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Effect Of Al Concentration On The Optical And Electrical Properties Of SnO_2 Thin Films Prepared By Low Cost Spray Pyrolysis Technique

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Abstract: Transparent p type Aluminum doped tin oxide(SnO_2:Al) thin films with different Al percentage (10,15,20,25 and 30) were fabricated using a low cost simplified spray pyrolysis technique. The optical properties of the deposited films were characterized in order to study its transmittance and to calculate the optical constants such as refractive index (n) and extinction coefficient (k). The calculated refractive indexes of the films with various Al concentrations were in the range of 1.668 to 1.676. The extinction coefficient values shows that the grown films were stronger absorbing medium in the lower wavelength region. The electrical studies confirm that the deposited films are p type and have the carrier concentration of the order of 10^{16} to $10^{17}/cm^3$.
Keywords: p type SnO_2 thin films, optical constants, electrical properties.

INTRODUCTION

Transparent conducting oxide (TCO) materials have greater importance due to variety of applications such as electrochromic devices[1], solar cells[2], opto electronic devices[3] etc., Tin Oxide(SnO_2) is one of the TCO material having wider band gap of 3.6eV[4] and it has a wide range applications such as gas sensors[5], lithium batteries[6], electrodes[7], photovoltaic cells[8] , transistors[9] etc. SnO_2 behaves as a n- type semiconductor[10], however when there is a suitable dopant doped with it, the carrier conversion takes place and change to p-type semiconductor[11]. Among the various dopants Aluminium has a greater importance with SnO_2 since they produce high transparency in the visible range. SnO_2 thin films can be deposited by several methods such as electron beam evaporation[12], spray pyrolysis[13], Chemical vapor deposition[14], Sputtering[15] etc. Optical properties of thinfilms gives the information about its band gap energy, band structure, defects in the film etc., and may results the use of several applications. In this present work, the electrical properties of Al doped SnO_2 films have been studied. The optical constants such as refractive index(n), extinction coefficient(k) and thickness of Al doped SnO_2 films for different Al concentrations (10%.15%,20%,25% and 30%) prepared by a low cost spray pyrolysis technique[16,17] have been calculated and the results are discussed.

EXPERIMENTAL DETAIL

Film preparation

Al doped SnO_2 thin films were prepared by 0.1M of $SnCl_2.4H_2O$ with atomic percentage of $AlCl_3$ between 10 and 30% of starting solution have been deposited by means of a perfume atomizer on pre heated glass substrates of dimensions of 75x25x1.35 mm^2. The substrates were pre cleaned ultrasonically and using doubly deionized water to remove the impurities if any on the substrate surface. For film deposition, the substrates are maintained at a temperature of 350±5ºC using a temperature controller and a chromel-alumel thermocouple for the formation of SnO_2 films. After reaching 350ºC, the solution was sprayed intermittently using perfume atomizer with a deposition time of 3s after a waiting period of 1-3 min to give enough time for the formation of thin film.

Film characterization

The deposited films with various Al concentrations (10%,15%,20%,25% and 30%) were characterized for their optical, and electrical properties. The optical transmission spectra were obtained by UV Vis spectrophotometer (Perkin Elmer LAMBDA 35) for the wave length range 300 – 1100nm and the interference patterns were used to estimate the film thickness. The electrical studies such as hall mobility and charge density are done by Ecopia HMS 5000 Hall Effect measurement system.

RESULTS AND DISCUSSION

Optical Properties

Al doped SnO2 thin film optical constants of the different atomic percentage are measured using UV transmission spectrum. Fig 1. Shows transmission spectrum of Al doped SnO_2 thin films with Al concentration of 5%, 10%, 15%, 20%, 25% and 30%.

