EXTENDED ABSTRACTS

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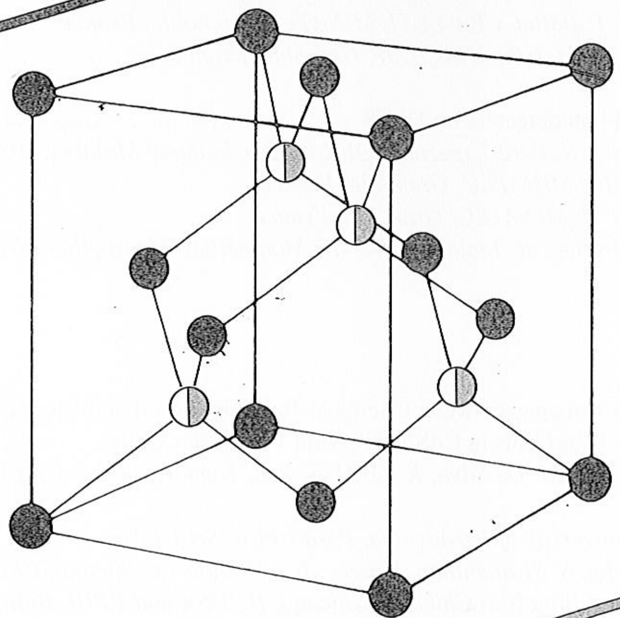

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Poster Session

A comparison of performance between chemical bath deposited and electrochemical bath deposited CdS thin films in CdS/CdTe thin film solar cells

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Abstract

CdS thin films of about 60 nm thick were grown on appropriately cleaned, commercially available 2.3 mm thick, TEC 15 conducting glasses (1.5" x 1.5") using both, chemical bath deposition (CBD) and electrochemical bath deposition (ECBD) techniques. Close space sublimation (CSS) technique was used to deposit CdTe thin films of about 6 μm thick on both types of CdS layers. All TEC15/CdS/CdTe structures were heat treated with $CdCl_2$, in inert environments. The following optimum performance characteristics were observed with initial, In/TEC 15/CdS/CdTe/Cu/Au devices made using the CdS thin films grown with both, CBD and ECBD processes.

Process	V_{oc} /(V)	J_{sc}/ (mA cm^{-2})	FF (%)	η (%)
CBD	0.814	25	71.3	14.5
ECBD	0.285	20.6	50.2	2.95

Key words: Chemical bath deposition (CBD), electrochemical bath deposition (ECBD) , close space sublimation (CSS), CdS/CdTe thin film solar cell.

Introduction

CdS/CdTe thin film solar cells are one of the promising photovoltaic devices for low cost large area terrestrial applications.[1-8]. Highly efficient poly-crystalline CdS/CdTe cells have been fabricated by different techniques, viz. screen printing, close-spaced vapor transport, chemical bath deposition, electrochemical bath deposition, vacuum evaporation, chemical vapor deposition, etc. The deposition techniques and substrates used have been found to influence the resulting microstructure of the thin CdS films and the efficiency of the final solar cell.The chemical bath deposition (CBD) and electrochemical bath deposition (ECBD) techniques the two most extensively used inexpensive techniques.[8,9,10].

Experimental

Chemical bath deposited CdS thin films were grown from alkaline solutions at 92°C, containing 0.0133 mol dm^{-3} cadmium acetate, 0.0266 mol dm^{-3} thiourea, and 4.0 mol dm^{-3} ammonium acetate each with a purity of 99.99 % or greater. About 37 minute of reaction time produced CdS layers of approximately 60 nm thick with n-type electrical conductivity.

A three electrode cell consisting of a working electrode and a counter electrode each of TEC 15 conducting glasses with a reference electrode of Ag(s)/AgCl(s)/Cl(aq) were used for the ECBD process. Cadmium chloride and ammonium thiosulfate each with a concentration of 0.0015 mol dm^{-3} and purity of 99 % were used as cadmium and sulfur precursors for all electrochemical depositions. CdS thin films were grown at a deposition voltage of -1100 mV with respect to the reference electrode. The pH of the solutions was 1.5 and the temperature was in the range of 28 to 30 °C. Solutions were moderately stirred during deposition and a film thickness of approximately 60 nm was obtained with a deposition time of about 60 minutes. All electrodeposited thin films of CdS were annealed at 400 ^{0}C in air for 10 minutes. Using UV visible absorption and transmission studies, the thicknesses and the band gaps of CdS thin films were estimated.

CdTe p- type thin films were grown on both chemical bath and electrochemical bath deposited CdS thin films using the close space sublimation (CSS) technique. Substrate and source temperatures used were550 and 600 ^{0}C. Thin films of about 6 μmcould be grown over 12 minute deposition time. All CdTelayers were annealed with $CdCl_2$ at 405 ^{0}C for 5 minutes.Cu based Au back contacts and indium front contacts were made on all TEC15/CdS/CdTe structures to fabricate initial solar cell devices and their subsequentelectrical characterization.

