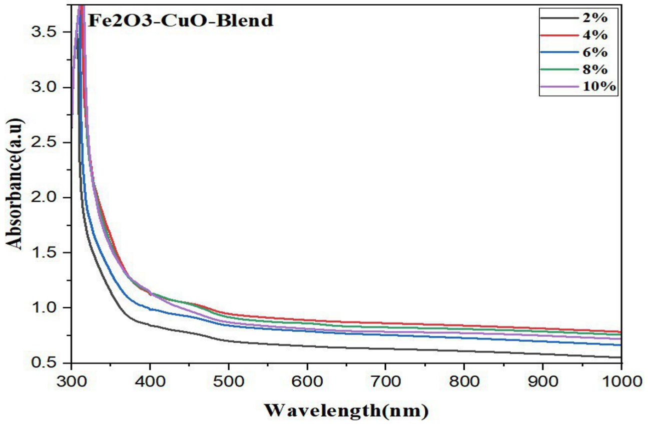

Fig. 2 Absorption spectra of PVA: PANI blend doped with different concentrations of CuO: Fe_2O_3 nanocomposites

3.2 Transmission (T_r)

Figure 3 displays the transmission spectra of pure polyvinyl alcohol (PVA), pure polyaniline (PANI), and their 50 : 50 weight blend across the wavelength range 300 – 1100 nm. Transmission spectra offer insights into the material's transparency, optical properties, and interactions between components in a polymer blend. The pure PVA showed the highest transmission among the samples, particularly in the visible and near-infrared regions (400 – 1100 nm). This is a feature of its amorphous, insulating behavior and its low interaction with light at this wavelength. On the other hand, a relatively large decrease in transmission was also observed in the UV absorption region (300 – 400 nm), which resulted from PVA's intrinsic absorption, such as electronic transitions (e.g., $n \rightarrow \pi^*$ from $C = 0$ groups of the polymer chains).

PANI showed reduced transmission across the spectrum compared to PVA due to its conjugated π-electron system, which enhances absorption in the UV and visible ranges. The primary electronic transitions in PANI are

$\pi \longrightarrow \pi^*$ transitions occurring in the conjugated chains of the polymer. These transitions involve the excitation of electrons from the highest occupied molecular orbital (HOMO), primarily a π orbital, to the lowest unoccupied molecular orbital (LUMO), which is a π^* orbital. Moreover, there was broad flattening in the visible region ($400-800$ nm). This behavior indicates strong light absorption, which is typical for doped or partially doped PANI, contributing to its semiconducting properties. The PVA: PANI blend curve lies between the PVA and PANI curves (Gray Curve), reflecting the combined optical properties of the two polymers. These blends showed reduced transmission in the UV region compared to pure PVA, likely due to the incorporation of PANI, which dominates the UV absorption. In addition, the transmission was lower than PVA but higher than PANI (intermediate transmission), suggesting a balance between transparency and light absorption in the blend. This behavior could be attributed to the partial interaction between the two polymers, where PANI's conjugated structure influences the optical properties of the composite.

On the other hand, the optical behavior of the 50:50 PVA-PANI blend suggests partial miscibility, where the hydrophilic nature of PVA interacts with the polar groups in PANI (e.g., amine groups). This interaction can influence the blend's morphology and optical properties. While the conjugated structure of PANI can form localized electronic states that modify the light interaction of the PVA matrix, reducing transmission and enhancing absorption.

