

A PHOTOELECTROCHEMICAL PERFORMANCE STUDIES OF CdSe: Sb ELECTROLYTE CELL

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The CdSe: Sb thin film electrodes of varying Sb³⁺ (0 to 5 mol %) concentration were synthesized by a solution growth technique in an aqueous alkaline medium. Using these films as an active electrode the photoelectrochemical cells were fabricated. A sulphide/polysulphide redox couple was used as a suitable electrolyte. The various cell characteristics such as I-V, C-V, in dark, power output (under 20 mW/cm² intensity), built-in-potential, photo and spectral responses were examined and the cell parameters namely, open-circuit voltage (V_{oc}) short-circuit current (I_{sc}), shunt resistance (R_{sh}), series resistance (R_s), form factor (ff%), efficiency (η%), lighted quality factor (n₁), junction ideality factor (n_d), barrier height (Φ_B) and flat band potential (V_{fb}) were then determined. The open-circuit voltage (voc) is found to be increased from 390 mV to 465 mV after doping (0.1 mol% Sb³⁺). The corresponding conversion efficiency and fill factor are also found to be maximum at this doping concentration.

(Received March 21, 2009; accepted April 3, 2009)

Keywords: thin film, solution growth technique, photoelectrochemical cells, doping

1. Introduction

The n-CdSe is quite interesting and becoming important [1-3] because of its major contribution in solar cells, photodetectors, light amplifiers, electro-photography, light emitting diodes, lasers, and photoelectrochemical cells and in the preparation of electronic elements based on the metal insulator semiconductor structures (MIS) and also in new area of R & D in the gas sensors [4]. Mostly for application in the photovoltaic solar cells [5] CdSe synthesized by a chemical deposition technique has been used. The efficiency of a photoelectrochemical cells has a direct bearing on the resistivity of the electrode material and in turn on the conductivity and it can be greatly increased by the incorporation of trace impurity. Keeping this in mind CdSe was doped with antimony (0 to 5 mol %) and employed to form the photo electrochemical solar cells. The photo electrochemical performance of these cells was examined with a special emphasis given to the Sb³⁺ doping concentration.

2. Experimental technique

CdSe: Sb thin film electrodes with a varying antimony content from 0 to 5 mol% were obtained on microslide glass and polished stainless steel substrates by a chemical deposition process [6-9]. An electrode / electrolyte solar cell was devised out of a photo electrode deposited on stainless steel substrates, an electrolyte consisting of (0.25M) sulphide/ polysulphide redox couple and a graphic rod as a counter electrode. The power output characteristics were obtained for all the cell configurations under a constant input light intensity of 20 mW/cm² (tungsten filament lamp, 250 W). A simple potentiometric arrangement in a two electrode system was used

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for this purpose. The dynamic current-voltage and capacitance-voltage characteristics in dark were obtained potentiometrically for all these cells. A three-electrode system was used for C-V measurements. A saturated calomel electrode (SCE) was used as a reference electrode. The reverse saturation current of the various cells was noted in the 373 K to 300 K-temperature range to calculate the built-in-potentials of the various cells. The various currents and voltages were measured by the 6 ½ digit, H P and 4 ½ HIL, 2665 multimeter. Illumination intensities were recorded by a Lutron-101 (Taiwan) luxmeter. A Ten turn 1 k helical potentiometer was used to vary the junction potential. The spectral response of the various cells was examined in the range of wavelengths from 450 nm to 950 nm.

3. Results and discussion

The growth mechanism of CdSe: Sb thin films are already reported. [8,9]. An illuminated photoelectrochemical (PEC) cell behaves similar to forward biased diode, the open circuit voltage (V_{oc}) of which is a critical parameter determining the energy conversion efficiency ($\eta\%$). A fundamental process that governs V_{oc} is the recombination of the photo-generated charge carriers that constitutes a the recombination mechanism current, the equilibrium value of which, under illumination, is made up of four major components: a) a recombination in the bulk of the semiconductor, b) majority carrier transport to the interface, c) recombination in an electrolyte and d) recombination at the interface via surface trapping levels [6]. At the open circuit condition v_{oc} is related to the photo generated current I_{ph} as

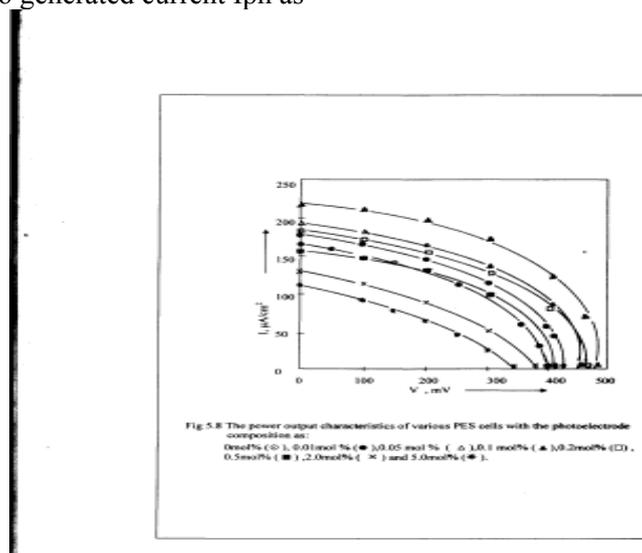


Fig. 1: The power out put characteristics CdSe: Sb electrolyte solar cell. 0 mol% (o), 0.01 mol% (·), 0.05 mol% (Δ), 0.1 mol% (▲), 0.2 mol% (□), 0.5 mol% (■), 2 mol% (×), and 5 mol% (*).

$$V_{oc} = \frac{n_1 KT}{q} \ln \frac{I_{sc}}{I_0} \quad (1)$$

Where n_1 is the junction quality factor, which is a measure of the recombination mechanism at the electrode/ electrolyte interface under illumination, I_0 is the saturation current density. The open-circuit photo-potentials (V_{oc}) and photo currents (I_{sc}) were therefore measured for the cell with these photo electrodes of various Sb-doping concentrations. The power output curves were obtained for all these cells under a constant illumination of 20 mW/cm² and few of the typical curves are shown in fig. 1.