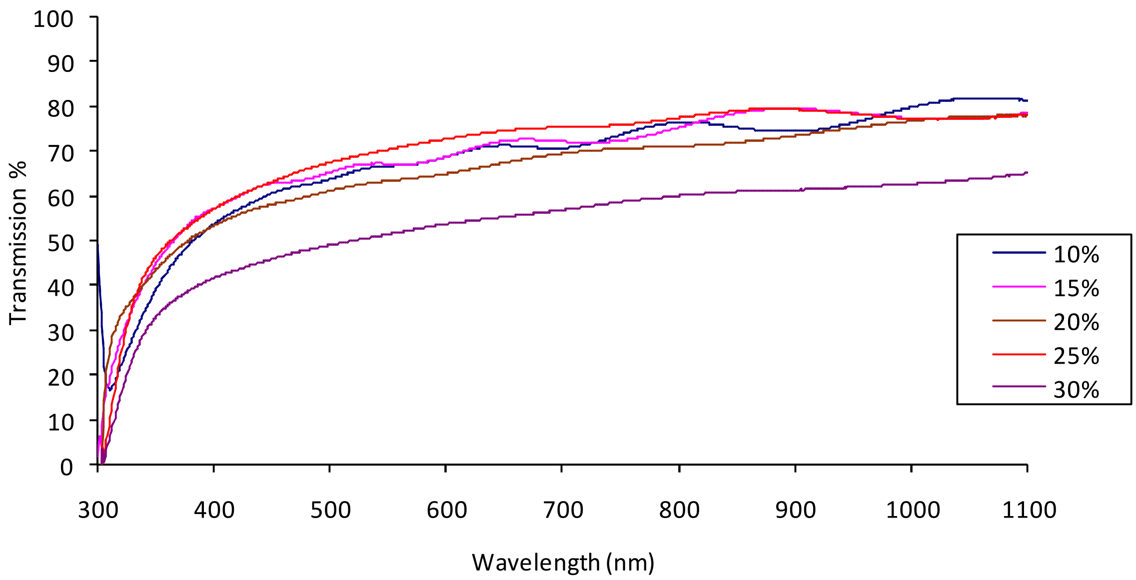

Figure 1. Transimission spectrums of Al doped SnO_2 thin films

From the Fig 1 it is observed that, the transmission of the film decreases with increase in Al concentration. The average percentage of transmission of all the thin film samples is lies between 55% and 75% in the visible region. However, higher Al concentration decreases the transmission percentage is observed for sample having

30% of Al concentration. This sample has a poor transparency compared to other films. The observed transmission percentage values are very low compared with earlier reported values [18]. The optical absorption edges of all samples were lying in the lower wavelength range of about 300 nm to 400 nm. Except the sample having 30% of Al concentration, all the other samples possess interference pattern indicates uniformity of the thickness.

Band gap calculation

The band gap of the deposited films are calculated by using the following formula[19]

$$(\alpha h\nu) = A(h\nu - E_g)^m \quad (1)$$

where A is an energy independent constant, m is a constant that determine the optical

transmission type whether it is direct band gap or indirect bandgap and Eg is the Energy gap. From the plot of $(\alpha h\nu)^2$ vs hν shown in Fig 2, it is observed that the variation of band gap not depends upon the concentration of the precursor soulution. The calculated band gap for 10%,15%,20%,25% and 30% of Al doped SnO_2 are 3.4eV, 3eV, 3.15eV, 3.55eV and 3.33eV respectively. These results imply that the deposited films can be used in photovoltaic devices. The values of the calculated band gaps are very low compared to other reported values [18] may due to the preparative conditions.