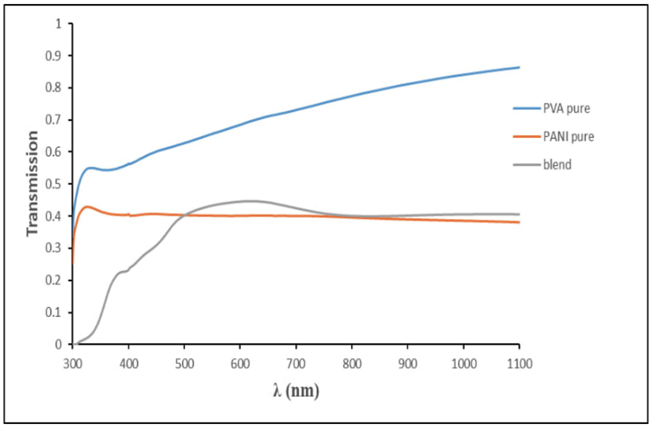

Fig. 3 Transmission of PVA pure, PANI pure, and PVA: PANI blend

Figure 4 illustrates the transmission spectra of a polymer blend consisting of polyvinyl alcohol (PVA) and polyaniline (PANI) ($50:50$ weight ratio) doped with varying concentrations ($2\%, 4\%, 6\%, 8\%$, and 10%) of copper oxide (CuO) and iron oxide (Fe_2O_3) hybrid nanoparticles. This spectrum provides insights into the impact of nanoparticle doping on the optical transparency and electronic interactions within the polymer blend matrix. The overall transmittance across the UV-Vis-NIR range of the nanocomposite films decreased as the doping concentration of CuO and Fe_2O_3NPs increased. This was consistent with the behavior of doped polymer nanocomposites, where the introduction of nanoparticles creates additional absorption centers and scattering sites, reducing light transmission. The sharp decrease in transmittance in the UV range ($300-400$ nm) is characteristic of electronic transitions in both the polymer blend and the metal oxide nanoparticles, where $\pi \longrightarrow \pi^*$ transitions in the conjugated polyaniline chains dominate. Additionally, both CuO and Fe_2O_3NPs exhibited strong absorption in the UV region due to their bandgap transitions. The reduced transmission at short wavelengths ($300-400$ nm) is consistent with the high absorption of oxides at these wavelengths. As the wavelength increases, transmission gradually increases, reflecting a reduction in absorbance [16].

A gradual increase in transmittance was observed in the visible region (400–700 nm). This is attributed to the semi-transparent nature of the polymer blend in this range and reduced absorption efficiency of CuO and Fe_2O_3 nanoparticles at longer wavelengths. The transmittance continues to increase slightly Near-Infrared Region (700–1100 nm), indicating that the material becomes more transparent as photon energy decreases. This is typical for materials with a significant reduction in electronic absorption and scattering at higher wavelengths.

3.3 Absorption coefficient (α)

Figure 5 shows the absorption coefficient curves (α) as a function of the wavelength (λ) of PVA and PANI and their blend with a ratio of $50:50$ by weight. Pure PVA is a polymer with a transparent nature, primarily in the visible and near-infrared regions. It shows a relatively low absorption coefficient across the spectrum. The absorption peak at shorter wavelengths (<400 nm) can be attributed to transitions related to minor impurities or the polymer's inherent electronic properties. The results of this study agree with the findings of previous researchers [17].

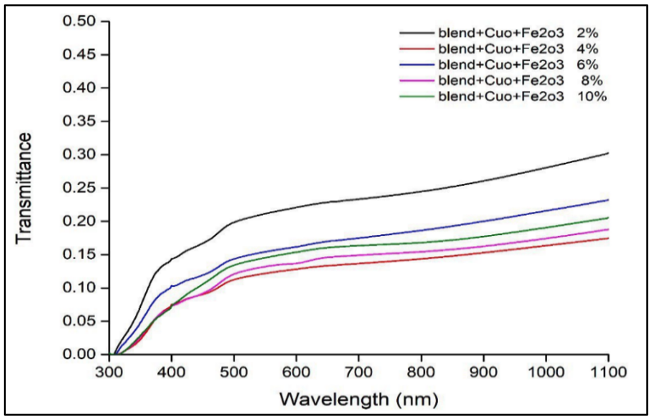

Fig. 4 Transmission of PVA: PANI with CuO: Fe_2O_3 at different concentrations, 2%, 4%, 6%,8% and 10%

