Optical And Electrical Properties of PVA/α-Al₂O₃ Nanocomposite Films

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Abstract

In the present study, α-Al₂O₃ nanoparticles were synthesized using the citrate-nitrate auto combustion method. Nanocomposites of PVA/α-Al₂O₃ were intended by solution casting technique. The micrograph of samples were analysed by X-ray diffraction (XRD), high resolution transmission electron microscopy (HRTEM), field emission scanning electron microscopy (FESEM) and UV-visible spectroscopy analysis. UV-visible results showed that the direct optical band gap decreased with the increase of α-Al₂O₃ content. The refractive index has been dissected using Wemple and DiDomenico model. Hopping of charge carriers besides interfacial polarization could expound the demeanor of dielectric constant (ε'), dielectric loss (ε'') and ac electrical conductivity (σac) with the frequency and temperatures.

Keywords: PVA; A α-Al₂O₃ nanoparticles; Nano composites; optical constants; electrical properties.

1. Introduction

Nanoparticles’ research is presently an objective domain of scientific weal due to its potential applications in several fields from optical, electrical to biological. Metal oxide nanoparticles have been exceedingly improved in the past decennium. They have been vastly utilized in numerous applications such as catalysts, sensors, semiconductors, medical science, capacitors, and batteries [1-6]. Among them, aluminum oxide, Al₂O₃, is transpiring. Alumina has sundry phases such as gamma, delta, theta, and alpha, the farthest thermodynamically stable form is α-Al₂O₃[7]. Al₂O₃ have become more prevalent for their high dielectric strength, a wide optical band gap, exceptional stability, and durability against hostile environments and high transparency down to 250 nm. Also, α-Al₂O₃ been excessively utilized for their practical applications, such as refractory coatings, antireflection coatings, anticorrosive coatings [8], microelectronic devices [9], capacitance humidity sensors [10], and silicon solar cells [11], and as insulating material, in the form of thin films, in semiconductor devices [12]. Polymer nanocomposites have received intensive awareness and research in the neoteric years. Polymer nanocomposites have been elaborated for their marvelous properties such as light weight, high flexibility, and ability to be feigned at low temperature and low cost, and application in various fields such as radiation detection, coating, paints, sensors, LEDs, display, optoelectronics devices and biological application [13-16]. The physical properties of polymers may be influenced by doping α-Al₂O₃. Polyvinyl alcohol (PVA) is a semi crystalline, non-toxic, water soluble and mild electrical conductivity material with numerous technological and biomedical applications [17]. In this work, synthesis and characterization of α-Al₂O₃ nanoparticles then preparing PVA/α-Al₂O₃ nanocomposite films via dispersion different amount of the α-Al₂O₃ (0, 2.5, 5, 7.5, 10, and 15 wt%) in PVA matrix were investigated. The resulting hybrid films were described by X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FT-IR), field emission scanning electron microscopy (FE-SEM), and UV-visible absorption spectra techniques, then optical and electrical properties were studied.

2. Materials and Methods

Polyvinyl alcohol (PVA) from Sigma Aldrich, with average molecular weight of 50,000–85,000 and 97% hydrolyzed was used without further purification. Aluminum nitrate [Al(NO₃)₃·9H₂O] and citric acid (C₆H₈O₇)
also were purchased from Aldrich. Reactant solutions were made in doubly distilled water. Nano-sized particles of \( \alpha-Al_2O_3 \) were prepared using the citrate-nitrate combustion method \[18\]. The molar ratio of metal nitrates to citric acid was 1:1. A small amount of ammonia was added to the solution to adjust the pH value at 7. The precursor mixture was then heated to 1200 °C for 5h. The nanocomposite films were prepared by the well-known solution casting technique. As prepared \( \alpha-Al_2O_3 \) nano powders was added into the aqueous solution of PVA in the following composition \( \text{w/w between} \ \alpha-Al_2O_3 \ \text{and PVA solution concentration): 0%, 2.5%, 5%, 7.5%, 10% and 15% then stirred carefully by using magnetic stirrer until well dispersion \( \alpha-Al_2O_3 / \text{PVA} \) was obtained. Each mixture is put in a Petri dish and leave to dry in a dust free chamber at room temperature to obtain the nanocomposite films. The X-ray diffraction (XRD) patterns were recorded at room temperature using an X-ray powder diffraction meter (Shimadzu XRD 6000) equipped with CuKα radiation source \( (\lambda = 1.54\AA) \) in the 2θ (Bragg angles) range \( (10° \leq 2θ \leq 80°) \) to report the information about their structure. The morphology and particle size distribution of the samples were identified using high resolution transmission electron microscope (HRTEM) JEOL-2100 at 200 KV. The Fourier transform infrared (FTIR) Jasco (Model 6100, Japan) was used in the range 400–4000 cm\(^{-1}\) and in the absorbance mode at a resolution of 4.0 cm\(^{-1}\). The morphology of the samples was identified using the field emission scanning electron microscope (FESEM) model Quanta FEG250. Different phases were conducted by Energy Dispersive X-ray Spectrometry (EDS). The absorbance spectra (A) and the transmittance spectra (T) of the films were recorded at 200–1100 nm wavelength using a dual beam (UVS-2800) UV–Visible spectrophotometer. The dielectric measurements were measured using impedance analyzer (IM3570) in the temperature range from 303 to 453 K in the frequency range from 4 Hz to 5 MHz.