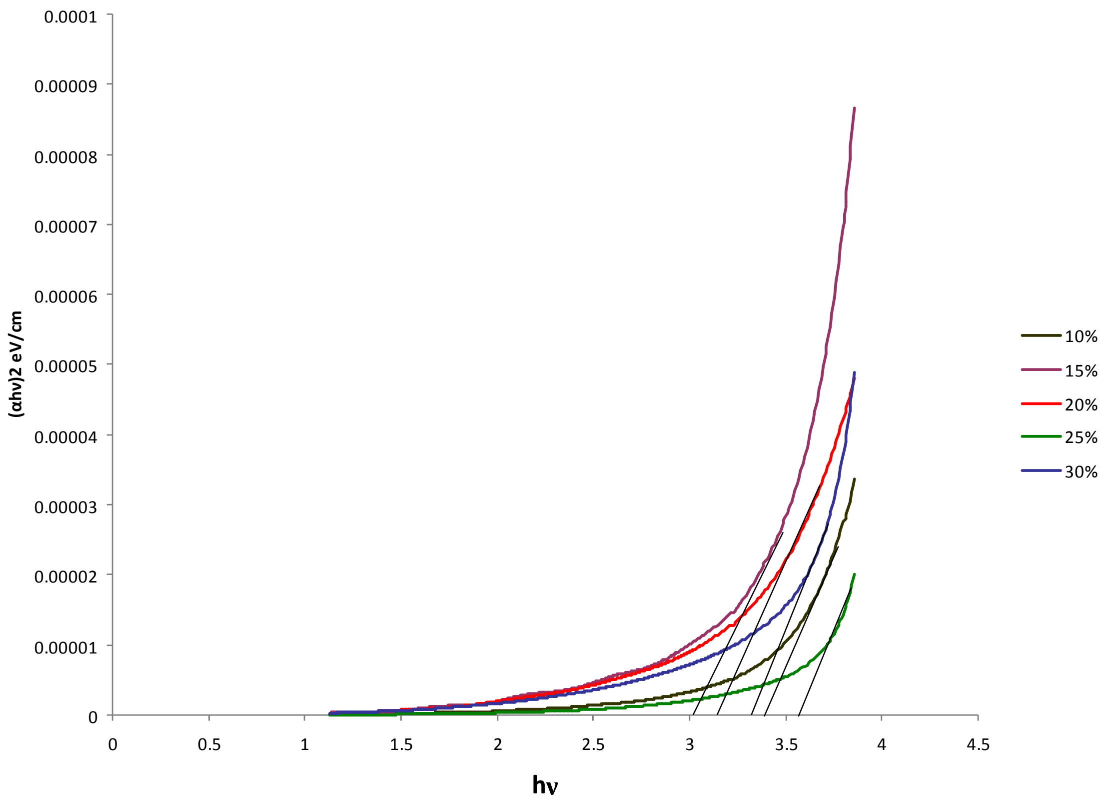

Figure 2. Optical band gap of Al doped SnO_2 thin films

Optical constant Measurement

The knowledge of optical constants of the thin films are very significant since they can determine the exact application of the films. Fig 3 shows the variation of refractive index(n) with photon energy (hν). It is clear from the figure that the refractive index of the film does not depends upon the concentration of Al. For 10%,20% and 25% Al concentrated thin films, the trend of the refractive index is decreasing however, for 15% and 30% the refractive index increases with photon energy. For all the deposited films, the refractive index value lies between 1.668 and 1.676.

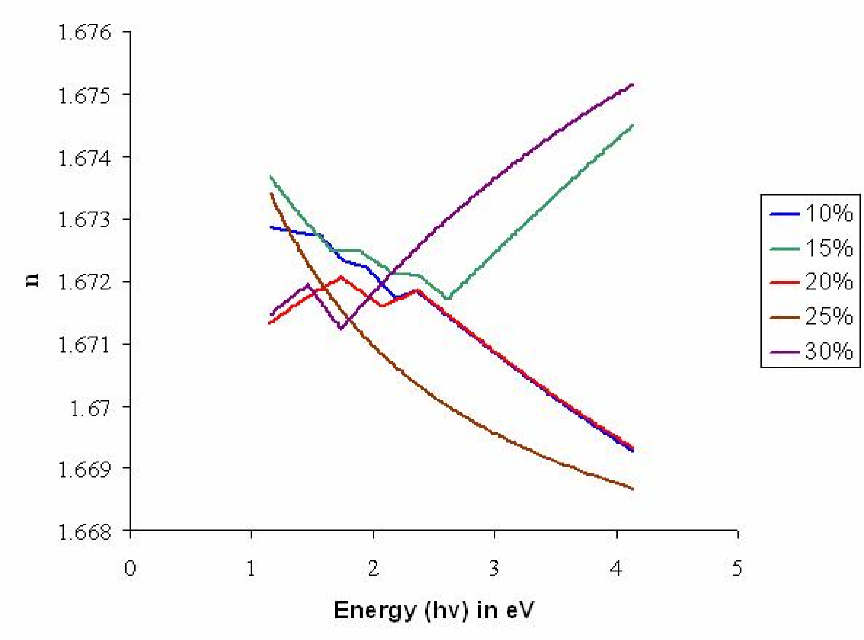

Figure 3 Variation of refractive index with photon energy of Al doped SnO_2 thin films

The another important optical constant, extinction coefficient(k) has been calculated by using the following formula[20]

$$k = \alpha\lambda/4\pi \qquad \text{---(2)}$$

The variation of k with photon energy is plotted in Fig 4. Irrespective of Al concentration all the films exhibits same trend. The k value for all the films behave a linear trend upto 3.8 eV after that there is a sudden increase in the extinction coefficient value. The blue shift in the extinction coefficient value denotes that the films are stronger absorbing medium in this range.