PANI had a significantly higher absorption coefficient compared to PVA, especially in the UV-visible region. This can be attributed to the $\pi - \pi^*$ electronic transitions in the benzenoid rings and excitations in the quinoid structures of the polyaniline backbone. In addition, PANI's absorption in the near-infrared region indicates the presence of delocalized polarons and bipolarons, which arise from the doping process. The flat absorption tail in the visible to NIR regions suggests the presence of conducting states. This was due to its conjugated structure. The high absorption coefficient of PANI makes it suitable for optoelectronic applications, such as solar cells and sensors. These results are in agreement with previous studies [18, 19]. While the blend exhibited a higher absorption coefficient than pure PVA, lower than pure PANI, indicating an intermediate behavior. The peak at shorter wavelengths resembles the contribution of PANI's conjugated system, while the absorption tail in the visible-NIR region reflects the interaction between PVA and PANI. The hybrid behavior suggests partial compatibility and interaction between the two polymers. The addition of PVA likely reduces the density of PANI's polarons, thereby slightly lowering the optical absorption. Polymer blends of conducting and insulating polymers often display intermediate optical properties, with studies confirming such behavior in similar systems [20].

Figure 6 represents the absorption coefficient (α) in terms of the wavelength (λ) for polymer blends composed of polyvinyl alcohol (PVA) and polyaniline (PANI) in a 50:50 ratio. The doping was performed using nanosized CuO (copper oxide) and Fe_2O_3 (iron oxide) nanoparticles at different concentrations (2%, 4%, 6%, 8%, and 10%). The high absorption coefficient (α) values, especially in the UV and visible regions (300–500 nm), indicate strong optical absorption in these regions. This can be attributed to the intrinsic electronic transitions in the polymer blend and the influence of the dopants. There is an observable increase in absorption across the UV and visible regions, with the effect stabilizing at higher concentrations (8% and 10%). The metal oxide nanoparticles, such as CuO and Fe_2O_3, create new energy levels within the band gap of the polymer blend, resulting in enhanced optical absorption. These levels act as trapping sites for electrons, promoting charge transfer between the nanoparticles and the polymer chains.

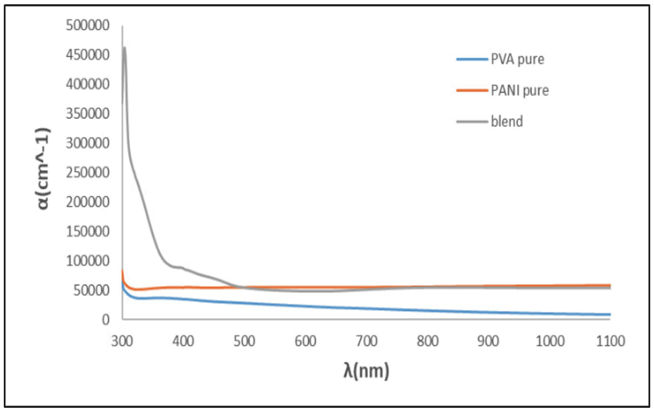

Fig. 5 Absorption Coefficient (α) of PVA pure, PANI pure, PVA: PANI blend

The interaction of PANI's π-electrons with the dopants leads to high charge transfer transitions and, consequently, a higher absorption coefficient. This type of behavior indicates that the introduction of the nanoparticles increases the polymer optical density by promoting more efficient charge transfer interactions between the metal oxide nanoparticles and the polymer matrix. The plateau appearing at 800 nm reflects decreased absorption in the near-infrared wavelength region, indicating the material's suitability for use in optical filters or solar cells [21]. The steep absorption edge in the UV region (300–400 nm) is primarily due to $\pi - \pi^*$ electronic transitions in polyaniline and the absorption characteristics of PVA. The doping enhances these transitions, suggesting the creation of defect states or better charge carrier generation. The visible light absorption increases with higher dopant concentrations in the visible region (400–700 nm), attributed to the localized surface plasmon resonance (LSPR) effect from CuO and Fe_2O_3 NPs. This effect indicates enhanced interaction between light and nanoparticles, improving the material's optical sensitivity.