Results & Discussion

Photo-electrochemical cell measurements indicated that, all electrochemical bath deposited CdS layers were of n-type in electrical conductivity. UV absorption and transmission studies showed that the band gaps of all CdS semiconductors and their thicknesses were ~2.40 eV and ~ 60 nm respectively.

Figure 1 indicates that among the initial solar cell devices fabricated the one with CdTe film thickness of 5.54 μm (CTC 377) has produced the highest efficiency of 14.5.

Figure 2 is a representation of variation of key performance characteristics of the devices with the thickness of the CdTe layer for the ECBD/CdS process. Among the 16 small devices, the device No C3, gave the highest efficiency 2.95 % and highest % fill factor of 50.

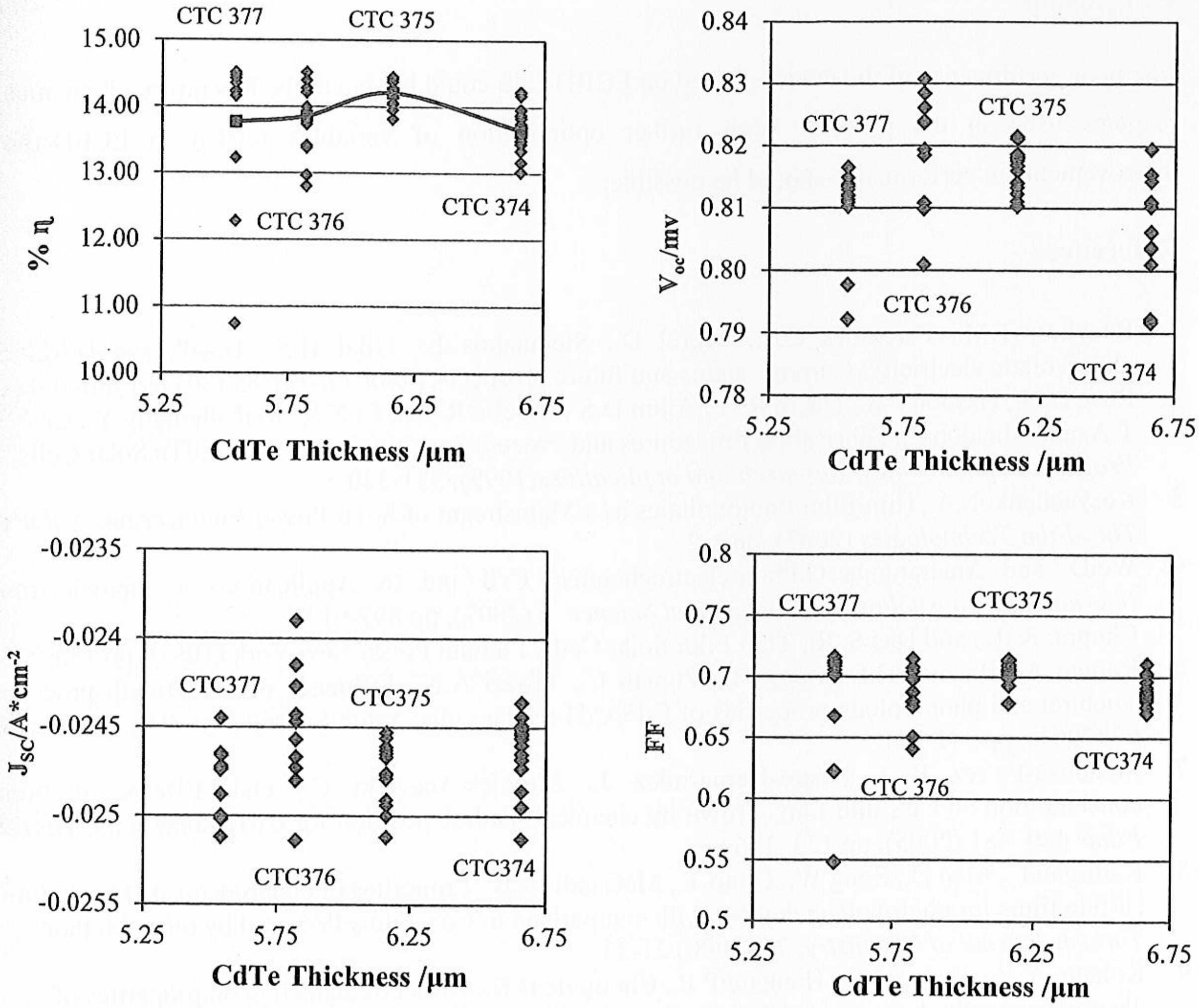

Figure 1: Variation of % Efficiency, V_{oc}, J_{sc} and Fill factor of CdS/CdTe semiconductor devices produced by CBD/CSS methods.

