SPIN SPEED DEPENDENCE OF OPTICAL BAND GAP OF SOL GEL SPIN COATED ZINC OXIDE THIN FILMS

By

RAJESH KUMAR * AAKANKSHA SAHU ** NARINDER ARORA ***

RABIA SAREEN **** GAGANDEEP KAUR *****

*-***** P.G. Department of Physics, D. A. V College, Amritsar, India.

ABSTRACT

The zinc oxide (ZnO) thin films have been obtained by sol gel spin coating technique on to the glass substrates kept at 400°C. The conditions have been optimized to obtain quality films. Optical absorption studies to find optical band gap of the films have been made through UV-Visible spectroscopy in the spectral range of 200 - 1100 nm. Effect of spin speed on the optical band gap of these films has been studied. Results show that optical band gap of the films get modified on increasing the spin speed of films.

Keywords: Spray Pyrolysis, Zinc Oxide, Optical Band Gap.

INTRODUCTION

ZnO is a wide band gap semiconductor, with interesting electro optical properties because of its large exciton binding energy and high thermal as well as chemical stability at room temperature. ZnO thin film has been extensively used as transparent conductive film and the solar cell window material because of its high optical transmittance in the visible region. With such technological important properties, ZnO has wide range of applications as sensors [1, 2], heat mirrors [3], transparent electrodes [4], solar cells [5-7] and piezoelectric devices [8].These films can be deposited by several techniques including, sputtering [9], metal organic chemical vapour deposition [10], sol gel [11] and spray pyrolysis [12]. A sol-gel method has advantages over other techniques due to its low cost instrumentation involved for obtaining films, its easy control over chemical components and thickness of the film along with the simple route for film deposition. Optical absorption coefficient, optical band gap and refractive index of semiconductors are important parameters for the design, fabrication and analysis of various optical and optoelectronic devices. The optical transmittance through the samples can be used to obtain direct and indirect optical band gap along with other optical constants. In the present work, low cost sol-gel spin coating technique has been exploited to obtain ZnO thin films onto the glass substrate. The effect of spin speed on optical band gap of the films so obtained has been discussed.

1. Experimental Details

Chemically and thermally stable films of zinc oxide were prepared using the spin coating method. Microscope glass slides were used as the substrates for thin films. Prior to deposition, the glass slides were sequentially cleaned in an ultrasonic bath with acetone and ethanol. Finally, they were rinsed with distilled water and dried. 0.1M solution of zinc acetate dehydrate ($Zn(CH_3COO)_2.2H_2O$) in ethanol was taken as precursor solution for all the films. The solution was continuously stirred for an hour with the help of magnetic stirrer in an air tight container. The resulting solution was allowed to get settled for 24 hours. 40µl of this spreading solution was dispensed on to the substrate from a distance of 5mm above the substrate and spinner (Apex system model NXG M1) was employed to spin the substrate at different speeds ranging from 2000 to 4000 rpm with spin time of 15 sec. for each film. The amorphous gel films were left to dry in air at 100°C for ten minutes. The films were then cooled down to room temperature in open air. This process was repeated four times/cycle for each film. The films were further kept at 400°C for half an hour in open air. The UV-visible-IR optical transmission spectra of ZnO thin films were recorded by using Shimadzu UV-VIS-2450 scanning spectrophotometer in the range of 300-1100 nm. The measurements were taken at a normal incidence using a reference blank glass substrate. The transmittance and absorbance spectra were used to calculate the absorption coefficient and optical band gap of the films. The thickness of the thin films were estimated using max-min method, using the formula: $t = \lambda 1\ \lambda 2/4n\ (\lambda 2 - \lambda 1)$, where 't' is the thickness of the film, λ1 and λ2 are the wavelengths which correspond to the maxima and minima of the transmittance spectra and 'n' is the refractive index of ZnO. Thickness of the films was also confirmed using microbalance method and has been shown in Table 1.

2. Results and Discussion

The most direct and perhaps the simplest method for probing the band structure of semiconductors is to measure the absorption spectrum. The absorption and percentage transmission spectra of ZnO thin films deposited at different spin speeds is shown in Figures 1 and 2 respectively.

