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Synthesis, Characterization and Antibacterial Application of ZnO Thin films

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ABSTRACT

The objective of this study is to synthesize ZnO nano particles in form thin film on glass substrate and study antibacterial active of such films. ZnO thin films were prepared by spray pyrolysis technique using zinc acetate and isopropyl alcohol as precursor in the temperature range 375°C to 425°C. The optical properties of the film were studied on UV/VIS/NIR spectrophotometer. The energy gap of the film is evaluated and it is found to be 3.31 eV. The polycrystalline nature of the ZnO film was confirmed by structural analysis by X-ray diffraction method and the grain size is determined. It is found to be 50nm. The electrical resistivity of the film was measured by four probe method at different temperatures and it is found that electrical resistivity varying in the range 10^3 to 10^4 Ω–cm. we studied the antibacterial activity of ZnO thin film against gram-negative bacteria. Escherichia coli (E- coli) were used as test micro organisms. It is found that ZnO film enhanced the significant antibacterial activity.

Keywords: *ZnO, Optical properties, Structural properties, Electrical properties, Antibacterial activity*

1. Introduction

Zinc Oxide (ZnO) is one of the most promising transparent conducting oxides (TCO) [1]. ZnO is an n- type semiconductor having wurtzite structure. It has unique and interesting properties such as wide band gap (3.37 eV) at room temperature [2], large excitation binding energy (60 MeV) at room temperature [2], high thermal and chemical stability [3], non toxicity [4], good electrical and optical behavior [5], photo catalytic activity and antibacterial activity [6,7, 8].

Several researchers has already done more work on zinc oxide in the last few decades, but still it is one of the favorite conducting oxide for the variety of applications such as optoelectronics, gas sensors, light emitting diodes, photo detectors, liquid crystal displays, solar cells [9,10,11].

To improve ZnO properties many growth techniques are used such as chemical bath deposition [5], hydrothermal [9], spin coating [10], screen printing [11], chemical refluxing [12], electro deposition [15]. In this paper undoped ZnO thin films were prepared by spray pyrolysis technique. Spray pyrolysis is one of the traditional methods to deposit thin films. It has low cost and simple mechanism over all other techniques [1, 2, 3, 4, and 13].

2. EXPERIMENTAL DETAILS

ZnO films are prepared on glass substrate by spray pyrolysis technique. The spray solution is zinc acetate, isopropyl alcohol and distilled water. In order to get 0.1 M homogeneous transparent solution of zinc acetate, 2.195 gm of zinc acetate is dissolved in 20 ml isopropyl alcohol and stirred at room temperature.

The substrate temperature and molar concentration of precursor solution is varied by keeping other process parameter constant.

Temperature of the substrate is varied from 375°C to 425° C. The spray gun used to spray the solution has diameter 0.3 mm. Volume of solution sprayed is about 90 ml to 100 ml. Air flow rate is maintained at 18 Lpm.

Chemical reaction

$Zn(CH_3COO)_2 \cdot 2H_2O + CH_3CHOHCH_3 \rightarrow ZnO + 2CH_3COOH (\uparrow) + CH_3CH_2CH_3 (\uparrow) + H_2O (\uparrow)$

3. STRUCTURAL PROPERTIES

In order to understand the structural properties of ZnO thin films, x-ray diffraction technique is carried out in the range 20 °C to 80 °C using CuK$_\alpha$ radiation.

Fig. 1 shows XRD pattern of ZnO thin film at temperature 400 °C. From the graph we can see that one sharp and five small peaks are present. It can be seen that the prepared ZnO material is polycrystalline in nature. The highest peak (002) intensity for ZnO is located at angle 34.4°.

