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Synthesis And Characterizations of ZnO Thin Films

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A B S T R A C T :

The ZnO films were deposited using a low-cost, simple, and homemade spray pyrolysis (SP) method. Films were deposited on cleaned glass substrates held at 110°C with various precursor solution concentrations (0.01M to 0.05M). The film thickness was determined by the weight difference method. The films exhibited increased thickness with rising precursor concentration. Atomic Force Microscopy (AFM) indicated non-homogeneous grain size with non-smooth surface morphology.

Optical analysis indicated maximum absorption greater than 200 nm, with increasing direct band gap with increasing film thickness. Electrical resistivity rose with a fall in temperature, which suggests that conductivity increases as temperature increases

Keywords: Zinc oxide, Chemical spray pyrolysis, Surface topography, Optical properties, Electrical properties, Thin films.

1. Introduction

Zinc oxide (ZnO) is a multifunctional semiconductor material with a broad spectrum of applications because of its large band gap (3.37 eV) and high exciton binding energy (60 meV). ZnO has high piezoelectric, pyroelectric, and luminescent properties. ZnO can find applications in solar cells, sensors, UV detectors, laser diodes, transparent electrodes, and display devices. The renewed interest in ZnO research was initiated in the 1990s using different growth techniques such as spray pyrolysis, which is an inexpensive method for thin film deposition.

2. Properties of ZnO

2.1 Direct Band Gap: ZnO possesses a direct band gap of 3.44 eV at low temperature and 3.37 eV at room temperature, which is optimum for UV and blue optoelectronic devices.
2.2 Exciton Binding Energy: ZnO demonstrates a large exciton binding energy (60 meV), enabling efficient excitonic emission at room temperature.
2.3 Piezoelectric Properties: ZnO's non-centrosymmetric wurtzite crystal structure leads to large piezoelectric and pyroelectric effects.
2.4 Luminescence: ZnO shows green-white luminescence, which is beneficial in phosphor and display technologies.
2.5 Thermal Conductivity: ZnO is appropriate as an additive in materials such as rubber and as an epitaxial growth substrate due to high thermal conductivity.

3. Experimental Details

3.1 Spray Pyrolysis Process: Thin films were deposited onto glass substrates by a spray pyrolysis system which includes an atomizer, nozzle, compressor, and temperature controller. The precursor solution was sprayed at 6.6 mL/min with the nozzle-substrate distance of 20 cm. The system facilitates control of the film morphology through solution concentration adjustment and substrate temperature.
3.2 Sample Preparation: Substrates of glass were preheated to 110°C and cleaned. Solutions with a concentration of 0.01M to 0.05M zinc acetate were sprayed to produce ZnO films. Thickness was determined by mass difference prior to and after deposition.
The following images are of the thin films which were prepared by the spray pyrolysis method

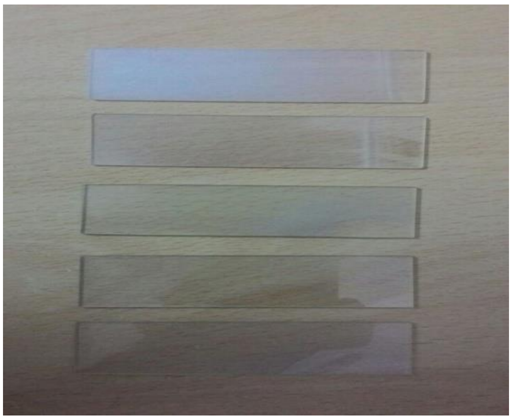

Figure (1): Prepared thin films using Chemical Spray pyrolysis technique.

4. Characterization Techniques

4.1 Structural Properties

- **Thickness Measurement:** Using substrate mass difference, thicknesses obtained were: 7.22 µm (0.01M), 9.027 µm (0.02M), 12.638 µm (0.03M), and 15.346 µm (0.04M).
- **Surface Topography (AFM):** AFM images showed columnar grain structures with non-uniform sizes. The surface exhibited roughness, suggesting that film morphology varies with deposition parameters.

4.2 Optical Properties

- **UV-Visible Spectroscopy:** Absorption spectra indicated fundamental absorption above 200 nm. The band gap values increased with film thickness: 3.52 eV (0.01M), 3.56 eV (0.02M), 3.58 eV (0.03M), 4.98 eV (0.04M).

4.3 Electrical Properties

- **Resistivity:** Measurements showed increasing resistivity with decreasing temperature, confirming semiconductor behavior. Conductivity increased with temperature.

5. Results and Discussion

- Film thickness increases with precursor concentration.
- AFM confirmed rough, non-uniform surfaces.
- Optical absorption and band gap showed clear dependence on film thickness.
- Electrical measurements confirmed thermally activated conductivity.

6. Conclusion

ZnO thin films were successfully deposited on glass substrates with spray pyrolysis. Thicker films with different optical and electrical properties were obtained with the higher concentration of the precursor. Film surfaces were non-uniform and rough based on the AFM analysis. Band gaps were higher in thicker films. Typical semiconductor behaviour with higher conductivity at higher temperatures was observed for the films.

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