JOURNAL OF NANO- AND ELECTRONIC PHYSICS
Vol. 12 No 2, 02013(3pp) (2020)
ЖУРНАЛ НАНО- ТА ЕЛЕКТРОННОЇ ФІЗИКИ
Том 12 № 2, 02013(3cc) (2020)

Study of Surface Morphology and Optical Properties of ZnO Thin Film Synthesized Using CBD Technique

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(Received 15 February 2020; revised manuscript received 10 April 2020; published online 25 April 2020)

A chemical bath deposition (CBD) technique was utilized in the synthesis of the Zinc oxide (ZnO) thin films. Aqueous solution of $ZnCl_2$ and NaOH were the sources of Zinc and Oxygen in this process. The thin films were deposited on microscope glass slides. We used Wedge shaped film method to estimate the thickness of the ZnO film. The average thickness of the films obtained was 55.349 μm. Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray Analysis (EDAX) were used in the study of the surface morphology and elemental composition of ZnO film. The topographical images (shape and size) were obtained in SEM. The presence of Zn and O was confirmed through EDAX. Optical properties of the film were studied by Ultraviolet-Visible spectroscopy technique. The analysis of the UV-Vis spectrum suggested the optical band gap of the ZnO film was 3.54 eV.

Keywords: Surface morphology, Optical properties, ZnO, Chemical bath deposition (CBD) technique.

DOI: 10.21272/jnep.12(2).02013 PACS numbers: 68.55. – a, 78.66.Bz

1. INTRODUCTION

Zinc oxide (ZnO) is a semiconductor material with wide band gap and large excitation energy. ZnO is an important technological material because it has many applications and it is cost effective. The thin films of ZnO are highly transparent and conducting. Hence, they are used in applications as transparent electrodes, display devices, piezoelectric devices, light emitting diodes, photovoltaic devices, gas sensors, solar cells, dye-sensitized solar cells and ultraviolet sensors. [1-3].

To synthesize the ZnO film with superior qualities like good optical and electrical properties is many times a challenge. Several methods, types of substrates and experimental conditions have been tried in deposition of ZnO thin films for various applications. The methods include magnetron sputtering, ion implantation, molecular beam epitaxy, metal-organic chemical vapor deposition, sol-gel method, spray pyrolysis and chemical bath method [4-7]. All these have their own plus points. The chemical bath deposition technique has an advantage over other methods since (1) it is very simple, (2) it does not require sophisticated equipment, (3) it can be carried out at room temperature (4) it has low cost of deposition and (5) it is well suited for large area thin film applications.

In this paper, we describe the CBD technique that is used in the preparation of ZnO thin film on glass substrate. Also, we report here the study of surface morphology and optical characteristics of ZnO thin film. The elemental composition was also determined in the work done here.

2. MATERIALS AND METHODS

We have used microscope glass slides for ZnO film deposition. The slides were first cleaned by keeping it in chromic acid for 24 hours followed by rinsing in deionized water. The slides were then dried in air under IR lamp to avoid any kind of contamination.

The chemicals used in this experiment were zinc chloride ($ZnCl_2$) as a source of zinc, sodium hydroxide (NaOH) as a source of oxygen, tri ethanolamine (TEA) as a complexing agent to control the reaction rate and aqueous ammonia (NH_3). All the chemicals and reagents used to prepare the reaction bath were of analytical reagent (AR) grade.

$ZnCl_2$ (0.04M) and NaOH (0.08M) were added together in equal proportion (10ml) and stirred well. Then 3 ml of TEA was added to the solution and stirred again. While stirring continuously, few drops of aqueous ammonia were added to the solution to obtain the optimum pH of 9 to 10. The previously cleaned and dried glass substrates were immersed vertically at the center of the reaction bath in such a way that it should not touch the walls of the beaker. The deposition was carried out at the room temperature for 24 hrs. The films thus obtained were washed with water and annealed at 100 °C.

Before the deposition of ZnO thin film on the glass substrate, following chemical reactions take place in the creation of ZnO:

$$ZnCl_2 + TEA \leftrightarrow Zn(TEA)^{2+} + 2Cl^-$$

$$Zn(TEA)^{2+} \leftrightarrow Zn^{2+} + TEA$$

$$NaOH + OH^- \leftrightarrow Na^+ + 2OH^-$$

$$Zn^{2+} + 2OH^- \leftrightarrow Zn(OH)_2$$

$$Zn(OH)_2 \leftrightarrow ZnO + H_2O$$

Thickness of the film was measured using wedge-shaped film method. The optical characterization of the film was done using the UV-Visible spectroscopy (Double Beam spectrophotometer 2203) in the range 200-

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900 nm to calculate the energy band gap. Surface morphology was observed with the help of Scanning Electron Microscope (Quanta FEG 450). The elemental analysis of the deposited films was carried out using the Energy Dispersive X-ray Analysis (EDAX).

3. RESULTS AND DISCUSSION

Thickness (t) of the films was determined using interference in the wedge-shaped film method. Thickness of the films was calculated using equation

$$d = \frac{\lambda}{4\mu \tan\theta},$$

where $\tan\theta = L/t$, θ is angle formed due to the wedge, L is length of the film, λ is wavelength of light used and d is fringe width. The average thickness of the films was found to be 55.349 μm. Film with thickness ranging from nanometers to several micrometer is considered as thin film. Thickness of our films is on higher side of the range.

