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Original Research Article

Zinc oxide nanoparticles: Solvo-thermal synthesis, characterization and calculation of band-gap energies

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ABSTRACT

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KEYWORDS

Ellipsometry; Zinc oxide; Nanoparticles; Surface morphology; Crystal structure; Absorbance. Because of its many potential uses in solar cells and other areas, zinc oxide (ZnO) nanoparticles have demonstrated a great deal of promise. Numerous techniques for synthesizing ZnO nanomaterials have been documented. In this work, a straightforward, economical, and easy synthetic approach was used to accomplish controlled synthesis of ZnO nanoparticles. The optical band gap energies were computed using ZnO film thickness and transmittance spectra. The bandgap energies for ZnO films as synthesized and as annealed were determined to be 3.40 eV and 3.30 eV, respectively. The material is a direct bandgap semiconductor, based on the nature of the optical transition. Dielectric functions were extracted via spectroscopic ellipsometry (SE) analysis, where the annealing of the nanoparticle layer caused the optical absorption of ZnO to begin at lower photon energy. Similarly, evidence from scanning electron microscopy (SEM) and X-ray diffraction (XRD) showed that the material is crystalline and pure, with an average crystallite size ~ 9 nm.

1. Introduction

ZnO is a broad bandgap II-VI semiconductor compound in materials science, having a significant contribution from ionic bonding and a primarily covalent chemical bonding structure [1]. The crystal formations of wurtzite, zinc blende, and rock salt are among those in which ZnO can form. The sp^3 covalent bonding is represented by the compound semiconductor's tetrahedral bonding arrangement, in which four cations surround each anion at the tetrahedron's corners, and each cation is surrounded by four anions [2]. With exceptional and distinctive physical and chemical characteristics, including strong chemical stability [3-5], high electrochemical coupling coefficients [6, 7], a wide range of radiation absorption [8], and high photo-stability [9], zinc oxide (ZnO) is one of the most useful materials.

The oxide semiconductor ZnO is one of the most interesting and adaptable materials in materials science, despite the wide range of materials and requirements. As seen by the sharp increase in publications about the materials, ZnO is becoming a more popular research topic each year [10]. The substance is inexpensive to produce on both small and big quantities and is non-toxic. ZnO is regarded as a promising material for the electronics industry's next generation as well as a useful component for medical devices [11]. Because of its high theoretical capacity, abundance, affordability, and environmental friendliness, zinc oxide has also been viewed as a promising anode material for Li-ion batteries [12]. With a direct bandgap energy of about 3.37 eV and an exciton binding energy of up to 60 eV, even at ambient temperature, ZnO is known as an n-type, multifunctional semiconductor material that is even more powerful than GaN [13]. ZnO is a profitable material for room-temperature UV lasing devices because of this unique property [14]. Additional uses for ZnO include solar cells, piezoelectric nano-generators, surface acoustic wave guides, ceramic positive temperature coefficient thermistors, UV light emitters, varistors, optoelectronic and spintronic devices, and transparent high-power electronics. It is a crucial component of solid-state lighting technology due to its high emission efficiency [15]. Additionally, it offers prospects for the development of efficient new magnetic and optical technologies, including magneto-optical switches, spinpolarized solar cells, and spin light-emitting diodes [16].

ZnO comes in a variety of nanostructured polymorphic shapes, including nanorods, nanowires, nanoflowers, and nanoparticles, in addition to bulk ZnO and thin films/epilayers. These nanostructures' high surface-to-volume ratios have made them crucial for optoelectronic devices [17]. These different configurations made possible by ZnO nanostructures give these materials a distinct set of properties and potential applications in a wide range of nanotechnology fields [18].

