Study of ZnO Thin Films Prepared by Chemical Bath Deposition at Varying Temperatures

D. R. Mahamne[1], M. D. Shinde[2], S. S. Jagtap[1], G. R. Pansare[1], K. D. Diwate[1]*

[1] Department of Physics, Haribhai V. Desai College, Pune - , India

[2] Centre for Materials for Electronics Technology (C-MET), Panchwati, Off Pashan Road, Pune – 411008, India

Abstract

Zinc oxide thin films were deposited on glass slide substrate using aqueous solution of zinc acetate, triethanolamie (TEA) and NaOH by chemical bath deposition (CBD) method. Thin films were prepared by varying deposition temperature in the range of 75 to 95 °C. Structural studies show formation of hexagonal ZnO thin film. Optical properties revealed the optical band gap of the ZnO thin film to be in the range of 3.4 eV. The film show high transmittance in the visible/near infrared region.

Key words: Zinc oxide film, Chemical bath deposition, XRD, Optical properties

Introduction : ZnO is one of the most studied wide-bandgap semiconductor of the II-VI semiconductor group. It shows an n-type electrical conductivity due to its native or intrinsic defects such as oxygen vacancies and interstitial zinc atoms [1]. Thi films of ZnO are generating great interest owing to their excellent properties such as wide band gap (3.3 eV), high optical transparency in the visible region, electrical and piezoelectrical properties, high electron mobility, and strong room-temperature luminescence [2]. ZnO is a cheap, abundant, chemically stable and nontoxic material that has been widely used in optoelectronic devices, photovoltaic devices and surface acoustic wave devices and sensors [3]. ZnO thin films have been deposited using various techniques such as sol-gel, sputtering, chemical bath deposition (CBD), etc [4, 5]. Among them, CBD is facile, environmental friendly and cheap technique for deposition of thin films over large area. Therefore, in the present work, ZnO thin films were deposited using CBD method for their prospective applications in gas sensing and solar cells.

Experimental Details :

Materials

Zinc acetate ($(CH3COO)_2.2H_2O$), triethanolamie (TEA) and sodium hydroxide (NaOH) were of analytical grade and were used as received without further processing.

Cleaning of glass substrate

The substrates used for the deposition of ZnO thin film were commercial microscope glass slides having the size of 75mm×25mm×1.35mm. Before deposition, the substrates were degreased in HNO_3 solution for 24 h and then cleaned by commercial detergent. Finally they were rinsed with deionised water and dried in air. This process was done to ensure a clean surface, which is necessary for formation of nucleation centers, required for thin film deposition.

Deposition procedure

Aqueous solution of 0.02M zinc acetate $(CH_3COO)_2.2H_2O$ in 80ml volume was prepared and 2ml triethanolamine was added to it under magnetic stirring for 60 min. Cleaned glass substrate was then immersed vertically at the centre of reaction bath in such a way it did not touch the walls of the beaker. The

solution was then heated at the pre-decided temperature. Subsequently, 1M sodium hydroxide (20ml) solution prepared separately was added drop wise till PH greater than 11 is achieved. The deposition time was set to 15 min and during the whole process continuous stirring was carried out to ensure uniform deposition of the film on glass substrate. At the end of the dip period, the films were washed with water and dried in air.

Characterization

The structural parameters of the powder were determined using X-Ray Diffraction technique. The XRD patterns were recorded with Pan analytical XPRT IPRO using a Cu Kα radiation source (λ= ± 1.54056 Å). The optical absorbance, transmittance, and reflectance of the film were studied in the spectral range of 200-900 nm using UV spectrophotometer (Varian) films

Results and discussion :

The deposition process may be due to the slow release of Zn^{2+} and O^{2-} ions in solution, which then condenses on the glass substrate. Initially Zn-TEA complex is formed which then reacts with OH^- ions to form Zn $(OH)_2$. The decomposition of ZnO leads to formation of ZnO. The deposition of ZnO occurs when the ionic product of Zn^{2+} and O^{2-} exceeds the solubility product of ZnO. Control of Zn^{2+} and O^{2-} ions in the solution controls the rate of precipitation and thus the rate growth of the film on the substrate.

