International Journal of Chemistry and Applications.
ISSN 0974-3111 Volume 17, Number 1 (2025), pp. 10-17

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Structural, Morphological and Optical Properties of electrochemically Synthesized Al_2O_3/ZnO Nanocomposite

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Abstract
In the present era, nanomaterial's have many uses due to their superior chemical and physical characteristics. The electrochemical deposition approach, which is quick, simple, and affordable, is one of the key techniques for creating Nano composites (Al_2O_3/ZnO). Advanced methods like x-ray Diffraction (XRD), field-emitted scanning electron microscopy (FESEM), microscopy using transmission electrons (TEM), ultraviolet-visible (UV-Vis), energetic dispersive x-ray (EDX), and atomic force microscopy, also called AFM, are used to analyze the Nano composite. According to the investigation, the Nano composite had an average crystal size of 8.4 nm, a band gap value of 3.23 (e.v), and a Nano rod form.
Keyword: Aluminum Foil; Composite; Electrochemical Cell; Solar Cell; Zinc Foil

1. Introduction

Introduction Metal oxide nanoparticles have demonstrated superior stability, low toxicology, high immovability, and selectivity compared to related organic compounds [1]. Moreover, the particle size of these particles is responsible for the changes in their basic physical and chemical characteristics. These microscopic particles show remarkable uses in catalysis, drug delivery, treatment of water, sensor gadgets, semiconductor materials, and solid oxide fills [2]. The main advantages of metal oxide nanoparticles are: -changes in surface properties that result in an extreme increase inside the band gap, which affects conductivity and chemical activity; -changes in electrochemical qualities due to the influence of quantum regulation; -structural changes that permit the modification of structural symmetry and cell parameters [3]. A material made up of multiple components is called a composite. One or more fillers, that include particles, sheets, having fibers with a high volume-to-surface ratio and diameters smaller than 100 nm, are usually supported by a matrix [4]. Nano composite is more electrically conductive, lighter, stronger, less brittle, resistant to scratches, recyclable, and flame-retardant than traditional composite materials. Adding nano fillers, such as carbon nanotubes, to the composite boosts its durability and resilience to wear, tear, overall breaking while preserving the material's surface transparency and high standards [5].

The properties of Nano composites at the Nano scale level are unique. Water purification, super capacitors, electro conductive scaffolds, anticorrosive and antiballistic optoelectronic devices, solar cells, hard coatings, biosensors, Nano devices, and renewable energy generation are just a few of the several industries in which they are extensively utilized. Silver/polyaniline (AgPani) Nano composites, which were produced by in-situ reduction of silver in aniline through photolysis at 265 nm, may be employed in additional bio sensing applications in addition to offering a viable technique for electro-catalytic hydrogen oxidation [6]. The use of Nano composites in state-of-the-art technological advancements, such as Nano biosensor-powered bio analysis and detection applications, is advantageous for the environment [7].

Structural, Morphological and Optical Properties.

2. Materials and Methods

2.1 Materials

97% aluminum foil, zinc foil, and polyvinyl alcohol (Fluka, Germany). Graphite, 99% ethanol, 98% acetone, 97% polyethylene glycol, 95% potassium chloride, and 97% potassium iodide (CDH, India). 99% iodine (Thomas Baker, India).

2.2 Methods

2.2.1 Preparation of Al_2O_3/ZnO Nano composite.

An inert electrode made of graphite and a working electrode constructed of aluminum and zinc foil were used to make the Al_2O_3/ZnO Nano composite using the electrochemical technique. A power supply is also utilized. Acetone and ethanol were used to wash the cathode and anode, followed by deionized water [8]. A 200 mL solution containing 5 mL of 10 g/100 mL electrolyte (KCl) and 10 mL of 10 g/100 mL stabilizer (polyvinyl alcohol (PVA) and ionized water, respectively) is poured into the electrochemical cell. Zinc foil (0.5 cm x 4 cm) and aluminum foil (0.5 cm x 4 cm) make up the working electrode, which is placed face-to-face with a graphite electrode (2 cm x 5 cm) in the cell electrolyte [9]. At a temperature of less than 30°C, the electrolysis process was carried out in an undivided electrolytic cell for sixty minutes while stirring. The voltage ranges from 9 to 15 volts. After centrifuging the resulting white precipitate of Al2O3/ZnO and repeatedly washing it with ethanol and deionized water, it was transferred into a drying vessel, dried for 60 minutes at 60°C, and then calcined for 60 minutes at 700°C [10].

