# Low Temperature Synthesis and Annealing effect of Transparent ZnO Thin Films on ITO Substrate by Sol-Gel Method

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#### Abstract

**Objectives:** Transparent Zinc oxide (ZnO) thin films to be prepared and annealed on the Indium tin oxide - ITO substrate using simple solution gel dip coating technique. **Methods/Analysis:** Thin films have been carried out by different characterization techniques such as X-ray diffractometer - XRD, Scanning Electron Microscopy - SEM, Energy dispersive analysis - EDAX, UV spectroscopic and FTIR spectroscopy. In the contemporary work, the ZnO films have been prepared on ITO substrate by dipping in the solution and annealed at the 300 °C. **Findings:** XRD pattern reveals that the annealed thin film is standard wurtzite zinc oxide hexagonal structure. SEM Morphological studies have been investigated using scanning electron microscopy and the elemental analysis confirmed by EDAX. Optical measurement shows the greatly transparent and the thin films are direct energy gap  $E_g$  of 3.70eV. FTIR confirm the metal oxide bond in the molecular structure. **Novelty/Improvement:** This research work helps for the future researcher's preparation of undoped Zinc oxide thin film for solar cell applications.

Keywords: ITO Substrate, Sol-Gel Method, ZnO Thin Film

# 1. Introduction

Zinc oxide is considered as an auspicious versatile material with good electrical conductivity and high transmittance for its semiconducting properties with band gap of 3.4eV, excitation binding energy with 60meV at room temperature with excellent thermal stability, low cost and non toxic<sup>1</sup>. Thus, ZnO is a promising material in many different applications such as gas sensors<sup>2</sup>, thin film transistors<sup>3</sup>, and solar cells<sup>4</sup>. ZnO thin films can be used by various preparation techniques like pulsed laser deposition<sup>5</sup> ,Chemical vapour deposition<sup>6</sup>, Radio frequency magnetron sputtering<sup>7</sup>, Chemical spray pyrolysis<sup>8</sup> and sol-gel spin-coating Technique<sup>9</sup>. For these techniques, sophisticated instruments (SI) and high temperature were involved. In the proposed work, the synthesis of

Zinc oxide nano particle thin film was prepared through dipping method in low temperature with low cost.

### 2. Materials and Methods

ZnO films have been inclined by solution gel dipping process. All chemicals were involved in this research from Merck Company. The process to prepare Zinc Oxide film on ITO zinc acetate dehydrate, was deliquesced in a Monoethanolamine acted as stabilizer, ethanol and the prepared solution was continuously mixed at an hour to get consistent precursor solution Figure 1. The resulting ZnO thin film was achieved by well cleaned ITO substrate into prepared solution by dip coating method. Film deposition was important to optimize at room temperature by this dipping method with a controlled departure

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speed of 2cm/min. At last, prepared ZnO nanoparticle thin films were formed after annealing at 300 °C for an hour. A structural study on the thin film specimen has been studied using PANalytical X-ray diffractometer. FEI QUANTA-200 was influenced to study the Morphology of the thin film. Chemical composition of the film sample has been analyzed using EDAX-JEOL Model JED-2300. Spectrophotometer - JASCO V-570 is involved to explore the UV optical absorbance spectra. FTIR spectrometer study is involved for the presence of chemical bonding in ZnO nanoparticles.



**Figure 1.** Experimental procedure for ZnO thin film deposition by sol-gel method.

### 3. Results and Discussion

Crystalline structure of deposited thin film samples was investigated using XRD and the results are shown in the Figure 2. X-ray diffractrograms pattern were recorded for  $20-80^{\circ}$  (2 $\theta$ ) at scanning rate of  $0.02^{\circ}$ /s with the presence of the peaks estimated with the standard ZnO structure - JCPDS No.36 - 1451. The corresponding spectrum of diffraction peaks observed to (110), (002),

(101),(102),(110) with different intensities<sup>8,10</sup>. The obtained result of XRD peaks corresponding to zinc oxide is present and the relevant phases are formed.

SEM is the promising techniques to study the growth of the thin film. The SEM images of ZnO films are shown in the **Figure 3**. Morphology of the film shows the presence of vertically aligned and a change in the shape of the grain to heat the ITO substrate at 300 °C. EDX analysis indicates that the presences of Zinc and Oxide in the prepared thin film samples are shows in **Figure 4**. Compositional analysis of the elements in the thin film reported as Zn= 41.24% and O=58.76%.

UV visible spectra of absorbance for pure ZnO thin film are depicted in **Figure 5.** Optical transition prevails the absorption spectra of the optical absorption edge of a film<sup>11</sup> Optical energy gap is governed by

$$(\alpha h \upsilon)^2 = A(h\upsilon - E_{\sigma})^n$$

Here *A* is a constant,  $E_g$  is the energy gap, v is the frequency, *h* is the Planck's constant, and n (n=2) for direct allowed transitions. The obtained energy gap from the plot of  $(ahv)^2$  vs hv ZnO films see Figure 6 depicts that the films exhibit direct band gap<sup>12</sup> with 3.70eV.

Figure 7 shows the FTIR spectra of a ZnO thin film with well defined peaks at 807,877, 1028,1259,1595,2323 and 2959 was observed in the spectrum to conform the surfactant molecules from the sample<sup>10, 13</sup> see Table 1.The broad band at 3447cm<sup>-1</sup> is the stretching vibration of the OH group and 1669 cm<sup>-1</sup> which is due to bending mode of water molecules present in the sample. The sharp vibrational peak at 1408 cm<sup>-1</sup> is attributed to the scissoring mode of CH<sub>2</sub> chain. Stretching mode was observed in the spectral region of approximately 450cm<sup>-1</sup> is the typical bond between metal oxides (Zn-O).



Figure 2. X-ray diffraction spectra of the ZnO thin film.



**Figure 3.** Scanning Electron Microscope (SEM) images of ZnO nanoparticle thin film.







**Figure 5.** The absorption spectra of ZnO Nanoparticle thin film.



**Figure 6.** Plot of  $(\alpha h \upsilon)^2$  vs Photon energy of ZnO thin film.



Figure 7. FTIR spectra of ZnO thin film.

Table 1.Fourier Transform Infrared Spectroscopy(FTIR) absorption bands

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3447 cm <sup>-1</sup>	O-H stretching vibration
3145 cm <sup>-1</sup>	O-H stretching vibration
1559 cm <sup>-1</sup>	O-H bending vibration
1408 cm <sup>-1</sup>	C=O stretching vibration
400 cm <sup>-1</sup>	Metal oxide bond

## 4. Conclusion

Amalgamation of pure ZnO thin films using ITO substrate by simple dip coating technique at 300 °C. The structural analysis of XRD revealed that ZnO thin film has hexagonal wurtzite structure. SEM image of the thin film showed smooth with relatively small grain size distribution. The UV optical absorbance properties revealed that the direct band gap of 3.70eV after annealing at 300 °C. FTIR analysis is confirmed the presence of chemical bonding with various functional groups. This paper highlights on understanding structural and optical properties which leads to special applications on solar cell.

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