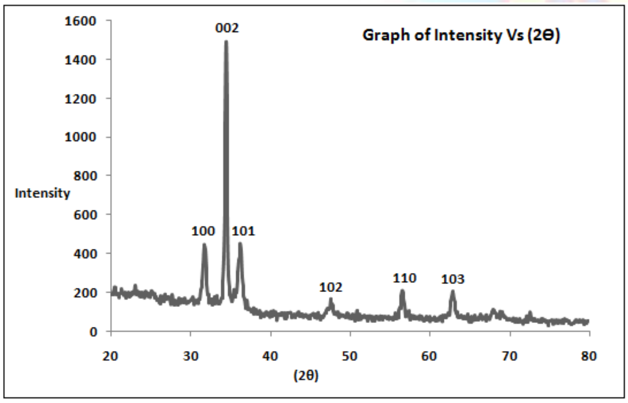

Fig.1 X- ray diffraction pattern

The average grain size are calculated from XRD data and using Debye scherer's formula [9],

$$D = 0.94\,\lambda / \beta \cos\theta_B$$

Where, λ = wavelength of x-ray (1.542 Å)

B = full width at half maximum of the diffraction peaks in radians (0.3)

θ_B = Bragg's angle in degrees (17.2°)

For calculating grain size, FWHM of only highest intensity reflection was considered.

4. OPTICAL PROPERTIES

UV Spectroscopy-

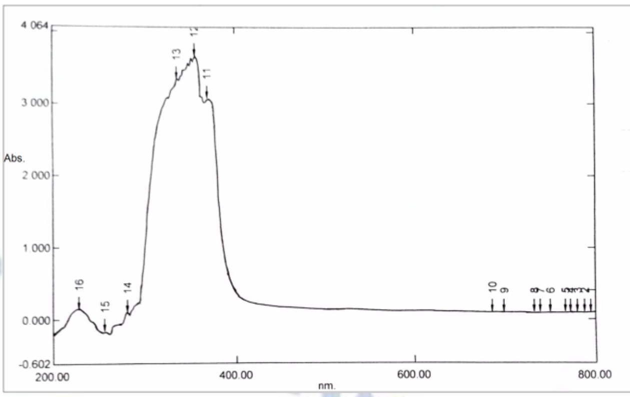

Fig.2 UV/VIS absorption curve

Fig. 2 shows the variation of absorbance (αt) of ZnO thin film. Fig. 2 indicates that the prepared ZnO film has low absorbance in the visible region, which is one of the characteristics of ZnO.

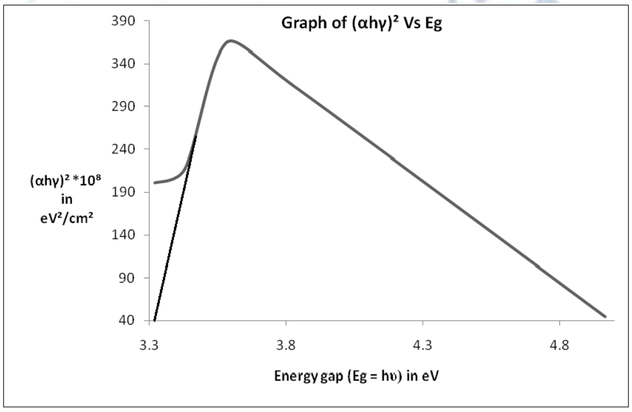

Fig. 3 graph of $(ah\upsilon)^2$ Vs $(h\upsilon)$

The band gap of the film is calculated by using the equation,

$$\alpha = (h\upsilon - E_g)^{1/2} / h\upsilon$$

From this equation we can plot a graph of $(\alpha h\upsilon)^2$ Vs $(h\upsilon)$ for ZnO film. From fig. 3 the direct band gap energy is found to be 3.31 eV for the prepared ZnO film.

IR Spectroscopy

Infrared spectroscopy is carried out to understand the molecular structure, chemical bonding and the functional groups. Fig. 4 shows IR spectrum of the ZnO thin film. Frequency band of the spectrum located at 557.43 cm^{-1} could be assigned for bending and stretching vibrations of Zn-O bonds.

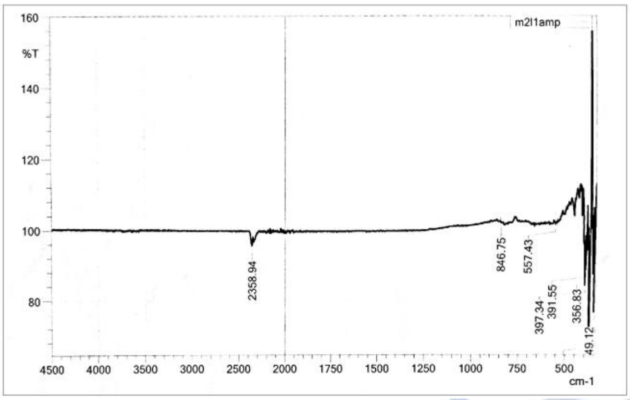

Fig. 4 IR transmission curve

5. ELECTRICAL PROPERTIES

The electrical resistivity of ZnO films is measured by four probe method at different temperatures (25 °C to 100 °C)