Figure 1: The Al_2O_3/ZnO Nano composite is prepared using an electrochemical method.

3. Results and Conversations

3.1 Al_2O_3/ZnO Nanocomposite X-Ray Diffraction Analysis.

The Al_2O_3/ZnO Nano composite's XRD patterns were created at room temperature using an electrochemical process. The electrochemically produced Al_2O_3/ZnO NPs' XRD spectrum. The XRD patterns have revealed interference across the peaks that exist in the same location or close to both $Al_2O_3$and ZnO NPS, and some maxima appear isolated where interference does not occur. Additionally, it has been found that the intensities of these peaks vary, as illustrated in figure 2. Several diffraction peaks were observed at 2θ (32.023°, 36.856°, 48.352°, 57.320°, 63.253°, and 69.643°) in relation to miller indices (100), (101), (102), (110), (103), and (112) of ZnO NPs, and 35.972°, 46.860°, and 74.784°) in relation to miller indices (311), (400), (440), and (620) of Al_2O_3NPs.A shift in the majority of peaks toward different diffraction angles, a decrease in the XRD intensity of some peaks, an increase in other peaks, and the removal of some peaks for Al_2O_3 NPs result in the formation of Al_2O_3/ZnO Nano composite, a new nanomaterial [11].

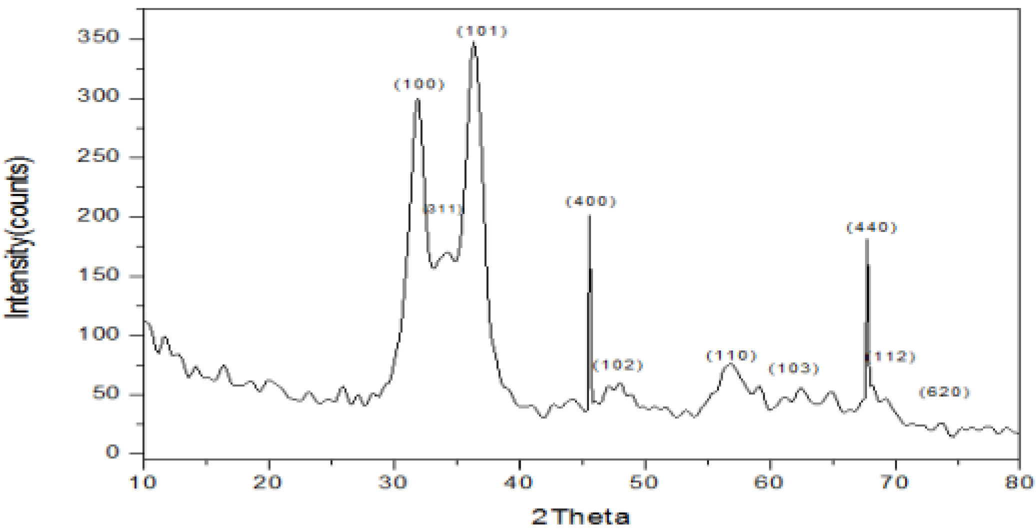

Figure 2: The Al_2O_3/ZnO Nano composite's X-ray diffraction pattern.

3.2 Al_2O_3/ZnO Nano composite Analysis Using Transmission Electron Microscopy (TEM). Figure 3 displays TEM micrographs of Al_2O_3/ZnO Nano composite that were produced electrochemically at room temperature. The electrochemically produced Al_2O_3/ZnO Nano composite crystalline forms have a nanorods shape, according to the TEM data [12].