In order to determine the optical band gap of the films, the absorbance spectra of the films were recorded at room temperature. The absorption coefficient (α) was calculated from the absorbance spectrums using the formula: $\alpha = 2.3026\ (A/d)$, where d is the film thickness and A is the optical absorbance. The absorption edge of ZnO has been examined in terms of a direct transition using the equation of Bardeen et al [13], stating that: $\alpha h\nu = B(h\nu - E_g)^n$, where α

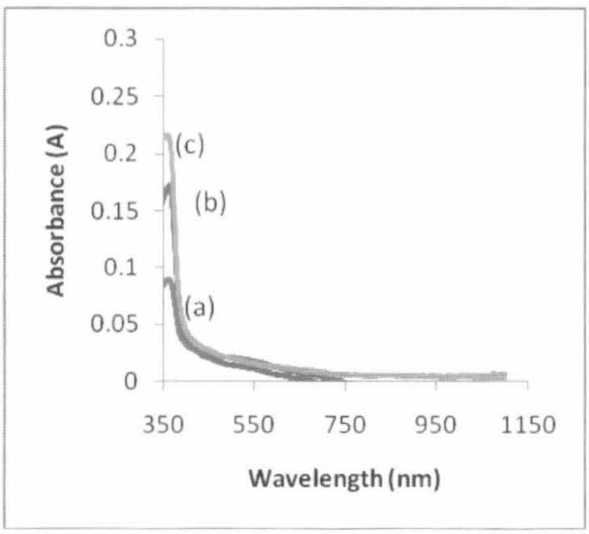

Figure 1. Optical absorbance spectra of ZnO films deposited at spin speed (a) 2000 rpm (b) 3000 rpm (c) 4000 rpm

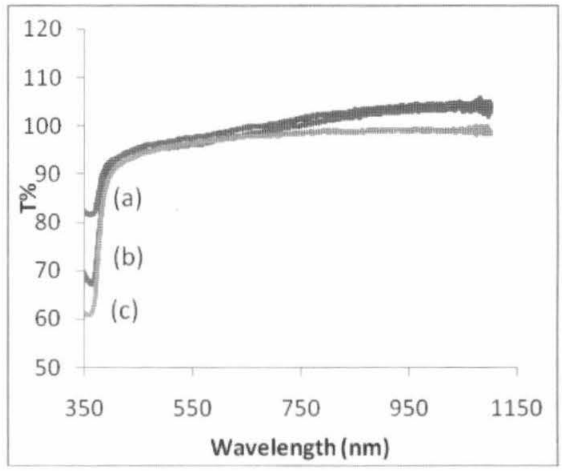

Figure 2. Optical transmittance spectra of ZnO films deposited at spin speed (a) 2000 rpm (b)3000 rpm (c) 4000 rpm.

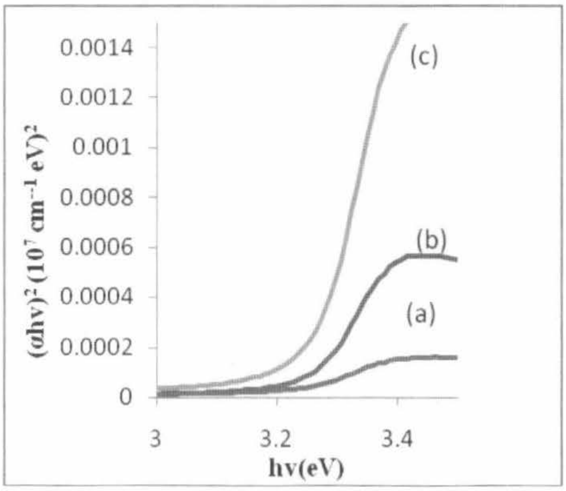

Figure 3. Variation of (αhν)2 as a function of photon energy hν of ZnO films deposited at spin speed (a) 2000 rpm (b) 3000 rpm (c) 4000 rpm.