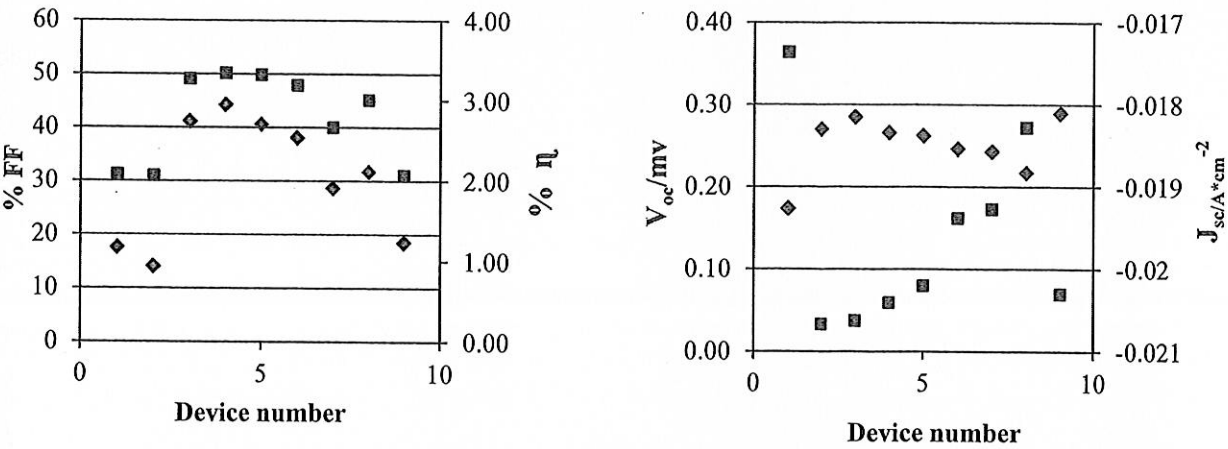

Figure 2: % Efficiency, V_{oc}, J_{sc} and Fill factor of CdS/CdTe semiconductor devices produced by ED/CSS methods

Conclusion

The poor performance of the devices based on ECBD/CdS could be due to the low purity of chemical and reagents used in the process. With further optimization of variables related to ECBD process improvements in performance should be possible.

References

1. Razykov T.M., Ferekides C.S., Morel D., Stefanakos E., Ullal H.S., Upadhyaya H.M., Solar photovoltaic electricity: Currents status and future prospects, *Solar Energy* 85 (2011) 1580-1608
2. Rose D.H., Hasoon F.S., Dhere R.G., Albin D.S., Ribelin R. M., Li X.S., Mahathongdy Y., Gessert T.A. and Sheldon P., Fabrication Procedures and Process Sensitivities for CdS/CdTe Solar Cells, *Progress in photovolics: Research and applications*(1999), 331-340
3. KosyachenkoL.A.,Thin-Film Photovoltaics as a Mainstream of Solar Power Engineering., *Solar Cells Thin-Film Technologies* (2007), pp 1-2
4. WeiD. and Amaratunga G.Photoelectrochemical Cell and Its Applications in Optoelectronics., *International Journal of Electrochemical Science*, 2 (2007), pp 897-912
5. Chopra. K.,L., and Das S. R., Thin Film Solar Cells, Plenum Press, New York (1983), pp 153-275
6. Romeo A., Batzner D.L., Zogg H., Vignali C., Tiwari A.N., Influence ofCdS growth process on stucturel and photovoltaic properties of CdS/CdTe solar cells, *Solar Energy Materials & Solar Cells* 67 (2001), pp 311-321
7. Mendoza-Pe´rez R., Sastre-Herna´ndez J., Morales-Acevedo C., etal, Effects of thiourea concentration on CdS thin films grown by chemical bath deposition for CdTe solar cells, *Thin Solid Films* 480–481 (2005), pp 173–176
8. Kadirgan F., Mao D., Song W., Ohno T., McCandless B., Properties of electrodeposited Cadmium sulfide films for photovoltaic devices with comparison to CdS Films Prepared by other Methods , *Turkish Journal of Chemistry*, 24 (2000) 21-33
9. Kokate A.V., Asabe M.R., Hankare P.P., Chougule B.K., Effect of annealing on properties of electrochemically deposited CdTe thin films, *Journal of Physics and Chemistry of Solids* 68 (2007) 53–58
10. Daniel R. Johnson, Microstructure of electrodeposited CdS/CdTe cells, *Thin Solid Films*, pp 321-326, 2