Among these deposition techniques, hydrothermal, precipitation, colloidal, and sol-gel fall within the primary category of liquid-phase nanomaterial production. These techniques are significant due to their easy-to-follow operating procedures, straightforward synthesis pathway, and regulated particle size distribution. One of the greatest techniques for high-temperature synthesis is hydrothermal synthesis, which may be utilized to create nanomaterials at any temperature. Likewise, a pure and uniform nanomaterial is produced using the precipitation approach. After precipitation, product separation is required, and maintaining product quality during the precipitation process can occasionally be difficult.

Using vapors produced by the chemical reaction of the components on or near the surface of a typically heated substrate, solid material is formed using the chemical vapor



deposition (CVD) process [19]. Even on a substrate with a complex shape, the resulting thin film has a consistent thickness and minimal porosity. This process yields a pure material with cost-effective manufacture and is crucial for fabricating selective deposition, even on patterned substrates. However, not every customer is a good fit for CVD because it necessitates a costly high-vacuum deposition apparatus.

In this study, we examine the optical, morphological, and structural characteristics of ZnO nanoparticles made using the solvothermal synthesis method. Nanoparticles in the solution self-assemble as a result of the solvothermal method's assistance in accelerating the reactant-to-reactant reaction and promoting crystal development. Zinc acetate and potassium hydroxide are used to finish the synthesis with methanol present (Section 2). Quantum dot solar cells have already made use of ZnO nanoparticles produced using this technique [20]. To further explore potential uses, the scientists acknowledge that a thorough characterization-including a spectroscopic ellipsometry study-is required. We discovered that this approach to ZnO nanoparticle production was easy to use and reasonably priced. XRD, SEM, SE, and a UV/Vis spectrophotometer were used to examine the nanoparticles' shape, structure, and optical characteristics.

2. Materials and methods 2.1 Materials

We bought and used the following: potassium hydroxide (KOH, certified ACS pellets, Fisher Scientific, Waltham, MA, USA); zinc acetate (ZnAc₂, 99.99%, Sigma Aldrich, St. Louis, MO, USA); chloroform (anhydrous, 99+%, Sigma Aldrich); and methanol (MeOH, anhydrous, 99.8%, Sigma Aldrich).

2.2 Synthesis of ZnO nanoparticles

ZnO nanoparticles were synthesized using a modified version of the solvo-thermal process that has been previously described [21]. Two solutions were made in different containers. To make solution 1, 0.55 g of zinc acetate (Zn(CH₃COO)₂) was dissolved in 25 mL of methanol (MeOH). At a hot plate temperature of 60°C, the solution was swirled for an hour. Similar to solution 1, solution 2 was made by swirling 0.28 g of potassium hydroxide (KOH) in 12.5 mL of methanol at the same hotplate temperature. In order to nucleate and develop the nanoparticles, solution 2 was added to solution 1 using a titration procedure with the use of a burette. The reaction was then allowed to proceed for two hours at 60°C. After two hours, the solution combination was re-suspended in methanol after being centrifuged to remove the nanoparticles. After three iterations of this procedure, dry ZnO nanoparticles were suspended in chloroform for thin-film and solution characterization. The following balancing equation was used to summarize the synthesis of ZnO nanoparticles:

$$\label{eq:constraint} \begin{split} &Zn(CH_3COO)_2+2KOH \rightarrow Zn(OH)_2+2CH_3COOK\\ &Zn(OH)_2 \rightarrow ZnO+H_2O \end{split}$$

2.3 Thin film fabrication

Spin coating was used to create thin films of ZnO nanoparticles. Chloroform was used to create a ZnO nanoparticle solution with the required concentration. At room temperature (23°C), the resulting solution was spin-coated on Fisher brand soda lime and borosilicate glass substrates at 1000 rpm for 10 s and 4000 rpm for 25 s. The produced films were

annealed for varying amounts of time at various hotplate temperatures.

