Volume : 3 | Issue : 2 | February 2014 • ISSN No 2277 - 8179

Cds/ Sno_2 Thin Films for Solar Cell Applications

Physics

KEYWORDS : Spray pyrolysis, optical transmission, ellipsometry

MAHENDRA KUMAR Department of Physics, University of Lucknow, Lucknow, 226007

ABSTRACT

Cadmium sulfide/tin oxide (CdS/ SnO2) two layer nanostructured thin films have been prepared by spray pyrolysis technique. The prepared films have been characterized using UV-VIS-NIR optical transmission, at different substrate temperatures and calculation of electrical resistivity and ellipsometry also. Finally, ellipsometric studies of CdS/ SnO2 interface show that the structure is very satble.

Introduction:

Thin transparent conducting film of metallic oxide such as SnO_2 has been studied for long time because of their experimental applications [1-3]. An intrinsic material does not show simultaneously high optical transparency and electrical conductivity. Partial transparency and fairly good conductivity may be obtained in thin films of a variety of materials. But non-stoichiometric and doped films of oxides of Sn ,In, Cd, Zn, etc deposited by various techniques exhibit high optical transparency in the visible region, high optical reflectivity in the IR region and nearly metallic conductivity. The oxide films, which exhibit high conductivity along with high transparency in the visible region are widely used in making opto-electronic devices such as displays and solar cells [2,4,5] because of their high stability, hardness and adherence to many type of substrates . Film of SnO_2 and other oxides find for aircrafts and automobiles windows, anti-static coating for instruments windows, heat mirrors for glass windows, anti-reflection coatings, gas sensors, humidity sensors etc [2].

Now a days, solar energy is very important source of energy. SnO_2 film can be produced by spray pyrolysis technique [6-9]. Spray pyrolsis involves spraying of a solution containing soluble salt of the constituent atoms of the desired compound onto a heated substrate. This is a very simple technique. SnO_2 films prepared at low temperature are amorphous and while film prepared at high temperature are polycrystalline in nature [10, 2]. It has also important been noted that the grain size increases with substrate temperature. In order to increase the conductivity of the film various dopents are added like Sb [12,13] F [7,13] and In [6,14].The drive for solar cells of high efficiency and long life has necessitated a more detailed understanding of CdS/ SnO_2 interface [15]. For high efficiency the CdS window layer must be very thin to allow maximum transmission into the absorber layer [16,17]. Here, we have studied the interlayer diffusion of both (CdS and SnO_2) due to high temperature employed.

2. Experiment:

2.1. Sample Preparation

The spraying technique is used for the preparation of CdS/SnO_2 samples. In the case of SnO_2 this techniques involves decomposition of alcoholic solution of stannic chloride at high temperature (450^0 C) in the presence of an oxidizing agent [18]. This reaction is given below

$$SnCl_2 + 2H_2O \rightarrow SnO_2 + 4HCL$$

The solution contains $SnCl_2$. $5H_2O$ at a molarity of 0.9M. The distance from the spray head to substrate is kept at ~35cm and the angle of incidence of solution droplets on the substrate is ~700. The flow rate of the liquid is controlled to ~10 ml/mts. 20 ml of the solution is sprayed for getting 450 nm thick SnO_2 film. Air is used as carrier gas. High scanning rate of spray head (100/mts) ensure a uniform film thickness. For optimizing the condition for good quality SnO_2 films, the films were prepared over optical glass substrates (R.I.-1.55) at different temperature in the range 350^0-500^0 C.

Optical transmission and electrical resistivity show that the film prepared at 450^0 C has optimum results and this film is used for the two layer (CdS/SnO_2) preparation. For this purpose SnO_2 (thickness ~450 nm) film was prepared at 450^0 C on glass substrate and above this CdS film (thickness ~400 nm) was deposited at 300^0 C.

The CdS films were also prepared by spray pyrolysis techniques using a solution of thiourea (0.01 M) and $CdCl_2$ (0.01 M).The CdS/SnO_2 film system was annealed at different temperature in the range 10^0-300^0 C in air. The heating and cooling rates were 20 C/mts for all cases.

2.2. Measurements

Spectrophotometer (UV-VIS-NIR-V670-JASCO) is used for transmission studies of the films prepared at different substrate temperatures. Variable Angle Spectroscopic Ellipsometer (VASE) is also used for the optical studies of the films. Electrical resistivity of the film is determined as described in section 5.35. VASE is used for the analysis of inter-diffusion taking place in the CdS/ SnO_2 two layer structure due to annealing. All VASE measurements were done at room temperature and in air. The VASE measurements were done in the angle of incidence range 600-750 and the wavelength range 500-620 nm as suggested by sensitivity analysis

Results and Discussion:

The CdS/SnO_2 two layer thin film system was prepared over glass substrate by spray pyrolysis technique. The summarized results of optical and electrical measurements of these films are given in Table-1.