Optical properties were determined from the measurement of absorbance in the range 200-900 nm. Fig. 1 shows the plot of absorption as a function of wavelength.

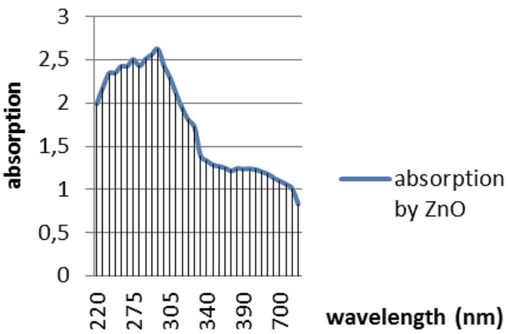

Fig. 1 – Application Absorption as a function of wavelength

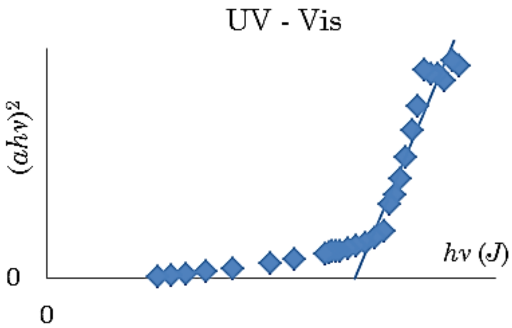

Fig. 2 – Plot of $(\alpha h\nu)^2$ versus $h\nu(J)$

The band gap of the ZnO film can be calculated using the Stern relation,

$$(\alpha h\nu)^2 = k(h\nu - E_g),$$

where α is absorbance, h is Plank's constant, ν is frequency, E_g is band gap energy and k is a constant. The band gap was determined by extrapolating the linear portion of the $(\alpha h\nu)^2$ versus $h\nu$ plot (Fig. 2) [8, 9]. The intercept obtained from the plot is 5.56×10^{-19} J (3.47 eV). This band gap is comparable to the reported value [10].

Figure 3 shows the EDAX spectrum of the ZnO film deposited on the glass substrate. EDAX analysis confirms the composition of Zn and O in the ZnO film is appropriate.

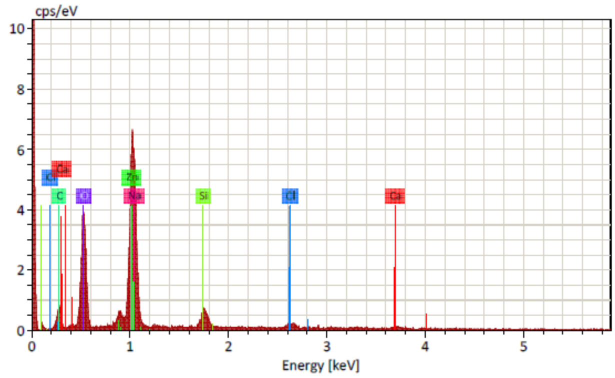

Fig. 3 – EDAX spectrum of the ZnO film deposited on glass substrate

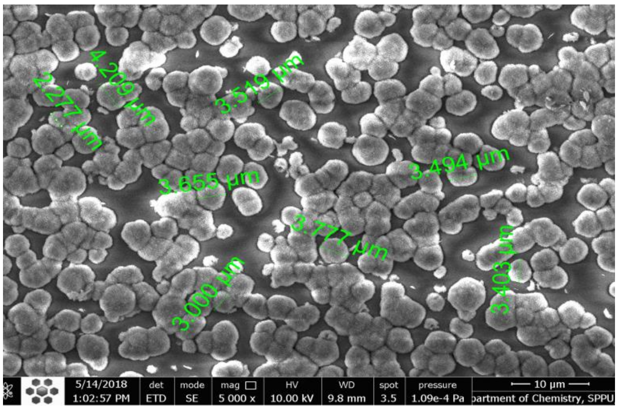

Fig. 4 – SEM image of ZnO film (magnification – ×5000)

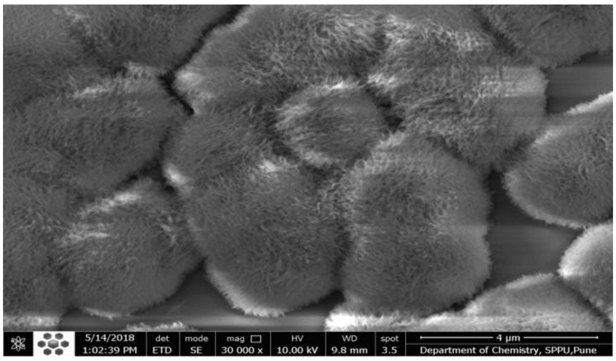

Fig. 5 – SEM image of ZnO film (magnification – ×30000)

Figures 4 and 5 show the SEM images of the ZnO film.SEM images show that most of the particles are circular in shape and also looking like a sponge [4]. The average crystallite size was obtained by drawing histogram for the SEM image. The particles in the ZnO film are observed to have the size between 2.277 to 4.209 μm.

4. CONCLUSION

The films of ZnO deposited using chemical bath deposition technique were having thickness 55.349 μm. Study of optical properties showed the bandgap of the film was 3.47 eV. The chemical composition of the film was determined by EDAX and it confirms the formation of ZnO film. The surface morphology study of the film showed the particles are spherical in shape and spongy which is in accordance with the results reported earlier [4].

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