3. Results and Discussion

3.1. X-ray analysis

The X-ray diffraction pattern (XRD) for pure polyvinyl alcohol (PVA) sample is shown in Fig.1a. The XRD pattern manifests a strong broad diffraction peak appeared at \( 2θ = 20.12° \) which identical to \( (101) \) reflection plane of PVA and a more peak at 41.62° confirming the semi-crystalline nature of PVA i.e., entity of crystalline and amorphous parts \[19-20\]. This diffraction peak assured that, the PVA film is pure without any other impurities. Fig.1b shows the XRD of highly crystalline \( \alpha-Al_2O_3 \). The crystal planes, \((012), (104), (110), (006), (113), (024), (116), (211), (018), (214) \) and \((300) \) confirmed the formation of \( \alpha-Al_2O_3 \) in a pure single hexagonal phase according to JCPDS card no. 42-1468. The X-ray diffraction patterns for \( \alpha-Al_2O_3 / \text{PVA} \) nanocomposite films are shown in Fig.1c. XRD patterns of all \( \alpha-Al_2O_3 / \text{PVA} \) nanocomposite films showed a broad peak at \( 2θ \approx 19.90 \) which is attributed to PVA \[19, 21\] and the other peaks correspond to \( \alpha-Al_2O_3 \). The diffraction peak correspond to \( \alpha-Al_2O_3 \) is very small compared with that of PVA, because the concentration of \( \alpha-Al_2O_3 \) is very low compared with that of PVA. This small peak increase by increasing \( \alpha-Al_2O_3 \) contents reaching 15%, as shown in Fig.1c. Meanwhile, in the \( \alpha-Al_2O_3 / \text{PVA} \) nanocomposite, the diffraction peaks of \( \alpha-Al_2O_3 \) are fixed at 2θ and show diffraction patterns similar to those of pure \( \alpha-Al_2O_3 \). This denotes that the \( \alpha-Al_2O_3 \) unchanged after being doped into the PVA matrix. The mean crystallite size of the ordered \( \alpha-Al_2O_3 \) nanoparticles has been inferred from Debye–Scherrer’s formula \[22\]:

\[
D = \frac{0.9λ}{βcosθ}
\]

The estimated crystallite size of \( \alpha-Al_2O_3 \) nanoparticles was found \( \approx 29 \) nm.

3.2. FTIR analysis

The IR spectroscopy in the range 400–1000 cm\(^{-1}\) can be utilized as a swift and easy gadget to characterize the entity of transition \( \alpha-Al_2O_3 \) phase. The FTIR spectra for pure PVA, \( \alpha-Al_2O_3 / \text{PVA} \) nanocomposite films and \( \alpha-Al_2O_3 \) are shown in Fig. 2 (a-c). In the spectra of pure PVA and \( \alpha-Al_2O_3 / \text{PVA} \) nanocomposites, the broad and strong band posted at 3340 cm\(^{-1}\) which assigned to the stretching vibration of hydroxyl group (OH) \[23\]. The
robust band at 2940 cm$^{-1}$ is attributed to the band of asymmetric CH stretching [24]. The two bands recognized at 1712 and 1658 cm$^{-1}$ are assigned to the stretching vibrational band of C=O [25]. The two bands spotted at