Preparation temperature	Thickness Resistivity		Refractive Index		Transmission
(^{0}C)	(nm)	)	590 nm	620 nm	(880 nm) %
350	192	12.2 x 10^{-4}	1.85	184	81
400	290	7.4 x 10^{-4}	1.88	1.87	83
450	298	7.2 x 10^{-4}	2.05	2.0	75
500	310	9.1 x 10^{-4}	1.86	1.92	54

Table-1: Properties of SnO2 film at different substrate temperatures.

From this table, it is clear that the film prepared at 4500 has better properties. At lower temperature the thickness of SnO_2 film is very low. Thickness of the film increases rapidly at 400^0C and remain more or less constant. The electrical resistivity of the film at first decreases with increase in substrate temperature and reaches at maximum at 450^0C and thereafter it increases slowly. Refractive index of the film measured using ellipsometer shows that the real part of refractive index has high value for the films prepared at 450^0C. This may be due to the better structure of the film. In this calculation imaginary part K of complex refractive index is taken as zero.

The Table-2 shows the results of CdS/SnO_2 interlayer analysis. Ellipsometrically calculated refractive indices of CdS and SnO_2 are used for the analysis. Different optical combinations are used for the analysis of CdS/SnO_2/glass system. The most important combination are given below.

Combination (a) air /CdS/SnO_2/glass

Combination (b) air/CdS/ (CdS+SnO_2)/SnO_2/glass

The ellipsometric data of the two layer system is used for the analysis of these optical combinations and best fit of these combinations were determined. At first the combination (a) is selected. It is on the assumption that the two layers have sharp boundaries and there is no inter-diffusion. The other combination (b) is on the assumption that CdS and SnO_2 do not have sharp boundaries due to the inter-diffusion of CdS into SnO_2 or vice versa. The values of unbiased estimator [19] of different optical combinations derived from VASE analysis are shown in Table-2. From this value it is clear that the first optical combination has the least value for compared to the other combination. This shows that this combination is best suited to the physical system, i.e., as prepared CdS/SnO_2 has sharp boundaries and CdS prepared over SnO_2 does not cause any inter-diffusion or chemical reaction.

The thermal stability of the CdS/SnO_2 interface is most important because the fabrication of the thin film solar cell involves the thermal treatment [15]. The high temperature annealing is an attempt to simulate a common fabrication technique i.e. heat treatment. We have annealed the CdS (400 nm thick) / SnO_2 (450 nm thick) at different temperatures in the range 100-300^0C in air. The result of post annealing VASE measurement is shown in Table-2.

Annealing temperature	δ Unbiased estimator value of optical combinations	
(^{0}C)	CdS/SnO_2/glass Combination (a)	CdS/ (CdS+SnO_2)/SnO_2/ glass Combination (b)
Unannealed (Ref.)	0.890	2.61
100	0.950	2.72
150	0.910	2.68
200	0.920	2.71
250	0.930	2.67
300	0.980	2.69

Table-2: Results of ellipsometry analysis of CdS/SnO_2/glass two layer thin film system after annealing at different temperatures.

If CdS reacts with or diffuse into SnO_2, the structure of CdS/SnO_2 bilayer changes from combination (a) to combination (b). This cause a considerable change in value of the optical combination. But the unbiased estimator of different optical combination has no considerable change due to annealing, as reavealed by values in Table-2. This lack of change in value with temperature suggest that the CdS/SnO_2 system is highly stable and annealing does not cause any inter-diffusion that results in the degradation of the two layer thin film system and ultimate failure of cell [20].

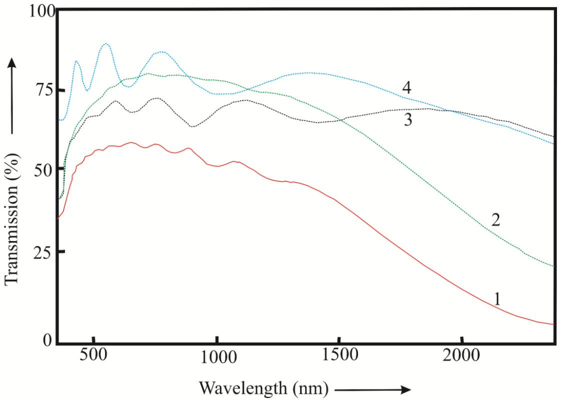

Fig-1: Transmission spectrum of SnO_2 film prepared by spray pyrolysis at different temperature. (1) 500^0 C (2) 450^0 C (3) 400^0 C (4) 350^0 C