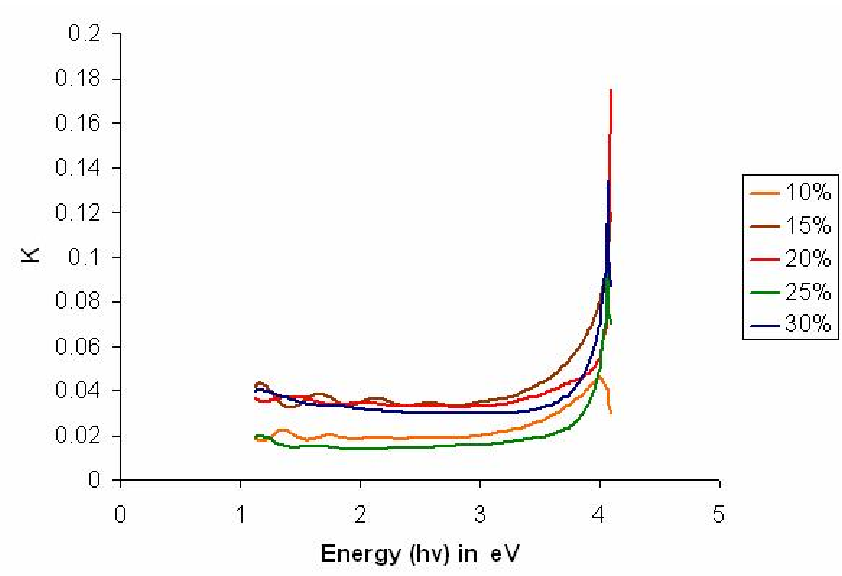

Figure 4 Variation of extinction coefficient with photon energy of Al doped SnO_2 thin films

Electrical properties

Table 1. Electrical properties of Al doped SnO_2 thin films

Sample	Thickness(nm)	Carrier Concentration(cm^{-3})	Mobility (cm^2/Vs)	Type
10%	954	6.9×10^{16}	3.4	P
15%	497	4.2×10^{16}	21.3	P
20%	594	5.23×10^{17}	6.19	P
25%	1093	7.2×10^{16}	22.5	P
30%	942	4.19×10^{17}	16.7	P

The electrical properties of SnO_2 films with various Al concentrations and thickness of the corresponding films are shown in Table 1. It is noted that all the films are P type in nature. The carrier concentration increases with increase in Al concentration. The variation of mobility of charge carriers depend up on the Al concentration. With the higher thickness value the carries concentration of the grown films are increasing. However, Al concentration also makes significant influence in the carrier concentration. The carrier concentration obtained from this study is very less compared to earlier reported values [18] due to the preparative conditions.

CONCLUSION

P type Al doped tin oxide (SnO_2) thin films were deposited using simplified low cost spray pyrolysis technique with various Al concentrations(10%,15%,20%,25% and 30%). The effect of Al concentration on the optical and electrical properties is discussed for the deposited SnO_2 films. The transparency of the film decreases with increase in Al concentration. The optical absorption edges of all films were lies in the range of 300nm to 400 nm. The calculated refractive index(n) reveals that the grown films were suitable for optoelectronic devices. The extinction coefficient (k) values of the grown films indicate the films are stronger absorbing medium in the lower wavelengths. The hall effect experiment confirms that the grown films are p type in nature with the carrier concentration range of 10^{16} and 10^{17} /cm^3.