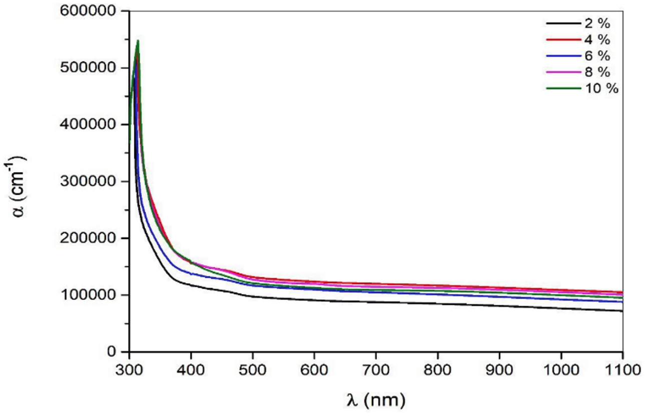

Fig. 6 Absorption Coefficient (α) of PVA: PANI with CuO: Fe_2O_3 hybrid NPs at different concentrations 2%, 4%, 6 %, 8% and 10%

3.4 Optical band gap

The plots shown in Figure 7 indicate the Tauc relationship used to determine the optical energy band gap (E_g) for Polyvinyl Alcohol (PVA), Polyaniline (PANI), and their 50:50 blend. The optical energy band gap (E_g) was calculated by extrapolating the linear portion of the $(\alpha h\nu)^2$ vs. $h\nu$ plot to the energy axis ($h\nu$) where $(\alpha h\nu)^2 = 0$. The parameter α represents the absorption coefficient, and $h\nu$ is the incident photon energy, which can be calculated from $h\nu = 1240/\lambda$ [9]. In the first graph, the linear region is extrapolated to intersect the energy axis around $Eg \approx 4.0$eV. This value aligns with the reported band gap for pure PVA, which is typically a wide-bandgap polymer due to its insulating nature. It is confirmed by earlier works that PVA exhibits a direct band transition between the localized highest occupied molecular orbital (HOMO) and lowest unoccupied molecular orbital (LUMO) band edges [14]. Such high values are indicative of electronic transitions predominantly involving $\pi - \pi^*$ or $\sigma - \sigma^*$ states [22]. The second graph shows $E_g \approx 3.8$eV, which is slightly lower than that of PVA. PANI exhibits semiconducting properties due to its conjugated structure, where delocalized π electrons contribute to its optical transitions. Typically, PANI has a relatively small energy gap due to its chemical structure, which allows for the possibility of electron movement when light is absorbed. This value is consistent with previous reports for PANI in its doped or dedoped forms, depending on the synthesis route [23]. The third graph indicates a band gap $E_g \approx 3.9$eV. The blending of PVA with PANI resulted in slight modifications to the band structure. The intermediate value reflects the interaction between the insulating PVA matrix and the semiconducting PANI. Such behavior is observed in hybrid materials where the polymer matrix influences the optical properties of the composite, which can lead to improved conductivity or other properties such as optical absorption.

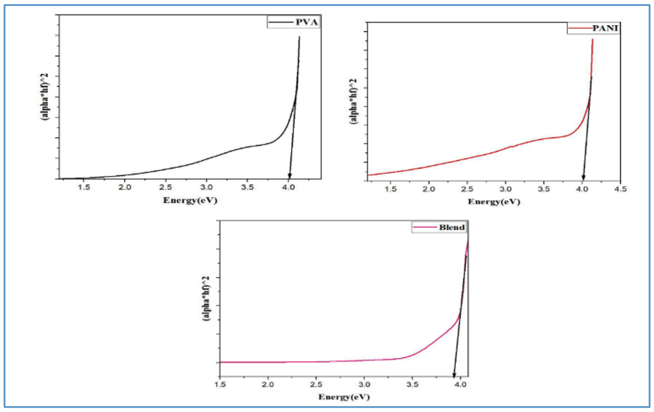

Fig. 7 Optical direct band gap energy (E_g) of the prepared PVA Pure, PANI Pure and PVA:PANI blend