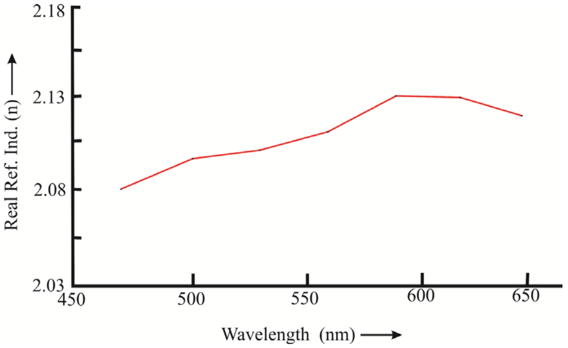

Fig 2: Variation of real part (n) of refractive index of SnO_2 thin film at 450^0 C

Conclusion:

The spray pyrolysis technique is again used for the preparation of SnO_2 film. SnO_2 films are optically transparent and good electrical conductors. They are more used as electrode material in many optoelectronic devices. An alcoholic solution (0.9 M) of $SnCl_{2.5}H_2O$ is used for this experiment. Very low resistivity (30 ohm-cm) films were obtained at a substrate temperature 450^0C. It has a very good optical transmission.

The two layer structure fabricated using the SnO_2 film is CdS/SnO_2. These two layer films are preapared by spray pyrolysis. Firstly, SnO2 film is prepared over glass substrate at 450^0 C and then CdS film is prepared at 3000 C over the SnO_2 film. The ellipsometric studies of CdS/SnO_2 interface using an approximate optical combination show that the structure is very stable and has very narrow interface. Since this two layer is widely used in thin film solar cells, the stability of CdS/SnO_2 interface is very important. This interface is stable for thin film system annealed at very high temperature (300^0 C).

Acknowledgement:
The author is very thankful to Dr. G. C. Dubey, Rt. Scientist-G, SSPL, New Delhi for his encouragement, several discussion during the course of this study and also for the financial assistance provided by the university grants commission (UGC). F.No.36-266/2008(SR) Physical Science , New Delhi.

REFERENCE

1. J.C. Manifacier. Thin Solid Films. 90 (1989) 297. | 2. K. L.Chopra, S.Major and D.K.Pandya. Thin Solid Films. 102 (1983) 1. | 3. I.Hamberg and C.G.Granqvist. J. Appl. Phys. 60 (1986) R123. | 4. A.L.Dawar and J.C.Joshi , J.Mater. Sci. 19 (1984). | 5. J.L.Vossen. Phys of Thin Films. Vol 9 (G Hass, M H Francombe and R W Hoffman Eds.) Academic Press, New York (1971) 1. | 6. Takao Nagatomo, Yukihiro Maruta and Osamu Omoto. Thin Solid Films. 192 (1990) 17. | 7. E. Shanti, A. Banerjee, V.dutta and K.L.Chopra. J. Appl. Phys.53 (1986)1615. | 8. V. Vasu and A. Subrahmanyam. Thin Solid Films. 202 (1991) 283 | 9. K.H.Yoon and J.S.Song. Thin Solid Films. 224(1993) 203. | 10. J.C.Manifacier, L. Szepessy, J.F.Bresse, M.Perotin and R.Stuk. Mater Res. Bull. 14 (1979) 109. | 11. H.Iida, T.Mishuku, A. Ito, K. Kato, M.Yamanaka and Y. Hayashi. Solar Energy Mater. 17 (1988) 407. | 12. D.Ravindra and J.K.Sharma. J. Phys Chem. Solids. 46 (1985) 945 | 13. F.J.Gracia, J.Muci and M.S.Tomas. Thin Solid Films. 97 (1982) 47. | 14. K. Kulaszewicz, W.Jarmoc and K.Turowska. Thin Solid Films. 112 (1984) 313. | 15. David w. Niles, Dennis Rioux and Hartmut Hochst. J.Appl. Phys. 73 (1993) 4586 | 16. Lars Stoit , Jonas Hedstorm, John Kesler, Martin Ruckh, Karl Otto Velthas and Han S-Werner Schock. Appl. Phys. Lett. 62 (1993) 597. | 17. Bulent M.Basol, vijay K. Kapur, Aravind Halani and Craig Leidholom. Solar Energy Mater. 29 (1993)163. | 18. K.L.Chopra and S.R.Das. "Thin Film solar cells",Plenum Press, New York. (1983) chapter 5. | 19. K.Vedam , P.J.Mc Marr and J.Narayan. Appl. Phys. Lett. 47 (1985) 339. | 20. Ping Yang, Adam Szatkowski, Michael Bredol, J.Sol-Gel Sci Technol (2009) 51:306-314 |