The equations describing the reaction mechanics are as follow:

$$Zn(CH_3COO)_2H_2O + TEA \Longrightarrow [Zn(TEA)]^{2+} + 2CH_3COO^-$$

$$[Zn(TEA)]^{2+} \Longrightarrow Zn^{2+} + TEA$$

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

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

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

X-ray diffraction graph of the prepared thin films is shown in Figure 1. The diffraction peaks match well with the JCPDS file number 80-0075 corresponding to the hexagonal phase of ZnO. It may be noted that with change in reaction temperature, the orientation of the film changed from (002) to (100). Peak broadening indicates formation of nanoparticulate film. UV-visible spectra of the prepared thin films are shown in Figure 2. Optical properties revealed the optical band gap of the ZnO thin film to be in the range of 3.3-3.4 eV. The slight increase in the band gap may be due to the quantum size effects of the nanoparticulate film. Optical constant is such as refractive index, extinction coefficient, real and imaginary parts of dielectric constant were evaluated from reflectance, transmittance and absorbance curve. The film show high transmittance in the visible/near infrared region.

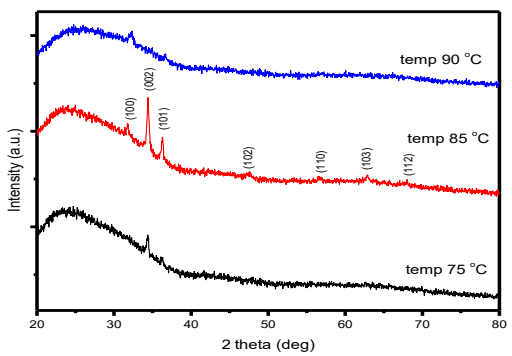

Figure 1: X-ray diffractograms of ZnO thin films on glass substrate prepared at different reaction temperatures

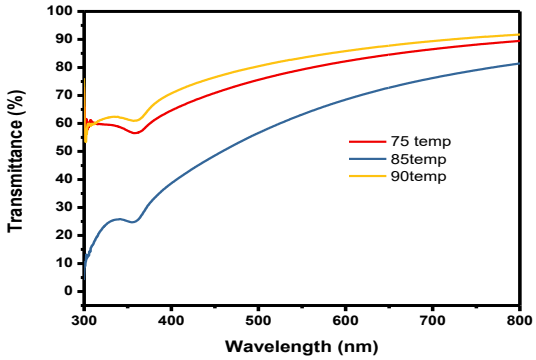

Figure 2: UV-visible spectra (transmittance mode) of ZnO thin films on glass substrate prepared at different reaction temperatures

Conclusions

Zinc oxide thin films has been successfully obtained using convenient, environment friendly, inexpensive and efficient chemical bath deposition method.

References

1] Gutierrez FM, Olive PL, Banuelos A, Orrantia E, Nino N,Sanchez EM, Ruiz F,Bach H, Gay YA, synthesis, characterization and evalution of antimicrobial and cytotoxic effect of silver and titanium nanoparticles.(2010).

2] M. Bouderbala , S. Hamzaoui, M. Adnane, T. Sahraoui, M. Zerdali, Thin Solid Films (2009) .

3] M. Krunks, A. Katerski, T. Dedova, I. Oja Acik, A. Mere Solar Energy Materials & Solar Cells (2008).

4] Jesus Cembrero, David Busquets-Mataix, Thin Solid Films (2009).

5] Lei Zhao, Jianshe Lian, Yuhua Liu, Qing Jiang, Applied Surface Science (2006)

6] K. Renugadevi*, P. Raji and M. Bavanilatha, In-vitro evaluation of antibacterial activity and cytotoxicity effect of chemically synthesized ZnO nanoparticles, IJPSR (2012)

7] A.Surti, S. Radha and S.S. Garje, Study of the Antibacterial activity of ZnO nanoparticles, (2013) .