In the case of the PVA/PANI blend with a 50:50 composition, doping with nanostructured metal oxides such as CuO and Fe_2O_3 introduces significant changes in the electronic and optical properties of the polymer blend matrix. Figure 8 represents the direct band gap of the PVA/PANI blend system with different iron oxide and copper oxide ratios (CuO : Fe_2O_3). The data shows that the optical energy gap is gradually decreasing from 3.96 eV by 2% to 3.79 eV at 10%. CuO and Fe_2O_3 nanoparticles, with their distinct electronic structures, are known to act as charge transfer centers when embedded in polymer matrices. Their inclusion creates localized states within the band gap of the polymer blend, resulting in a reduction of the optical band gap. This is often attributed to the formation of new energy levels, where the nanoparticles interact with the polymer chains, creating mid-gap states that facilitate electronic transitions at lower energies. Additionally, CuO and Fe_2O_3 nanoparticles enhance the conductivity of the PANI phase due to their inherent semiconducting properties, which further affects the energy gap. As shown in Figure 8, the presence of the CuO : Fe_2O_3 NPs within the PVA:PANI polymer causes the jumping of the electrons in the valence band to the conduction band with the generation of more structural impurities and localized states in the forbidden band, thus decreasing the optical energy values of these doped films [24, 25].

Iron and copper oxides act as quantum point analogues, providing additional electronic states in the energy structure of the system. With increased concentration, the effect of further fusion between polymeric components and oxides was observed. The optical band gap decreases with increasing concentrations of CuO/Fe_2O_3 nanoparticles. This trend can be attributed to enhanced interactions between the nanoparticles and the polymer chains, resulting in increased charge carrier density, enhanced polarization effects, and the formation of extended π-conjugation in the PANI chains. The absorption edge shifts toward longer wavelengths (redshift) with increasing doping concentration.

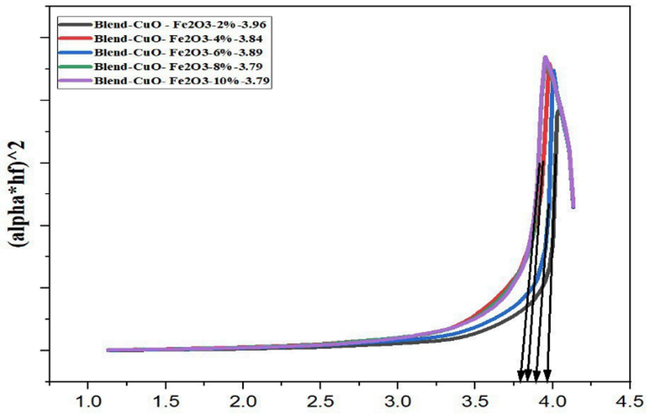

Fig. 8 Optical direct band gap energy (E_g) of the prepared PVA:PANI with different concentration at (2%, 4%, 6%, 8%, and 10%) of CuO:Fe_2O_3 NPs

Considerable attention has been focused on determining the optical band gap of films and colloids of polyvinyl alcohol (PVA), poly(aniline) (PANI), and the film and colloidal composite of PVA and polyaniline (PANI), especially concerning indirect electronic transitions. The optical band gap is one of the most important characteristics that affects the optical and electronic behaviour of materials and plays a seminal role in the optoelectronic development of materials. In polymers (e.g., polyvinyl alcohol), the optical band gap can be varied by several parameters, including film thickness, doping, and the addition of additives. For the PVA and PANI films, as well as their blend, it has been demonstrated that the optical band gap of the indirect transitions can be determined from the absorption spectra and from the application of Tauc's relationship, as presented in Figure 9.

The optical energy band gap (Eg) of the indirect transition is a fundamental parameter that determines the electronic transitions in a material, influencing its applications in optoelectronic devices. The blend of polyvinyl alcohol (PVA) and polyaniline (PANI) in a 50:50 ratio combines the properties of a flexible polymer matrix (PVA) and a conducting polymer (PANI), making it a versatile material for such studies. The energy gap of the indirect transfer allowed from drawing the relationship between $(\alpha h\nu)^{1/2}$ and energy $(h\nu)$ was also calculated, and it was found that it decreases with the increase in different concentrations of oxides, as shown in Figure 9.