2.4 Characterization techniques

ZnO surface SEM pictures were obtained using a field emission scanning electron microscope (Hitachi S-4800, Japan). A Rigaku Ultima III X-ray diffractometer (Rigaku, USA) equipped with a small-angle X-ray scattering at 42 kV accelerating voltage and 45 mA current was used to take the ZnO films' XRD patterns. A spectroscopic ellipsometry investigation was used to determine the dielectric functions. The J.A. Woollam Co. (St. Lincoln, NE, USA) M-2000 DI rotating compensator ellipsometer was utilized to get SE data. A Shimadzu UV 2401PC Spectrophotometer was used to get the films' unpolarized transmittance and absorbance spectra. In order to determine their dielectric functions, spectroscopic ellipsometry data were collected. Notably, all of these measurements were carried out at room temperature.

3. Results and discussion

3.1 Phase analysis and surface morphology

Using CuK_a radiation ($\lambda = 1.54059$ Å) in focussed beam geometry, XRD data were obtained from both the synthesised and annealed ZnO thin films in order to determine their purity and crystallinity. Figure S1 displays the XRD patterns derived from the synthesised film. The ZnO film's XRD spectra after 30 minutes of annealing at 300°C are displayed in Figure 1. It is evident from a comparison of Figures 1 and S1 that the annealed film is more crystalline than the synthesised film. The hexagonal wurtzite structure (#PDF 98-000-0483) of ZnO serves as an index for all XRD peaks, and it precisely matches the vertical lines that indicate the standard peaks for the wurtzite phase in Figure 1. MDI JADE (JadeTM computer software from Materials Data Inc., St. Livermore, CA, USA) provided these common reference peaks. Sharp diffraction peaks show that the materials have good crystallinity and phase purity, and there is no indication of any other material traces.

The ZnO nanoparticles' phase purity is shown by the XRD pattern's powerful and sharp peaks. In order to determine the lattice constants, lattice spacing, and crystallite sizes, additional material investigation was conducted using Bragg's law.



Figure 1: ZnO nanoparticles' annealed film XRD patterns on a borosilicate glass substrate (Fisher brand microscope slide). For 30 minutes, the film was heated to 300°C.

Bragg's law of diffraction is represented by the following equation:

$$2d_{hkl}\sin\theta = n\lambda\tag{1}$$

where d_{hkl} is the lattice interplanar spacing, λ is the X-ray wavelength, and *n* is the order of diffraction. The lattice constants a = b, *c* and the Miller indices (h, k, l) are connected to the plane spacing d_{hkl} for hexagonal structures according to the following relation [22]:

$$\frac{1}{d_{(hkl)}^2} = \frac{4}{3} \left(\frac{h^2 + hk + k^2}{a^2} \right) + \frac{l^2}{c^2}$$
(2)

Equation (2) reduces to the following using Bragg's rule for n = 1:

$$\sin^2 \theta = \frac{\lambda^2}{4a^2} \left[\frac{4}{3} (h^2 + hk + k^2) + \left(\frac{a}{c}\right)^2 l^2 \right]$$
(3)

The above equation for $\langle 100 \rangle$ and $\langle 002 \rangle$ planes, for example, becomes $a = \frac{\lambda}{\sqrt{3} \sin \theta}$ and $c = \frac{\lambda}{\sin \theta}$. Lattice constants were determined as follows: a = b = 3.2499 Å and c = 5.2070 Å, respectively, using $\lambda = 1.54059$ Å and 2 θ for two planes 31.767° and 34.419°. These figures are in excellent agreement with the earlier calculations made by Bindu et al. [23]. As indicated in Table 1, the interplanar spacing d_{hkl} was computed from XRD patterns using Bragg's law for a few prominent XRD peaks that corresponded to planes and compared with reference data.

Additionally, the crystallite size (D) was computed using the Debye-Scherrer formula [24]:

$$D = \frac{k\lambda}{\beta\cos\theta} \tag{4}$$

D is the size of the crystallite, θ is the Bragg's angle, β is the full width at half maximum (FWHM) of the associated peak, *k* is a dimensionless shape factor (~0.90), and λ is the incident X-ray wavelength. Wave Metrics' IGOR-Pro 9 Scientific data analysis program was used to get the β values. As indicated in Table 1, the crystallite size was rounded to the nearest whole number in nanometers. Synthesized ZnO nanoparticles have an average crystallite size of 9 ± 2 nm. The average crystallite size obtained for ZnO nanoparticles [25]. While the particle size represents the size of a nanoparticle, the crystallite size is thought to be the size of the smallest crystal.