Fig. 1(a-c): XRD pattern of pure PVA, α-Al$_2$O$_3$, α-Al$_2$O$_3$/ PVA nanocomposite films.
1427 and 1330 cm\(^{-1}\) are indexed as CH\(_2\) bending vibration and CH\(_2\) stretching, respectively [26]. The band at 1090 cm\(^{-1}\) engenders from the C–O stretching vibration while the band at 920 cm\(^{-1}\) generates from CH\(_2\) rocking vibration [27]. Also, the band at 850 cm\(^{-1}\) rises from C–C stretching vibration and that at 660 cm\(^{-1}\) arises from out of plane OH bending [19, 28]. The coalition α-Al\(_2\)O\(_3\) NPs in PVA produced slight mutates in the intensities of absorption bands besides the production of new absorption bands in the range of 600–400 cm\(^{-1}\); attributed to the Al–O stretching. This result assured the entity of α-Al\(_2\)O\(_3\) NPs in the PVA matrix. By adding 2.5 % and 5.0% Al\(_2\)O\(_3\), the bands were shifted higher wavenumber to 3575 and 6515 cm\(^{-1}\), respectively attributed to the Al–O stretching.

Fig. 2(a–c): FTIR spectrum of of pure PVA, α-Al\(_2\)O\(_3\), α-Al\(_2\)O\(_3\)/PVA nanocomposite films.
3.3. Electron microscopy analysis

HRTEM micrographs of α-Al2O3 nanoparticles are illustrated in Fig. 3a which exhibit clear platelet shape of hexagonal form, with average size 10 nm. Fig. 4(a,b) illustrates the field emission scanning electron micrographs FESEM images of α-Al2O3/PVA of 2.5% and 5% wt. nanocomposite, where it looks like clusters of cauliflower shape. From these micrographs, it was demonstrated that α-Al2O3 NPs were dispersed in the PVA matrix, because the α-Al2O3 nanofiller having excellent adhesion and strong interfacial bonding to the PVA beads. In addition, the results exhibited that the structure of the prepared 5% Al2O3 was more uniform than that of 2.5% Al2O3. The EDX patterns of 2.5% and 5% wt. nanocomposites are presented in Fig. 5 (a,b). It is distinctly seen that the two above concentrations consists of Al, C and O. The results indicate that the nanocomposite consists only of two phases namely α-Al2O3 and PVA as well as no other phases was detected which assure its successful preparation.

![HRTEM micrograph of the as-prepared α-Al2O3 nanoparticles.](image)

3.4 Optical properties:

Fig. 6 (a-c) shows the optical absorbance transmittance and reflectance spectra as a function of the wavelength of the incident light for α-Al2O3/ PVA nano composites of various filler contents are. The figure manifests that, the absorbance increases as a result of filler addition but no shift in the peak position. The adding of different amounts of filler to PVA does not alter the chemical structure of the material but new physical mixture is established. The analysis of the absorption coefficient, α at the fundament absorption edge was found to follow the relation [29]:

$$\alpha h \nu = B(h \nu - E_{op})^n$$

Where B is a constant rely on the transition probability and the exponent n, is an index that characterizes the
optical absorption process and is theoretically equal \((n = 1/2)\) for a direct allowed transition, \((n = 3/2)\) for a direct forbidden transition, \((n = 2)\) for an indirect allowed transition and \((n = 3)\) for an indirect forbidden transition. \(\alpha\) is the absorption coefficient, which calculated using the Beer-Lambert's relation [30]

\[
\alpha = 2.303 \frac{A}{t}
\]

Fig. 4(a,b): FESEM micrograph of 2.5 and 5% \(\alpha\)-\(\text{Al}_2\text{O}_3\)/PVA nanocomposites.
Fig. 5(a,b): EDS spectrum of 2.5 and 5% α-Al₂O₃/ PVA nanocomposites.

A and t are the absorbance and the thickness of the film. B is the parameter that depends on the inter band transition probability, hν is the incident photon energy, E₀ is the optical band gap. Fig.7 shows the relation between absorption edges (ahv)² for PVA and α-Al₂O₃/ PVA nanocomposites as a function of photon energy (hν), where n=1/2 for direct allowed. At extension of the curve to the value (ahv)²= 0, we can determine the direct band gap of the composites. The conclude values of optical band gap of the PVA and composites are recorded in table 1. It is exhibited thatPr the values of energy gap decrease with increasing α-Al₂O₃ concentration.