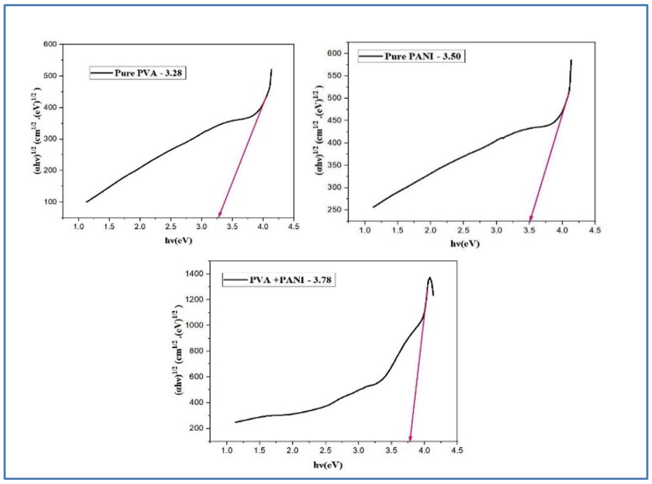

Fig. 9 Optical indirect band gap energy (E_g) of the prepared PVA Pure,PANI Pure and PVA:PANI

It can be observed that, with an increase in the concentration of metal oxides of nanoparticles or their mixture, the energy gap decreases due to increased interactions between the carriers in (VB) and (CB), which leads to shifts in the (VB) and (CB) and a decrease in the band gap. At the same time, the decrease in optical gap reflects the formation of charge transfer complexes (CTCs) as trap levels between the HOMO and LUMO bands of PVA [26, 27], which improves low-energy transitions, as shown in Figure 10 and Table 1.

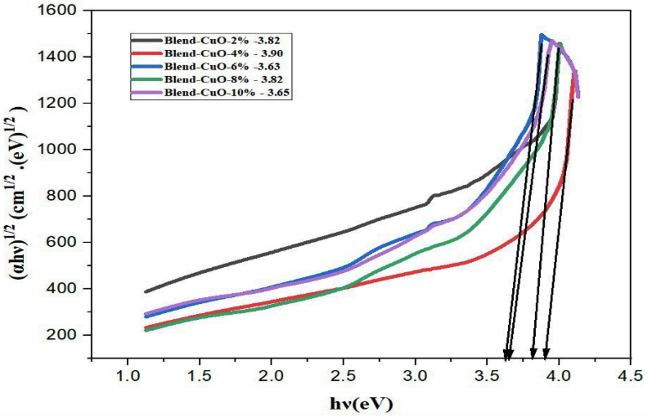

Fig. 10 Optical indirect band gap energy (E_g) of the prepared PVA:PANI with different concentrations at (2%,4%,6%,8%,10%) of CuO

Table 1 Optical energy band gap values for permissible direct and indirect conversions of (PVA: PANI/CuO:Fe_2O_3) nanocomposite films

Prepared films	**Concentrations of NPs wt%**	**Optical energy band gap (eV)**	
		Direct allowed	**Indirect allowed**
PVA PURE	0	4.1	3.28
PANI	0	4	3.50
PVA:PANI (50:50)	0	3.9	3.78
$CuO \cdot Fe_2O_3$	2	3.96	3.84
	4	3.84	3.66
	6	3.89	3.97
	8	3.79	3.6

4 CONCLUSION

Pure PVA exhibits high transparency across the UV, visible, and NIR regions, with low absorption due to its insulating and amorphous nature. While pure PANI demonstrates increased absorption, particularly in the UV and visible regions, attributed to $\pi \rightarrow \pi^*$ and $n \rightarrow \pi^*$ electronic transitions within its conjugated structure. However, the PVA:PANI blend exhibits intermediate properties, with enhanced absorption in the UV region due to the synergy between PVA and PANI, indicating partial miscibility and improved optical properties. The inclusion of CuO and Fe_2O_3 nanoparticles significantly improves the optical absorption properties of the PVA-PANI blend, particularly in the UV-Vis region. The variation of the absorption coefficient with dopant concentration reveals valuable insights into the optical behavior of the PVA-PANI blend. The interaction between the polymer matrix and metal oxide nanoparticles enhances absorption and modifies electronic transitions, making the material promising for optoelectronic and photovoltaic applications. Doping with CuO and Fe_2O_3 nanoparticles further reduces the optical band gap, from 3.96 eV at 2% doping to 3.79 eV at 10%, attributed to the formation of mid-gap states, increased charge carrier density, and enhanced interaction between nanoparticles and polymer chains.