Table 1: FWHM, crystallite size, reference for corresponding planes, and interplanar spacing from XRD. The average size of a crystallite is

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<hkl></hkl>	d_{hkl} (Å)	$d_{Ref}(\text{\AA})$	FWHM, β (°)	D(nm)
<100>	2.8029	2.8147	1.004	9
<002>	2.5896	2.6036	0.715	11
<101>	2.4687	2.4761	0.794	12
<102>	1.9059	1.9113	0.936	9
<110>	1.6222	1.6251	1.042	9
<103>	1.4746	1.4776	0.982	9
<112>	1.3735	1.3786	1.633	7
<201>	1.2370	1.3599	1.292	8

SEM results of synthesised ZnO nanoparticles placed on a glass substrate at two distinct magnifications are displayed in Figure 2. Since nanoparticles are an agglomerated form of crystallite, as seen in Figure 2, they are larger than their crystallite sizes as determined by the Debye-Scherrer equation despite having very small sizes and unclear forms. In order to reduce charge caused by the low carrier concentration of undoped nanoparticles, all of these pictures were captured at 5.0 kV accelerating voltage with a lower SE detector.



Figure 2: Scanning electron microscopy (SEM) images of ZnO nanoparticles. The nanoparticle thin film was spin-coated and SEM images were taken without the prior heat treatment.

Depending on the experimental methods and the use of precursors, ZnO nanoparticles can have a variety of sizes and forms. Typically, the nucleation and growth processes result in the production of nanoparticles. The Gibbs–Curies–Wulff theorem states that the surface free energy of each crystallographic face determines the form of a crystal, and the final shape of the nanoparticles is chosen to minimize the system's total free energy. Since spherical shapes have the lowest surface energies for a given volume, spherical nanoparticles are often expected. Nanostructures with a regulated size and shape, such as nanorods, nanowires, nanobelts, and nanostars, can be created by varying the reaction time, the quantity of precursors, the temperature, the pH and the kind of material utilized for the synthesis

3.2 Optical properties using Spectroscopic Ellipsometry

Through careful study of XRD and SEM findings, we see that ZnO nanoparticles can be considered as a good material for photovoltaic (PV) applications. Analyzing these ZnO nanoparticles' optical characteristics using dielectric functions is another method of determining their viability for PV applications. Findings of optical and morphological characteristics relevant to photovoltaic and other electrical devices are made possible by the optical responses of nanocrystalline ZnO thin films, which take the form of energydependent complex dielectric functions: $\varepsilon(E) = \varepsilon_1(E) + i\varepsilon_2(E)$. External spectroscopic ellipsometry (ex-situ SE) data were obtained from a ZnO thin film that was formed on soda lime glass using the spin coating process in order to determine the dielectric constants at room temperature. The ZnO thin film was annealed at a hot plate temperature of 300°C for 30 min before acquiring the SE data. A M2000 SE system with a backside tape was used to capture the SE spectra ex situ at a 70° angle of incidence. The system recorded 635 data points across a spectral range of 0.734 to 4.00 eV. Two critical point parabolic bands (CPPB) and one Tauc-Lorentz [26] oscillator were used to parameterize the complex dielectric functions for the ZnO thin film; the specific process is explained elsewhere [27]. Similarly, a Bruggeman effective medium approximation (EMA) was used to describe the film surface roughness layer. According to the SE analysis, the nanoparticle thin film sample's bulk layer thickness is $d_h = 340 \pm 1$ nm and its surface roughness is $d_s = 58 \pm 1$ nm. In the same way, the material's bandgap energy is 3.23 ± 0.01 eV and its overall effective thickness is 381 ± 1 nm.