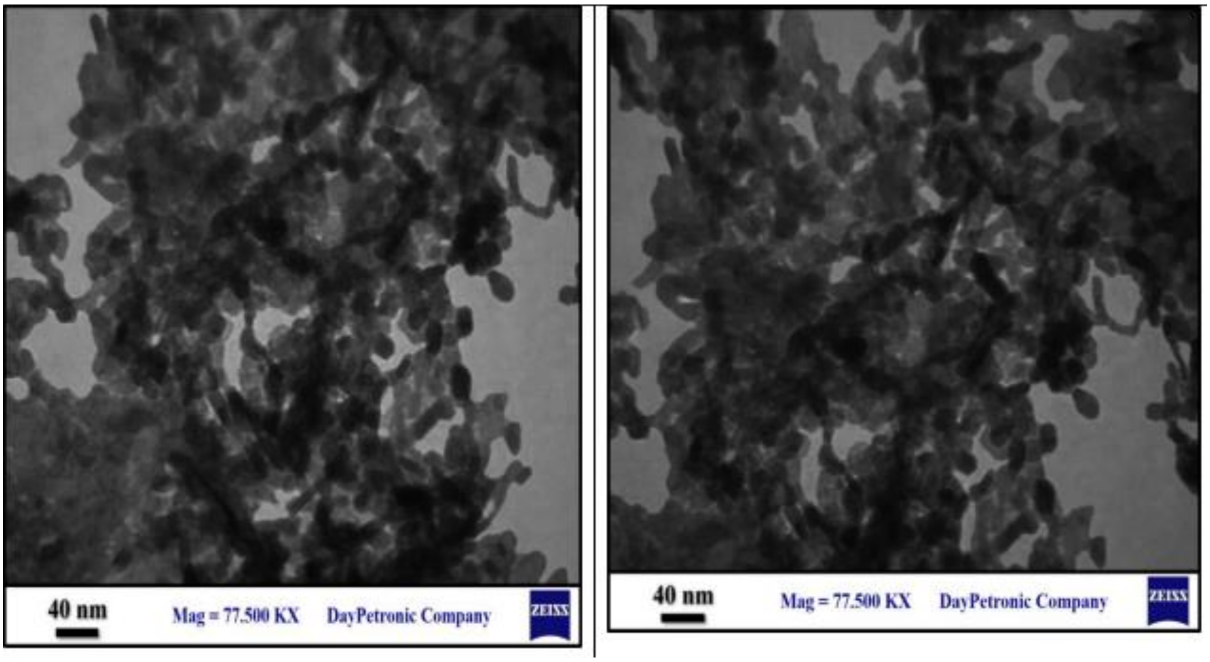

Figure 3: TEM images of Al_2O_3/ZnO Nano composite.

3.3 The Al_2O_3/ZnO Nano composite Field Emissions Scanning Electron Microscope (FESEM). It is utilized by FESEM to ascertain the shape and structure of the produced films. The FESEM in secondary electrons mode at 100,000x magnification and 10 kV operating voltage may produce high-resolution pictures of a sample surface. The arrangement of the particles was seen in the FESEM picture. As seen in figure 4, the external layer of the Al_2O_3/ZnO composite had a full and consistent coating of compacted nano sheets that were coupled to one another to produce a three-dimensional porous structure. In order to create the Al_2O_3/ZnO composite, Al_2O_3NPs were essential since they not only provided structural support for the ZnO NPs but also stopped them from aggregating [13].

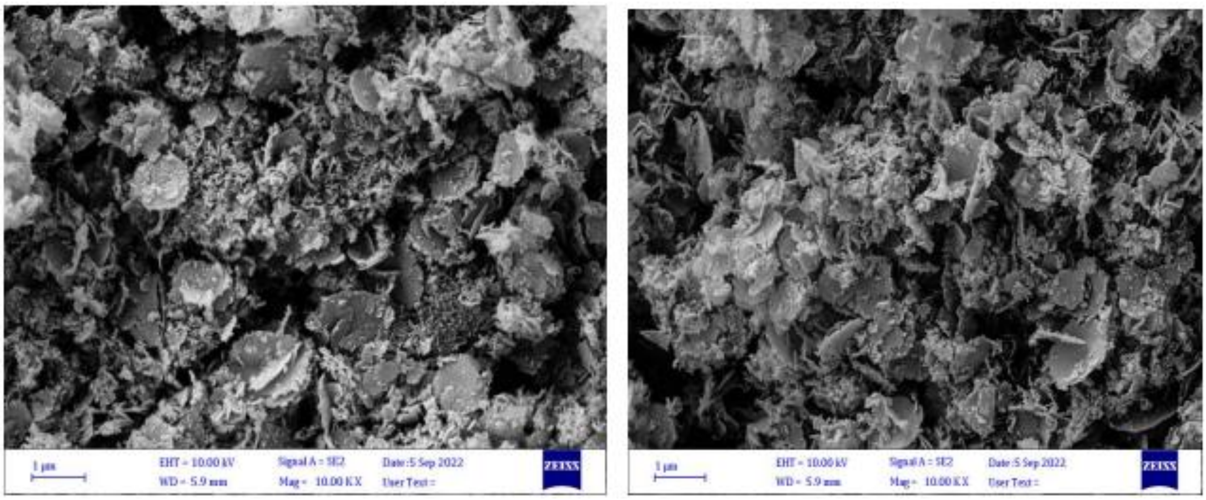

Figure 4: FESEM images of Al_2O_3/ZnO Nano composite.