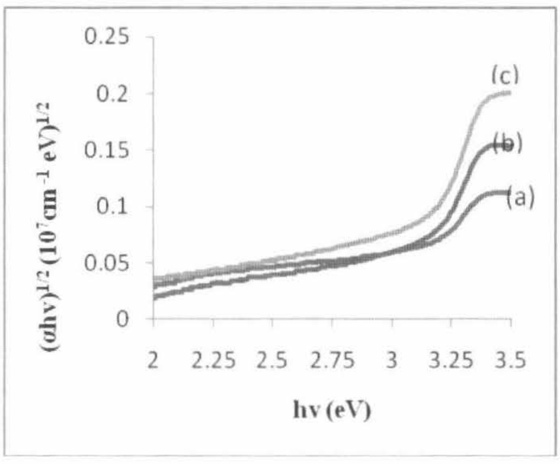

Figure 4. Variation of (αhν)1/2 as a function of photon energy hν of ZnO films deposited at spin speed (a) 2000 rpm (b)3000 rpm (c) 4000 rpm.

Spin Speed (rpm)	Thickness (nm)	Direct Band Gap (eV)	Indirect Band Gap (eV)
2000	60	3.22	2.98
3000	57	3.26	3.05
4000	43	3.27	3.08

Table 1. Band gap energy of spray deposited zinc oxide films on glass substrate kept at different spin speeds.

is the absorption coefficient, hv is the photon energy, E_g is the optical band gap, B is a constant which does not depend on photon energy and n is respectively 1/2 and 2 for direct and indirect transitions. The direct and indirect band gap was determined by plotting $(\alpha hv)^2$ vs. hv and $(\alpha hv)^{1/2}$ vs. hv curves and have been shown in Figures. 3 and 4 respectively.

The intercepts (extrapolations) of these plots (straight lines) on the energy axis give the optical energy band gaps. It has been observed that both direct and indirect optical band gap increases from 3.22 eV to 3.27 eV and from 2.98 eV to 3.08 eV respectively with the increase in spin speed. This increase in band gap energy may be attributed to the improvement of crystallinity of the films with the increase in spin speed and due to the fact that homogeneity of the films increases with increase in the spin speed of films. Hence, more ordered films causing comparatively less contribution to the absorption is obtained at higher spin speeds. Results are in good agreement with the findings of Halin et al [14] and Capan et al [15]. The direct and indirect band gap energy of zinc oxide films obtained on glass substrate at different spinning rates have been listed in Table 1.

Conclusion

The spin coated zinc oxide films at different spin rates have been obtained on glass substrates. The optical absorbance and transmittance spectra of the films so obtained has been recorded in the wavelength range of 200-1100 nm. It has been observed that both the allowed direct and indirect optical band gap of the films increases with the increase in spinning rate.

Acknowledgment

The authors would like to pay thanks to Dr. K.N.Kaul, Principal, DAV College, Amritsar for providing the necessary infrastructure at work place.

References

[1]. **P. Mitra, A. P. Chatterjee, H.S. Maiti, (1998).** "ZnO thin film sensor". *Materials Letters,* Vol.35, No.1-2, April 1998, pp 33-38.

[2]. **C. H. Kwon, H. K. Hong, D. H. Yun, K. Lee, S. T. Kim, Y. H. Roh, B. H. Lee, (1995).** "Thick-film zinc-oxide gas sensor for the control of lean air-to-fuel ratio in domestic combustion systems" *Sens. Actuators B* 25,610, Vol 25,No.1, pp 610-613.

[3]. **K. L. Chopra, S. Major, D. K. Pandya, (1983).** "Transparent conductors—A status review" *Thin Solid Films,* Vol.102, No.1, pp 1-46.

[4]. **S. Major, A. Banerjee, K. L. Chopra, (1986).** "Thickness-dependent properties of indium-doped ZnO films" *Thin Solid Films,* Vol.143, No.1,pp 19–30.

[5]. **J. B. Yoo, A. L. Fahrenbruch, R. H. Bube, (1990).** " Transport mechanisms in ZnO/CdS/CuInSe2 solar cells", *J. Appl.Phys,* Vol.68,No. 9 pp. 4694.