Dielectric constants at each spectral point for the sample over the measured spectral range were extracted using numerical inversion after thicknesses were determined from the parametric models. Figure 3 displays the model-fitted complex dielectric response function for the ZnO nanoparticle thin film in the spectral range of 0.734 eV to 4.00 eV. The displayed dielectric function is similar to the work that was previously published [28]. With an energy start of about 3.0 eV for the nanoparticle layer, the imaginary part of the dielectric function ε_2 exhibits a distinctive peak at about 3.22 eV. The absorption edge of ZnO, a direct bandgap semiconductor, is where absorption begins, and this value agrees well with the figures determined in Figure 4. The $\varepsilon_1(E)$ and $\varepsilon_2(E)$ spectra of the ZnO nanoparticle thin film calculated in this work are also slightly smaller in magnitude than that in the work of Girish Lakhwani et al. [29], as shown in Figure 3. Thin films of nanoparticles exhibit bulk-like properties at higher temperatures.

3.3 Unpolarized absorbance and transmittance

Figure 4A displays the optical absorbance spectrum of ZnO nanoparticles that were produced and dispersed in chloroform using UV/Vis/NIR absorption spectroscopy. At a wavelength of 334.5 nm (3.7 eV), which is significantly lower than the bulk bandgap wavelength of 368 nm, the spectrum shows the first exciton absorption peak. The electron transitions from the valence band to the conduction band ($O_{2p} \rightarrow Zn_{3d}$) are responsible for the approximate intrinsic bandgap of ZnO, which is attributed to the first exciton absorption peak [30]. Furthermore, the narrow peak location and severe absorption at the band edge indicate that the nanoparticles' size distribution is tiny. The absorbance peak position (334.5 nm) found in this study is at a shorter wavelength than that found in

earlier studies, which found it to be between 355 and 380 nm [31]. The entire visible spectrum (400–700 nm) and a portion of the infrared spectrum (>700 nm) are included in the measurement range of the weak absorption area. Following the initial exciton peak, there is a steady rise in light absorption until the glass's influence at the middle ultraviolet (MUV) region breaks at 248.5 nm, as seen in Figure 4A. In a further experiment, the ZnAc₂ solution was combined with all of the KOH solution at once rather than by adding it drop-wise. The resulting poly-dispersed ZnO nanoparticles are displayed in Supplementary Information Figure S2.

The largest size nanoparticles contribute the most absorbance at the absorbance edge, whereas all particles contribute to the absorbance at the region of absorbance maximum. The wavelength at which absorption first starts must be known as the threshold wavelength (λ_s). As seen in Figure S3, the threshold wavelength is 354.6 nm, which is just 20 nm above the first exciton absorption peak.

Figure 4B displays the transmittance percentage spectra of ZnO nanoparticles in thin films of around 100 nm both before and after annealing. Transmission from synthesised film is shown by the red line in Figure 4B, while transmission from annealed films is represented by other data. As seen, four films were annealed at 300°C for varying lengths of time, and five films of roughly comparable thickness were made. As seen in Figure 4C, the transmission measurements of four ZnO thin films at various temperatures were used to estimate the ideal annealing temperature of 300oC. Annealing reduces or eliminates flaw states in the film and causes solvent and other byproduct traces to dissipate. The film becoming more crystalline, which could be the cause of the incident light being scattered and the transmission being reduced. The slightly varying film thicknesses could be the cause of the tiny variation in transmission in the visible spectrum. These ZnO thin films can be used as a window layer in quantum dots solar cells [33], as well as an antireflection coating in solar cells that operate primarily in the visible region, like silicon solar cells [32], or in a large spectrum, like GaN-based concentration solar cells [32]. Figure 4B illustrates that all films in the visible spectrum have a high average transmittance greater than 60%, indicating low absorbance and low reflectance.