3.4 Al_2O_3/ZnO Nano composite Energy Dispersive X-Ray Spectroscopy (EDX).

Energy dispersive X-ray spectroscopy (EDX) was used to assess the purity and stoichiometry of the electrochemically produced Al_2O_3/ZnO Nano composite. The results, which are displayed in Figure 5, demonstrate that the samples were extremely clean because only particular signals for oxygen, aluminum, and zinc were present. As can be observed in the EDX chart for ZnO NPs, the appearance of gold in the chart is a result of gold covering the sample during testing. Zn=58.1%, Al=22.8%, and O=19.1% are the weight proportions of Al_2O_3/ZnO. These ratios show that the ZnO: Al_2O_3ratio is 2:1, in conjunction with the presence of free metal deposits of zinc and aluminum that function as doping [14].

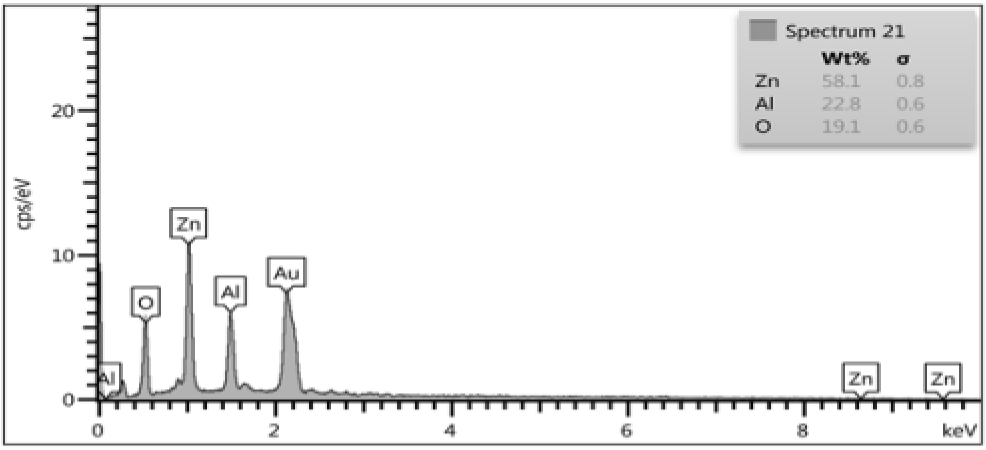

Figure 5: Al_2O_3/ZnO Nano composite's EDX spectrum.

3.5 Analysis of the Al_2O_3/ZnO Nano composite by Atomic Force Microscopy (AFM).

Atomic force microscope (AFM) topographical imaging is a useful method for gathering detailed information on the morphology, topography, and texture of different surfaces. The faint structures are represented by opaque colors in AFM pictures, whereas the soaring structures are represented by bright colors due to the various orientations of the particle grains. Surface skewness, Root Mean Square, and surface roughness Average (Sa) were among the many important features that were included in the comprehensive data that was obtained from AFM measurements. On the other hand, AFM measurements offer superior information on the average nanoparticle diameter, size dispersion, and uniformity of nanoparticle surfaces [15]. Figure 6 illustrates how Al_2O_3/ZnO Nano composite can be used to create images and configurations in two and three dimensions (D and 3D).