**Table 1:** Dispersion parameters of α-Al₂O₃/ PVA nanocomposite films at different concentration of α-Al₂O₃.

<table>
<thead>
<tr>
<th>α-Al₂O₃%</th>
<th>E₀ (eV)</th>
<th>Eₐ(eV)</th>
<th>Eₐ (eV)</th>
<th>Eₐ/ E₀</th>
<th>n₀</th>
<th>εₘ</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0%</td>
<td>3.82</td>
<td>5.10</td>
<td>3.86</td>
<td>1.34</td>
<td>1.33</td>
<td>1.76</td>
</tr>
<tr>
<td>2.5%</td>
<td>2.99</td>
<td>4.85</td>
<td>14.80</td>
<td>1.62</td>
<td>2.01</td>
<td>4.05</td>
</tr>
<tr>
<td>5.0%</td>
<td>2.94</td>
<td>4.65</td>
<td>25.49</td>
<td>1.58</td>
<td>2.54</td>
<td>6.48</td>
</tr>
<tr>
<td>7.5%</td>
<td>2.75</td>
<td>4.37</td>
<td>36.67</td>
<td>1.58</td>
<td>3.06</td>
<td>9.39</td>
</tr>
<tr>
<td>10.0%</td>
<td>2.42</td>
<td>4.31</td>
<td>144.92</td>
<td>1.78</td>
<td>5.88</td>
<td>34.62</td>
</tr>
<tr>
<td>15.0%</td>
<td>2.33</td>
<td>4.14</td>
<td>366.37</td>
<td>1.79</td>
<td>9.46</td>
<td>89.49</td>
</tr>
</tbody>
</table>
The ultimate remarkable optical property is the refractive index (n). The refractive index depends on the wavelength of light, and this dependence is called dispersion. In The refractive index as a function of wavelength can be estimated from the reflection coefficient data R and the extinction coefficient k using equations [31 - 32]:

Fig. 6(a-c): UV-visible absorption, transmission and reflection spectra of α-Al₂O₃/ PVA nanocomposite films.
The ultimate remarkable optical property is the refractive index \( n \). The refractive index depends on the wavelength of light, and this dependence is called dispersion. In the refractive index as a function of wavelength can be estimated from the reflection coefficient data \( R \) and the extinction coefficient \( k \) using equations [31 - 32]:

\[
k = \frac{\alpha \lambda}{4\pi}
\]

\[
n = \frac{(1 + R)}{(1 - R)} + \sqrt{\frac{4R}{(R-1)^2} - k^2}
\]

Fig. 6(a-c): UV-visible absorption, transmission and reflection spectra of \( \alpha-\text{Al}_2\text{O}_3/ \) PVA nanocomposite films.
Fig. 7 Relation between $(\alpha h \nu)^2$ and $(h \nu)$ for the pure PVA and $\alpha$-Al$_2$O$_3$/ PVA nanocomposite films.
Fig. 8 shows the variations of extinction coefficient with wavelength of α-Al₂O₃/ PVA nanocomposite. Fig. 9 shows the refractive index of the α-Al₂O₃/ PVA. The enhancement of the refractive index n and extinction coefficient k with wavelengths is correlated to the higher concentration of α-Al₂O₃ (from 25 to 15 wt. %) and thus more scattering of photons are occurred with the added aluminum oxide (α-Al₂O₃). The figure displays an increase with increasing fillers. The demeanor of (k) can be ascribed to high absorption coefficient. This result manifests that; the α-Al₂O₃ nanoparticles will amend the properties of the host polymer.

Fig. 8: The extinction coefficient of α-Al₂O₃/ PVA nanocomposite films.