ACKNOWLEDGEMENT

N/A

FUNDING SOURCE

No funds received.

DATA AVAILABILITY

N/A

DECLARATIONS

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Consent to publish

All authors consent to the publication of this work. Written informed consent for publication was obtained from the participants.

Ethical approval

N/A

REFERENCES

[1] Singh P, Shukla SK. Advances in polyaniline-based nanocomposites. Journal of Materials Science. 2019;55(4):1331–1365. 10.1007/s10853-019-04141-z

[2] Tadesse MG, Ahmmed AS, Lübben JF. Review on Conductive Polymer Composites for Supercapacitor Applications. Journal of Composites Science. 2024;8(2):53. 10.3390/jcs8020053

[3] Alshammari AH. Structural, Optical, and Thermal Properties of PVA/SrTiO3/CNT Polymer Nanocomposites. Polymers. 2024;16(10):1392. 10.3390/polym16101392

[4] Omar RA, Hammed MG. PPY: PVA Blend Enhanced with Metal Salt for Gas Sensing Appli-

cations. Journal of Inorganic and Organometallic Polymers and Materials. 2024;35(4):3158–3168. 10.1007/s10904-024-03450-4

[5] El-naggar AM, Heiba ZK, Kamal AM, Mohamed MB. Assessment of performance based on structure, dielectric and linear/nonlinear optical properties of PVA/CMC/PVP blends loaded with ZnS/Co. Optical and Quantum Electronics. 2023;55(6). 10.1007/s11082-023-04779-9

[6] Morad MA, Abo Ghazala MS, El-Shaarawy MG, Gouda ME, Elrasasi TY. Preparation and characterization of conjugated PVA/PANi blend films doped with functionalized graphene for thermoelectric applications. Scientific Reports. 2024;14(1). 10.1038/s41598-024-66691-w

[7] Hassan AA, Hammed MG. Synthesis, and Study the Electrical Properties of Conductive (PVA:PANI)/CuI Blend Composite. Journal of Physics: Conference Series. 2021;1829(1):012009. 10.1088/1742-6596/1829/1/012009

[8] Abdelhamied MM, Atta A, Abdelreheem AM, Farag ATM, El Sherbiny MA. Oxygen ion induced variations in the structural and Linear/Nonlinear optical properties of the PVA/PANI/Ag nanocomposite film. Inorganic Chemistry Communications. 2021;133:108926. 10.1016/j.inoche.2021.108926

[9] Abdelhamied MM, Atta A, Abdelreheem AM, Farag ATM, El Okr MM. Synthesis and Optical Properties of PVA/PANI/Ag Nanocomposite films. Journal of Materials Science: Materials in Electronics. 2020;31(24):22629–22641. 10.1007/s10854-020-04774-w

[10] Greenaway DL, Harbeke G. Optical Properties and Band Structure of Semiconductors: International Series of Monographs in The Science of The Solid State. vol. 1. Elsevier; 2015

[11] Thejas Urs G, Hurkadli RV, Basavaraj RV, Niranjana M, Manjunath A, Somashekar R. Study of optical and conducting properties of FeCl3 doped PVA polymers. Progress in Crystal Growth and Characterization of Materials. 2014;60(3–4):87–93. 10.1016/j.pcrysgrow.2014.09.003

[12] Mansour A, Elfalaky A, Maged FA. Synthesis, characterization and optical properties of PANI/PVA blends. IOSR J Appl Phys. 2015;7(4):37-45

[13] Bhadra J, Madi NK, Al-Thani NJ, Al-Maadeed MA. Polyaniline/polyvinyl alcohol blends: Effect of sulfonic acid dopants on microstructural, optical, thermal and electrical properties. Synthetic Metals. 2014;191:126–134. 10.1016/j.synthmet.2014.03.003

[14] Sangamesha MA, Rajanna K, Shivaraju VK, Madhukar BS. Preparation and characterization of down converting poly (vinyl alcohol)/ PANI@CuS hybrid nanocomposites for optoelectronic application. Chemistry of Inorganic Materials. 2023;1:100025. 10.1016/j.cinorg.2023.100025