A common technique for determining the bandgap energy is the optical absorption measurement close to the basic absorption edge. The band structure and the kind of electron transition are explained by the way the optical absorption coefficient changes with incident wavelength (or energy). Beer-Lambert's relation was used to determine the ZnO thin films' optical absorption coefficient [34]:

$$I = I_0 e^{-\alpha(\lambda)x} \to \alpha(\lambda) = 2.303 \frac{A}{\lambda}$$
(5)

where *A* represents the absorbance, and *t* represents film thickness. The fundamental process for analyzing absorption coefficients involves obtaining optical absorbance (*A*) data from ZnO thin-film transmittance obtained from a UV/Vis/NIR spectrophotometer using the following relation: $A = 2 - \log_{10}(T\%)$. The optical absorption coefficient very slightly changes with temperature, as seen in Figure 4D, although it increases significantly at the band edge compared to the synthesised film. The commencement of interband transitions, which are more effective in annealed (crystalline) films than synthesised (less crystalline) ones, could be the

cause of this rise at the band edge. The absorption coefficient depends on the material's extinction coefficient (κ : how strongly a material absorbs light of a particular wavelength) and the wavelength of light (λ) being absorbed by the relation: $\alpha = \frac{4\pi\kappa}{\lambda}$. The κ value depends on the type of bandgap (direct vs. indirect) and the λ depends on the bandgap of the material.



Figure 3: SE studied the dielectric function spectra of a thin sheet of ZnO nanoparticles at ambient temperature. The black curve, which is depicted by a circle with an arrow to the right, indicates ε_2 , while the red curve, which is plotted to the left y-axis, depicts ε_1 .

Tauc's relation [35] is used to estimate the optical bandgap of ZnO:

$$\alpha h v = A(h v - E_{g})^{n} \tag{6}$$

where A is a constant, E_g is the material's bandgap to be found, and hv is the energy of the incident photon. The factor n, which is equal to 1/2 for the direct bandgap transition and 2 for the indirect bandgap transition, depends on the kind of electron transition.

The Tauc plot for ZnO, which plots α times the to the second power against the hv, is shown in Figure 5A. Since ZnO is known to have a direct permitted transition, the second power of αhv is utilized. The Tauc plot's distinguishing characteristics are clear: The material is transparent, therefore the absorption is negligible at low photon energies; it becomes stronger and exhibits a region of linearity in this squaredexponent plot close to the bandgap value. To determine the bandgap value, the linear fit applied at the linear area is projected to the x-axis intercept. After the film was annealed for 15 minutes at 300°C, the direct bandgap values dropped from 3.40 eV at ambient temperature to 3.33 eV. After 30 minutes at 3.30 eV, the bandgap saturated and continued to decrease. It is well known that the effects of lattice dilatation (expansion), electron-phonon interaction, or phonon-induced atomic vibrations are responsible for the temperature change of the energy gap in semiconductors. Zhang et al.'s theoretical and experimental research [36] has demonstrated that bandgap reduces with increasing temperature. Because of their larger lattice expansion with temperature, ionic compounds-like ZnO-are more likely to exhibit this behavior than covalent ones. The annealed sample's bandgap closely resembles some of the earlier findings [36].



Figure 4: Results of VU/Vis/NIR spectroscopy: (A) Absorbance spectrum of ZnO nanoparticles as obtained and dispersed in chloroform. (B) ZnO thin-film transmission percentage at ~100 nm both before and after annealing. (C) Transmission of ZnO thin films annealed for 30 minutes as a function of temperature. (D) ZnO thinfilm absorption coefficients (α , cm⁻¹) as a function of wavelength in nm. Upon annealing the films for varying durations, slight variations in α were noted.

Figure 4A illustrates the clear red shift in the absorption edge for the ZnO film in relation to the exciton peak seen in the solution. When the nanoparticles become close to one another after the solvent evaporates, there may be a significant electronic coupling and a rise in the dielectric constant. Furthermore, interference-related phenomena in thin films may result in peak shifts in addition to unexpected absorbance values.