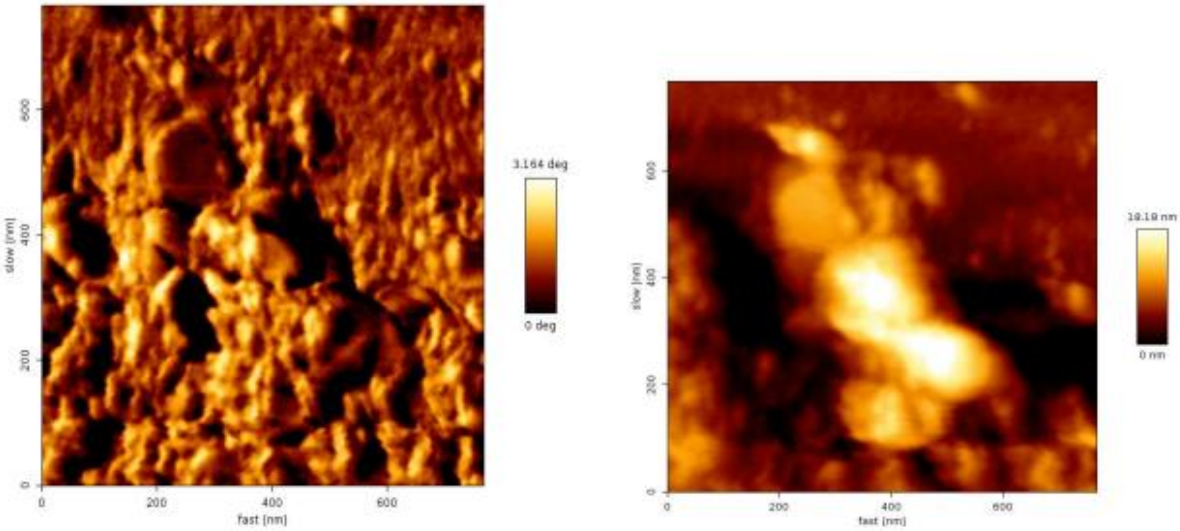

Figure 6: Al_2O_3/ZnO Nano composite AFM 2D and 3D pictures

3.6 Al_2O_3/ZnO Nano composite Fourier transformation infrared spectroscopy analysis (FT-IR).

FTIR spectroscopy was employed to get additional insight into the chemical relationship between Al_2O_3NPs and ZnO NPs. The Al_2O_3/ZnO FTIR spectrum are shown in Figure 7. The presence with Al-O and Zn-O bonds was shown by the typical absorption peaks of the Al_2O_3/ZnO Nano composite that were mainly visible in the FTIR spectrum. The contraction vibration from Zn-O was linked to the peak at 464 cm, and the Al-O expansion mode was suggested by the stronger absorption at 500–750 cm-1 [16].

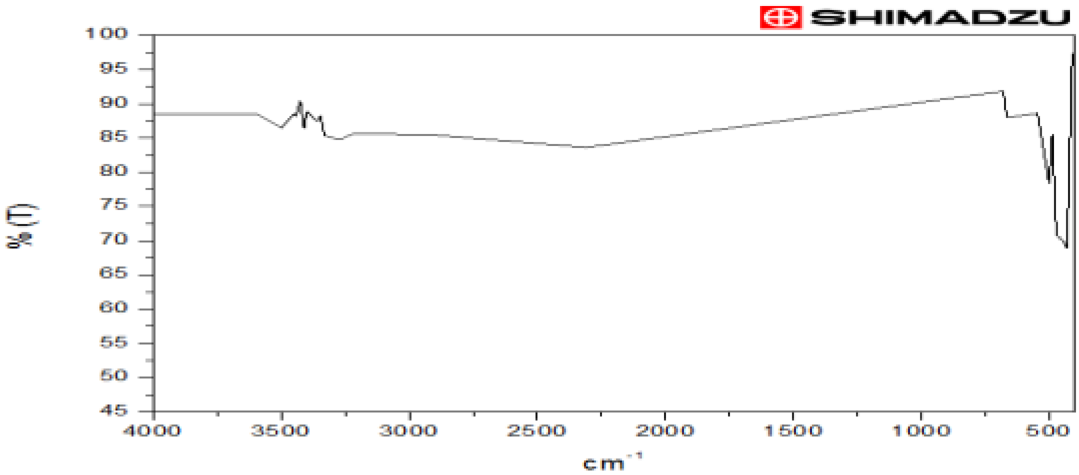

Figure 7: Al_2O_3/ZnO Nano composite FTIR spectrum; UV-Vis analysis of Al_2O_3NPs.

3.7 UV-Visible Spectroscopy (UV-Vis $Al_2O_3$and ZnO Nano Composite).

Solid state ultraviolet (UV)-visible spectroscopy was used to analyze Al_2O_3/ZnO composites thin films made on glassy slides at temperatures below 30 C^0. Figure 8 displays the generated UV-visible spectra, which seem to have a defined maximum wavelength [17].