[6]. **D. Dimova-Malinovska, (1999).** "Application of stain-etched porous silicon in light emitting diodes and solar cells", *J. Lumin*. Vol.80,No. 1–4,pp 207-211

[7]. **Z.-C. Jin, I. Hamberg, C. G. Granqvist, B. E.Sernelius, K.-F. Berggren, (1988).** "Reactively sputtered ZnO: Al films for energy-efficient windows", *Thin Solid Films,* Vol.164 pp 381-386.

[8] **.J. G. E. Gardeniers, Z. M. Rittersma, G. J. Burger, (1998).** "Preferred orientation and piezoelectricity in sputtered ZnO films" *J.Appl. Phys*. Vol.83,No.12,pp 7844-7854.

[9]. **Soon-Jin So, Choon-Bae Park, (2005).** "Diffusion of phosphorus and arsenic using ampoule-tube method on undoped ZnO thin films and electrical and optical properties of P-type ZnO thin films", *Journal of Crystal Growth 285,* Vol.285,No. 4, pp 606-612.

[10]. **S. T. Tan, B. J. Chen, X. W. Sun, X. Hu, X. H. Zhang, S. J.Chua, (2005).** "Properties of polycrystalline ZnO thin films by metal organic chemical vapor deposition", *Journal of Crystal Growth* ,Vol.281,No. 2,pp 571-576.

[11]. **Young-Sung Kim, Weon-Pil Tai, Su-Jeong Shu, (2005).** "Effect of preheating temperature on structural and optical properties of ZnO thin films by sol–gel process", *Thin Solid Films,* Vol.491,No. 1–2, pp 153-160.

[12]. **R. Martins, R. Igreja, I. Ferreira, A. Marques, A.Pimentel, A. Gonçalves, E. Fortunato, (2005).** "Room temperature dc and ac electrical behaviour of undoped ZnO films under UV light", *Materials Science and Engineering*, Vol.118,No.1,pp 135-140.

[13]. **J.Bardeen, F.J.Blatt and L.H.Hall, (1956).** *"Indirect Transitions from the valence to the conduction bands"*, Photoconductivity Conf. Ed. R.Breckenridge, B.Russel and T.Hahn, John-Weiley, New York. pp.146-154

[14]. **D.S.C Halin, I.A.Talib, A.R.Daud and M.A.A.Hamid,(2009).** "The Effect Of Spin Coating Rate On Morphology And Optical Properties Of Cuprous Oxide Thin Film Prepared By Sol-Gel Technique" *Solid state science and technology*, Vol. 17, No 1,pp 119-125.

[15]. **R Capan, N.B.Chaure, A K Hassan and A K Ray, (2004).** "Optical dispersion in spun nanocrystalline titania thin films." *Semicod. Sci. Tech*, Vol.19 No.2,pp 198-202

ABOUT THE AUTHORS

Dr. Rajesh Kumar is doctorate in the field of Materials Science and has worked on Chalcopyrite thin films during his Ph.D. work. He has guided nine M.Phil. students and guiding one Ph.D. student at present. Presently he is Assistant Professor in the P.G. Department of Physics, D.A.V. College, Amritsar from last twelve years. His current area of research includes metal oxide thin films, fuel cells, organic and hybrid solar cells.

Aakanksha sahu is presently serving as Physics lecturer, Department of Physics, D.A.V. College, Amritsar (Punjab).

Dr. Narinder Arora is an Assistant Professor of Physics at D.A.V. College, Amritsar in the Post Graduate Department of physics since 2002. He received his Ph.D. in the field of Materials Science, particularly on "Transport studies of polymer gel electrolyte containing lithium salts and carboxylic acids" from Guru Nanak Dev University. His research interest is in the areas of nano-material based gel electrolyte, polymer electrolyte, composite electrolyte and their applications. His research has been published in various Journals such as Solid State Ionics, Electrochimica Acta, European polymer journal, Ionics and i manager J. Matr. Sc. Till now, he has published 16 research papers in reputed Journals and Proceedings.

Rabia Sareen is M.Sc. Physics student at PG Department of Physics, D.A.V. College, Amritsar (Punjab).

Gagandeep Kaur is M.Sc. Physics student at PG Department of Physics, D.A.V. College, Amritsar (Punjab).