Lower and upper departures from the linear behavior region are shown in Figure 5A. Defect absorption states close to the band edge can be linked to the divergence from the linear area on the lower energy side. The energy dependence of these defect absorption states is exponential, which is consistent with a usual density of states distribution. On the higher energy side, the leveling out of absorbance strength is caused by saturation of the available density of states.



Figure 5: (A) Plot of $(\alpha hv)^2$ vs. hv of ZnO nanoparticles' thin films. The heated films with y-axis to the left are represented by the remaining curves, while the red curve is from the synthesised film with y-axis to the right. The y-axis directions for each curve are shown by yellow circles and arrows. (B) ZnO nanoparticle Urbach energy calculation. Annealed films with low Eu are crystalline and pure. Higher Eu indicates the presence of more defect states in the synthesised film.

By measuring the material's Urbach energy, one might identify changes in the band structure that might be caused by the introduction of flaws. According to Ref. [36], it was discovered that the absorption coefficient close to the band edge exhibits an exponential relationship on photon energy.

$$\alpha(h\nu) = \alpha_0 \exp\left(\frac{h\nu - E_0}{E_U}\right) \tag{7}$$

where E_U , an inverse logarithmic slope of the absorption coefficient, is the Urbach energy, which is understood to be the width of the tails of localized states, connected to the amorphous state, in the bandgap, and E_0 and α_0 are typical properties of the material. As seen in Figure 5B, a plot of lna versus photon energy was created in order to determine the Urbach energy. The reciprocal of the slopes of the linear section in the curve's lower photon energy area was then used to determine the value of E_U . A film heated to 300°C for 30 minutes had the lowest Urbach energy of 0.91 eV, while the film had the highest Urbach energy of 1.24 eV. The impure state of the material is the reason for the greater E_U from the film. Structural disorder, stoichiometry imperfection, and unpassivated surface condition are the factors that determine the Urbach energy. The thin layer of nanoparticles may have more structural irregularity. Imperfection in stoichiometry may be induced by leftover materials left after synthesis. Furthermore, annealing the film causes the dangling bonds to vanish from the nanoparticles' surface.

4. Conclusions

In this study, we used the solvothermal synthesis method with ZnAc₂ as the zinc precursor and KOH as the oxygen precursor to create monodispersed ZnO nanoparticles with a hexagonal Wurtzite structure. XRD, SEM micrograph examination, SP, and UV/Vis/NIR spectroscopy studies were used to confirm the nanoparticles. The ZnO nanoparticles' consistent particle size distribution and identical shape were visible in the SEM pictures. The particles' crystalline structure was confirmed by the XRD studies. Scherrer's equation yielded an average crystallite size ~ 9 nm, which was among the smallest for ZnO nanoparticles. Using ellipsometry, the optical and morphological characteristics of ZnO nanoparticle films were also investigated in the 0.734 eV - 4.00 eV spectrum region. At 3.22 eV, the observed spectra showed clear band edge structures, which were around 0.1 eV smaller than those discovered using a different technique. The ZnO nanoparticle size in these samples was almost mono-disperse, as indicated by the strong initial exciton peak. With a threshold absorption wavelength of 354.6 nm (~3.5 eV), the first exciton peak in solution measurement dispersed in chloroform was located at 334.5 nm (~3.7 eV). At 350 nm (~3.5 eV), the initial exciton peak was discovered to be red-shifted in thin film measurements in comparison to nanoparticles in solution. The significant electronic interaction of nanoparticles and the elevated dielectric constant caused the red shift in the first exciton peak. With values of 3.40 eV and 3.30 eV for annealed films, respectively, it was discovered that the bandgap energy transition of ZnO nanoparticles was directly permitted, as anticipated. Our analysis showed that the nanoparticles produced in this work have several uses, particularly in the electro-technological sectors, including solar cells, UV lasers, sensors, photoelectronics, and field emitters.

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