Fig. 9: The refractive index of α-Al₂O₃/ PVA nanocomposite films.
The energy dependence of the refractive index for PVA and α-Al₂O₃/ PVA can be fitted by using the single oscillator model in the normal dispersion region developed by Wemple and DiDomenico [33] as:

\[ n^2 - 1 = \frac{E_o E_d}{E_o^2 - (h\nu)^2} \]

where \( E_o \) is the energy of the effective dispersion oscillator and \( E_d \) is the dispersion energy or oscillator strength. Fig. 10 illustrates \((n^2 - 1)^{-1}\) as a function of \((h\nu)^2\), for the investigated sample. \( E_o \) and \( E_d \) are obtained from the slope \((E_o E_d)^{-1}\) and intercept \(E_o/E_d\). The static refractive index, \( n_o \), at zero photon energy (long wavelength) can be predestined from equation, i.e. \( n_o^2 = 1 + E_d/E_o \) and then the static dielectric constant \( \varepsilon_s \) is given as \( \varepsilon_s = n_o^2 \). The values of \( E_o \) and \( E_d \) are listed in Table 1. The oscillator energy, \( E_o \), is an “average” energy gap and, in close approximation, it scales with the optical band gap, \( E_o \) \( E_o \approx 2 \) \( E_g \), as was found by Tanaka [34]. The ratio \( E_o / E_g \) for PVA and α-Al₂O₃/ PVA shows good agreement with this relation.

![Fig. 10: Relation between \(1/(n^2-1)\) and \((h\nu)^2\) for α-Al₂O₃/ PVA nanocomposites.](image)

### 3.5 Dielectric properties

Dielectric constant \( \varepsilon' \) of materials is fundamentally depends on sundry factors such as micro-structural arrangement, charge polarization and other agents [35]. The real part of dielectric constant \( \varepsilon' \), has been estimated utilizing the following equation [36]:

\[ \varepsilon' = \frac{c_p \times t}{\varepsilon_o A} \]
where \( C_p \) is the capacitance of the film in (F), \( \varepsilon_r \) is the permittivity of the free space \((8.85 \times 10^{-12} \text{ F/m})\), \( t \) is the thickness of film and \( A \) is the cross sectional area of the surface of the film. Dielectric loss \( \varepsilon'' \), has been determined using the following relation [36]:

\[
\varepsilon'' = \varepsilon' \tan \delta
\]

The ac electrical conductivity \( \sigma_{ac} \), of samples was evaluated by the relation [37]:

\[
\sigma_{ac} = 2\pi f \varepsilon' \varepsilon_0 \tan \delta
\]

where \( f \) is the frequency of the applied field and \( \tan \delta \) is the dielectric loss tangent.

Fig. 11(a-c) and Fig. 12(a-c) show the temperature dependence of dielectric constant \( \varepsilon' \) and dielectric loss \( \varepsilon'' \), for pure PVA and PVA/\( \alpha-\text{Al}_2\text{O}_3 \) nanocomposites in the frequency range 10 kHz- 5 MHz. All samples have possessed the same demeanor. Firstly, it is noticed that the dielectric constant \( \varepsilon' \) and dielectric loss increase \( \varepsilon'' \) increases with temperature but decreases with increasing frequency, i.e., \( \varepsilon' \) and \( \varepsilon'' \) have higher values in low frequency range and then decrease with increasing frequency. In low frequency range, besides polarization due to PVA and \( \alpha-\text{Al}_2\text{O}_3 \), the space charge polarization plays a major role in increasing dielectric constant of composite [38]. The space charge polarization arises from the \( \alpha-\text{Al}_2\text{O}_3/PVA \) interfaces. The dielectric constant increases with weight fraction of \( \alpha-\text{Al}_2\text{O}_3 \). The increase in dielectric constant with weight fraction of \( \alpha-\text{Al}_2\text{O}_3 \) upholding the fact of the space charges polarization contribution. The dielectric constant of composite increases with addition of \( \alpha-\text{Al}_2\text{O}_3 \) reflects the formation of capacitance network of Al. [39].

Fig. 13(a-c) shows the relationship between the In\( (\sigma) \) and inverted absolute temperature of the \( \alpha-\text{Al}_2\text{O}_3/PVA \) nanocomposites. It is clear that the conductivity increases with increasing temperature. At low temperature region, the conductivity is slightly temperature and frequency dependent. In this region, the thermal energy is not appropriate to unleash charge carriers and increasing the frequency could reinforce their hopping. At high temperature region, the conductivity becomes frequency independent and a linear relation was obtained. The activation energy and conduction mechanism can be determined using equation \( \sigma = \sigma_0 \exp(-E_a/kT) \) and tabulated in Table 2. The high activation energy values for neat sample and low \( \alpha-\text{Al}_2\text{O}_3 \) concentration sample can be attributed to the thermal movement of the ions and molecules. Whereas the low activation energy values for the samples of higher \( \alpha-\text{Al}_2\text{O}_3 \) content can be attributed to the electronic conduction mechanism which is related to the decreasing of the distance between the \( \alpha-\text{Al}_2\text{O}_3 \) particles [39]. Furthermore, it was observed that values of the activation energies in eV for pure PVA, \( \alpha-\text{Al}_2\text{O}_3 \)/PVA nanocomposites decreased with increasing frequency. The composition dependence (\( \alpha-\text{Al}_2\text{O}_3 \)) of \( \varepsilon' \), \( \tan \delta \) and \( \sigma_{ac} \) at (10 kHz and 303 K) are given in Fig.14 (a-c).