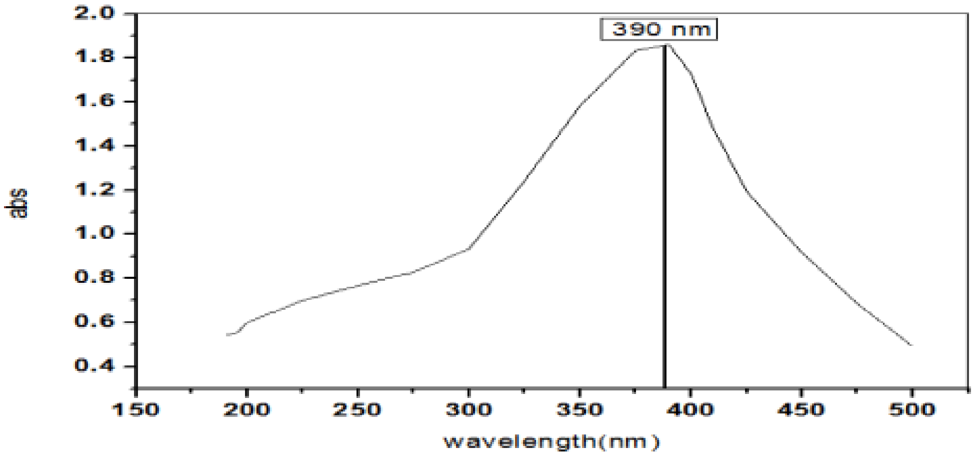

Figure 8: Al_2O_3/ZnO Nano composite spectrum.

Furthermore, optical absorption is an essential technique for determining the optical energies band gap of crystallized and amorphous materials, as seen in figure 9. The type and magnitude of the optical band gap can be determined using the fundamental absorption, which is equivalent to the acceleration of electrons from the band called the valence band to the band for conduction. All of the films made for this investigation were subjected to UV-Vis spectroscopy using a spectrophotometer that operated in the 150–500 nm range. By calculating radiation along the (hv) and (α hv) 2 lines on the Taucplot, the optical band gap of the fabricated films was also determined. The shifting characteristics of Al_2O_3/ZnO films in the optical energy gap at 25 was studied using the UV area absorption peak [18].

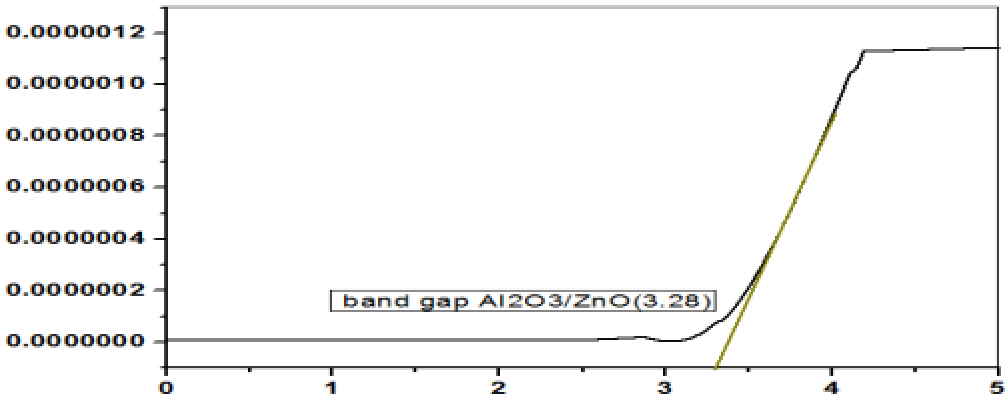

Figure 9: the optical band gap of Al_2O_3/ZnO Nano composite.

4.Conclustion

A straightforward and inexpensive electrochemical deposition technique was used to successfully create the Al_2O_3/ZnO nano hybrid. The creation of a new composite material was verified by XRD structural characterization, which showed peak shifting, intensity variations, and the emergence or disappearance of particular diffraction peaks. While FESEM pictures showed evenly distributed crumpled nano sheets producing a porous 3D structure, showing successful interaction between Al2O3 and ZnO nanoparticles, TEM investigation revealed that the nano composite had a nano-rod shape. Energy-dispersive X-ray spectroscopy (EDX) verified a ZnO: Al_2O_3 ratio of roughly 2:1 and demonstrated the exceptional purity of the produced nano composite.AFM investigation also revealed a homogeneous surface with appropriate roughness and well-distributed nanoscale features. The presence of Al–O and Zn–O functional groups was confirmed by FT-IR spectroscopy, indicating effective bonding within the composite. Tauc plot analysis revealed an optical band gap of 3.23 eV and UV-Vis measurements demonstrated a distinct optical absorption peak, indicating that the nano composite has promising optical properties appropriate for optoelectronic and photocatalytic applications. Overall, the study shows that electrochemical synthesis is an effective way to create high-quality Al_2O_3/ZnO Nano composites with desired structural, morphological, and optical characteristics that make them appropriate for use in advanced electronic devices, sensors, energy storage, and catalysis.

5. Conflict of interest. The authors declare that they have no conflict of interest in this article.

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