[15] Al-Hammadi AH, Alnehia A, Al-Sharabi A, Alnahari H, Al-Odayni AB. Synthesis of trimetallic oxide (Fe2O3–MgO–CuO) nanocomposites and evaluation of their structural and optical properties. Scientific Reports. 2023;13(1). 10.1038/s41598-023-39845-5

[16] El-naggar AM, Alsaggaf A, Heiba ZK, Kamal AM, Aldhafiri AM, Mohamed MB. Impact of MWCNTs on the structural, electrical, and optical characteristics of PVA/PANi blends. Journal of Taibah University for Science. 2023;17(1). 10.1080/16583655.2023.2207769

[17] Hussien HM. Optical properties of polyvinyl alcohol-glass waste powder composites. Discover Applied Sciences. 2025;7(2). 10.1007/s42452-025-06477-5

[18] Ghoswami M, Ghosh R, Chakraborty G, Gupta K, Meikap AK. Optical and electrical properties of polyaniline-cadmium sulfide nanocomposite. Polymer Composites. 2011 nov;32(12):2017–2027. 10.1002/pc.21235

[19] Khan I, Mansha M, Jafar Mazumder MA. Polymer blends. InFunctional polymers 2019 (pp. 513-549). Springer, Cham.

[20] Matysiak W, Tański T, Smok W, Gołombek K, Schab-Balcerzak E. Effect of conductive polymers on the optical properties of electrospun polyacrylonitryle nanofibers filled by polypyrrole, polythiophene and polyaniline. Applied Surface Science. 2020;509:145068. 10.1016/j.apsusc.2019.145068

[21] Elessawy NA, Gouda MH, Elnouby M, Taha NA, Youssef ME, Santos DMF. Polyvinyl Alcohol/Polyaniline/Carboxylated Graphene Oxide Nanocomposites for Coating Protection of Cast Iron in Simulated Seawater. Polymers. 2022;14(9):1791. 10.3390/polym14091791

[22] El-naggar AM, Alsaggaf A, Heiba ZK, Kamal AM, Aldhafiri AM, Fatehmulla A, et al. Exploring the structural, optical and electrical characteristics of PVA/PANi blends. Optical Materials. 2023;139:113771. 10.1016/j.optmat.2023.113771

[23] Stejskal J, Gilbert RG. Polyaniline. Preparation of a conducting polymer(IUPAC Technical Report). Pure and Applied Chemistry. 2002;74(5):857–867. 10.1351/pac200274050857

[24] Al-Hakimi A, Asnag G, Alminderej F, Alhagri I, Al-Hazmy S, Qahtan T. Enhancing the Structural, Optical, Thermal, and Electrical Properties of PVA Filled with Mixed Nanoparticles (TiO2/Cu). Crystals. 2023;13(1):135. 10.3390/cryst13010135

[25] Tekin D, Birhan D, Kiziltas H. Thermal, photocatalytic, and antibacterial properties of calcinated nano-TiO2/polymer composites. Materials Chemistry and Physics. 2020;251:123067. 10.1016/j.matchemphys.2020.123067

[26] Soliman TS, Abouhaswa AS. Synthesis and structural of Cd0.5Zn0.5F2O4 nanoparticles and its influence on the structure and optical properties of polyvinyl alcohol films. Journal of Materials Science: Materials in Electronics. 2020;31(12):9666–9674. 10.1007/s10854-020-03512-6

[27] Khairy Y, Yahia IS, Elhosiny Ali H. Facile synthesis, structure analysis and optical performance of manganese oxide-doped PVA nanocomposite for optoelectronic and optical cut-off laser devices. Journal of Materials Science: Materials in Electronics. 2020;31(10):8072–8085. 10.1007/s10854-020-03348-0

How to cite this article

Abed BM, Hammed MG. Preparation and study of PVA/PANI nanocomposite films properties doped with metal oxides using spectroscopic analysis techniques. Journal of University of Anbar for Pure Science. 2025; 19(2):116-125. doi:10.37652/juaps.2025.157078.1354