**Table 2: Values of the activation energies in eV for pure PVA, \( \alpha-\text{Al}_2\text{O}_3 \)/PVA nanocomposites at different frequencies.**

<table>
<thead>
<tr>
<th>f (Hz)</th>
<th>PVA</th>
<th>2.5 %</th>
<th>5.0 %</th>
<th>7.5%</th>
<th>10.0 %</th>
<th>15.0 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>10000</td>
<td>0.33</td>
<td>0.76495</td>
<td>0.63429</td>
<td>0.66488</td>
<td>0.790</td>
<td>0.85373</td>
</tr>
<tr>
<td>100000</td>
<td>0.25</td>
<td>0.75101</td>
<td>0.53684</td>
<td>0.79162</td>
<td>0.780</td>
<td>0.71108</td>
</tr>
<tr>
<td>1E6</td>
<td>0.14</td>
<td>0.67002</td>
<td>0.48099</td>
<td>0.5338</td>
<td>0.480</td>
<td>0.27921</td>
</tr>
<tr>
<td>3E6</td>
<td>0.09</td>
<td>0.36814</td>
<td>0.29538</td>
<td>0.23351</td>
<td>0.199</td>
<td>0.08293</td>
</tr>
</tbody>
</table>
Fig. 11: Dependence of dielectric constant $\epsilon$, on absolute temperature for pure PVA, $\alpha$Al$_2$O$_3$/PVA and pure $\alpha$Al$_2$O$_3$ in the frequency range 10 kHz - 5 MHz.
Fig. 12: Dependence of dielectric constant $\varepsilon''$, on absolute temperature for pure PVA, $\alpha$-Al$_2$O$_3$/ PVA in the frequency range 10 kHz- 5 MHz range 10 kHz- 5 MHz.
Fig. 13: Dependence of ac conductivity on the reciprocal of the absolute temperature for pure PVA, $\alpha$-$\text{Al}_2\text{O}_3$/PVA in the frequency range 10 kHz - 5 MHz.
It is clear that, $\varepsilon'$ and $\sigma_{ac}$ have the same trend; they increase with $\alpha$-$\text{Al}_2\text{O}_3$ content, till $x=10$ wt%, and then decrease. Tan$\delta$ at first increase with $\alpha$-$\text{Al}_2\text{O}_3$ content, then decrease for $x=10$ wt%, and finally increase again. Thus the critical composition is PVA/ 10% $\alpha$-$\text{Al}_2\text{O}_3$ which is a suitable nanocomposite for different applications. It was reported that the increase of the electrical conductivity is accompanied by an increase of the eddy current, which in turn increases the energy loss to tan $\delta$. This behavior can be attributed to a gradual decrease in the series resistance with increasing frequency [40].

Fig. 14(a-c): The composition dependence of (a) $\varepsilon'$, (b) tan$\delta$ and (c) $\sigma_{ac}$ 10 kHz and 303 K.
4. Conclusion

Alumina ceramic nanoparticles were successfully prepared using the citrate-nitrate combustion method. XRD spectrum shows rhombohedral (hexagonal) structure of α-Al₂O₃. A series of PVA/α-Al₂O₃ hybrid films was prepared by the casting method. XRD, FTIR, FE-SEM, EDS, and UV/Vis spectroscopy verified the formation of α-Al₂O₃ NPs and PVA/α-Al₂O₃ NCs. The optical band gap is found to decrease with increasing Al₂O₃ NPs content from 3.82 eV to 2.33 eV. The nanocomposite with concentration (10% wt) has the highest dielectric constant, lowest dielectric loss and highest electrical conductivity. The properties of virgin PVA is modified and improved by doping with α-Al₂O₃ NPs, making it a promising material for different applications.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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