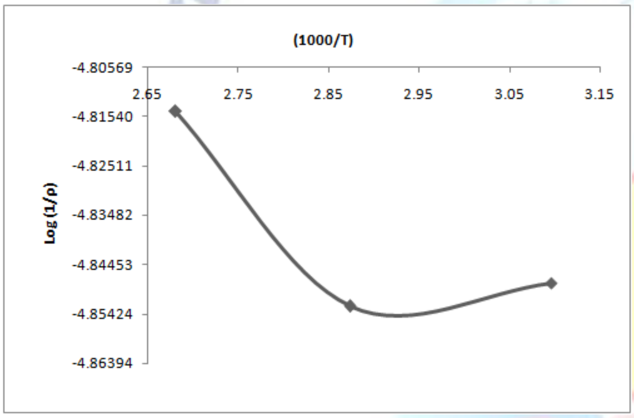

Fig. 5 Variation of electrical resistivity (1000/ T) Vs Log (1/ρ)

Fig. 5 shows the variation of electrical resistivity (Log 1/ρ) with temperature (1000/ T). It is seen that the resistivity of ZnO film goes on decreasing with increase in temperature. This shows that the ZnO film has negative temperature coefficient. This also indicates that the ZnO film has semiconductor nature. The electrical resistivity is of the order of 10^3 to 10^4 Ω – cm.

6. ANTIBACTERIAL ACTIVITY

The antibacterial activity of the prepared ZnO thin films was studied against gram negative bacteria (Escherichia coli). These bacteria species are not purchased. They are collected from the patients and identified using standard biochemical tests. The nutrient agar is used as the bacterial culture medium. All the bacterial strains are grown aerobically in the nutrient agar for 24 hours at 37℃ before using as a target organism [6, 7, and 8].

In order to examine the antibacterial activity of ZnO film, the prepared film are placed aseptically on the agar surface with the help of sterile forceps and then pressed slightly with the forceps to make complete contact with the surface of the medium. The plated are incubated at 37℃ and observed the inhibition after 24 hours (Fig. 6) [6, 7, and 8].

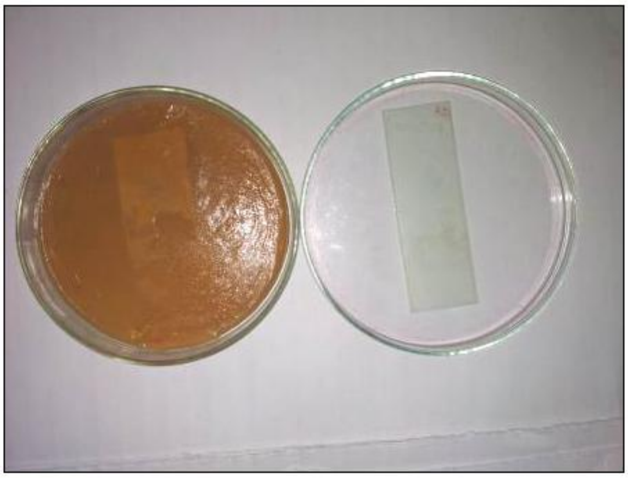

Fig. 6 Antibacterial activity of ZnO film against E-coli micro organism

7. CONCLUSIONS

- Transparent ZnO thin films are successfully prepared by the spray pyrolysis technique on glass substrate at 375° C to 425° C using zinc acetate & air as a carrier gas.
- The x-ray diffraction analysis shows that the films are polycrystalline in nature. The interplaner distance is found to be 2.6048 Å.
- The estimated grain size is 50.53 nm.
- Optical measurements showed that the ZnO film show low absorbance in the visible region. This shows that the prepared ZnO film possesses semiconductor nature.
- The film has the direct band gap with an optical value of 3.31 eV.
- The electrical resistivity decreases with increase in temperature. This concludes that the film has negative temperature coefficient of resistance.
- The prepared ZnO thin film shows significant antibacterial activity against the gram- negative bacteria E- coli.

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