REFERENCES

1. Chin-Guo Kuo,Chih-Yin Chou, Ya-Chieh Tung and Jung-Hsuan Chen, Experimental Study of the Electrochromic properties of WO_3 thin films derived by Electrochemical Method, J. Mar. Sci. Technol., 2012, 20(4), 365-368.
2. Tae Youn Kim, Jeong Woo Lee, Won Seo Park, Seong-Kee Park, Ki Yong Kim and In yeong Kang, Development of Transparent Conductive Oxide for Thin-film Silicon Solar Cells, J. Korean Phys. Soc., 2010, 56(2), 571-575.
3. Ramamoorthy K., Sanjeeviraja C., Jayachandran M., Sankaranarayanan K., Pankaj Misra and Kukreja L.M., Development of a novel high optical quality ZnO thin films by PLD for III–V opto-electronic devices, Curr. Appl Phys., 2006, 6,103-108.
4. Ganesh E Patil, Kajale D.D., Chavan D. N., Pawar N.K., Ahire P .T. , Shinde S. D., Gaikwad V. B. and Jain G. H., Synthesis, characterization and gas sensing performance of SnO_2 thin films prepared by spray pyrolysis, Bull. Mater. Sci., 2011, 34(1), 1-9.
5. Du X., Du Y. and George S. M., CO Gas Sensing by Ultrathin Tin Oxide Films Grown by Atomic Layer Deposition Using Transmission FTIR Spectroscopy, J. Phys. Chem. A 2008, 112, 9211–9219.
6. Xianjun Zhua, Yanwu Zhu, Shanthi Murali, Meryl D. Stoller and Rodney S. Ruoff, Reduced graphene oxide/tin oxide composite as an enhanced anode material for lithium ion batteries prepared by homogenous coprecipitation, J. Power Sources, 2011, 196, 6473–6477.
7. Moses P. R , Wier L., Murray R. W., Chemically modified tin oxide electrode, Anal. Chem., 1975, 47 (12), 1882–1886.
8. Masaharu Fujinaka and Alexander A. Berezin, Cuprous oxide–indium–tin oxide thin film photovoltaic cells, J. Appl. Phys., 1983, 54, 3582 -9.
9. Presley R. E. , Munsee C.L., Park C.H, Hong D. , Wager J.F. and Keszler D.A., Tin oxide transparent thin-film transistors, J. Phys. D: Appl. Phys., 2004, 37, 2810–2813.

10. Moholkar A.V. , Pawar S.M., Rajpure K.Y., Patil P.S. and Bhosale C.H., Properties of highly oriented spray-deposited fluorine-doped tin oxide thin films on glass substrates of different thickness, J. Phys. Chem. Solids, 2007, 68, 1981–1988.
11. Zhenguo Ji, Lina Zhao, Zuopeng He, Qiang Zhou and Chen Chen, Transparent p-type conducting indium-doped SnO_2 thin films deposited by spray pyrolysis, Mater. Lett., 2006, 60 ,1387–1389.
12. Shamala K .S., Murthy L.C.S. and Narasimha Rao K., Studies on tin oxide films prepared by electron beam evaporation and spray pyrolysis methods, Bull. Mater. Sci., 2004, 27(3), 295-301.
13. Mishra R. L., Sheo.K.Mishra and Prakash S. G., Optical and gas sensing characteristics of tin oxide nano-crystalline thin film, J. Ovonic. Res., 2009, 5(4), 77-85.
14. Maleki M. and Rozati S. M. , An economic CVD technique for pure SnO2 thin films deposition: Temperature effects, Bull. Mater. Sci., 2013, 36(2), 217-221.
15. Vijay Kumar, Anshul Jain, Deepti Pratap, Agarwal D.C., Sulania I., Siva Kumar V. V., Tripathi A., Varma S. and Chauhan R.S., Modification of nanocrystalline RF sputtered tin oxide thin film using SHI irradiation, Adv. Mat. Lett. 2013, 4(6), 428-432.
16. Sriram S. and Thayumanavan A., Optical and electrical properties of Nitrogen doped ZnO thin films prepared by low cost spray pyrolysis technique, Journal of Electron Devices, 2012, 15, 1215-1224.
17. Vasanthi M., Ravichandran K., Jabena Begum N., Muruganantham G. , Snega S. , Panneerselvam A. and Kavitha P., Superlattices Microstruct., 2013,55, 180-190.
18. Mohammad-Mehdi Bagheri-Mohagheghi and Mehrdad Shokooh-Saremi, The influence of Al doping on the electrical, optical and structural properties of SnO2 transparent conducting films deposited by the spray pyrolysis technique, J. Phys. D: Appl. Phys., 2004, 37, 1248–1253.
19. J. Tauc: “Amorphous and Liquid Semiconductors”, Plenum Press, New York (1974).
20. Sharma D., Sharma P. and Thakur N., Analysis of the optical constants of spun cast polystyrene thin film, Optoelectron. Adv. Mat,. 2009,2(3), 145-148.

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