The series resistance (R_s) and shunt resistance (R_{sh}) are calculated and are listed in table – I. The power conversion efficiency ($\eta\%$) and form factor (ff %) have also been computed

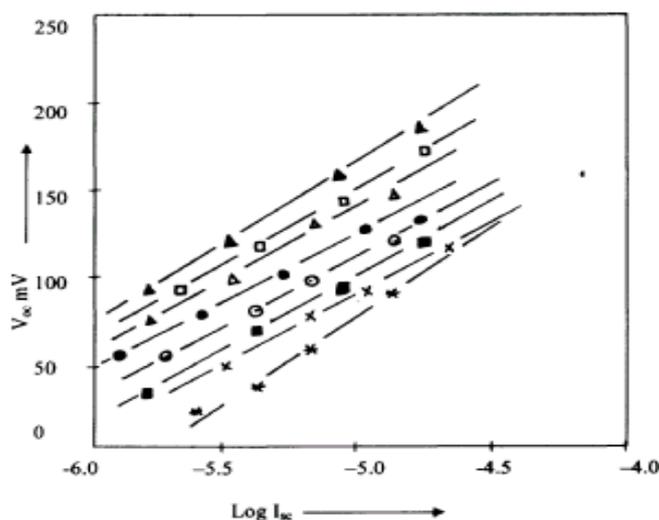


Fig. 2: The plots of V_{oc} vs. $\log I_{sc}$ of CdSe: Sb electrolyte solar cell. 0 mol% (o), 0.01 mol% (·), 0.05 mol% (Δ), 0.1 mol% (\blacktriangle), 0.2 mol% (\square), 0.5 mol% (\blacksquare), 2 mol% (\times), and 5 mol% (*).

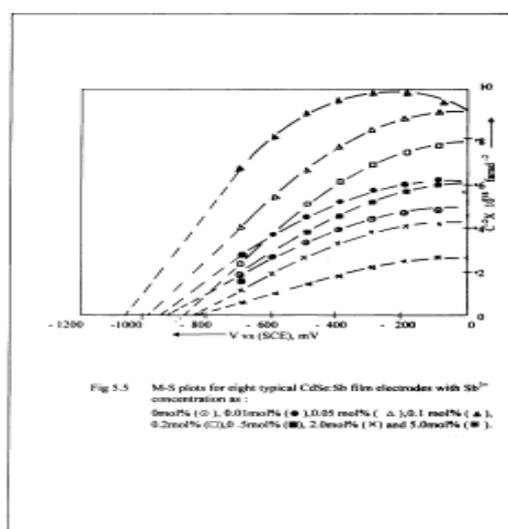


Fig. 3: The MS plots for CdSe: Sb film electrodes 0 mol% (o), 0.01 mol% (·), 0.05 mol% (Δ), 0.1 mol% (\blacktriangle), 0.2 mol% (\square), 0.5 mol% (\blacksquare), 2 mol% (\times), and 5 mol% (*).

and are tabulated in table -I. It is seen that $\eta\%$ and $ff\%$ have been significantly increased from 0.138% to 0.243% and 42% to 51% respectively with the increased Sb^{3+} concentration from 0 to 0.1 mol% and thereafter they decreased for further addition of Sb^{3+} -content in the CdSe. This could be mainly attributed the decrease in series resistance (R_s) and increase in photo potential V_{oc} , upto 0.1 mol% Sb^{3+} doping concentration. The current-voltage relations have been studied over the whole doping range under forward and reverse bias conditions, which show that the junctions formed are of Schottky type. The junction ideality factors (n_d) were therefore determined from the slopes of $\log I$ vs. V plots and are cited in table-I. It is seen that magnitude of n_d deviates from its ideal value indicating the presence of the recombination centers at the interface [11, 12]. The lighted quality factors (n_l) were determined from the plots of V_{oc} vs. $\log I_{sc}$ (fig 2) and are listed in table-I.

Fig. 3 represents variation of C-2-V under dark and was obtained by measuring the junction capacitance (at 1 Vpp-1KHz ac signal) as a function of the applied dc bias from 0 to 0.7 with respect to saturated calomel electrode (SCE). The intercepts on the voltage axis gives the flat band potentials for various cells and are cited in table-I. It is seen that V_{fb} has been considerably increased from 920 mV to 1050 mV with increased Sb-doping concentration from 0 to 0.1 mol% and thereafter decreased. The variation in C-2 vs. V also shows presence of the surface states. The height of the potential barrier at the junction was determined from the plots of $\log I_0 / T^2$ vs. $1/T$ for all the cells. These heights are cited in the table-I.

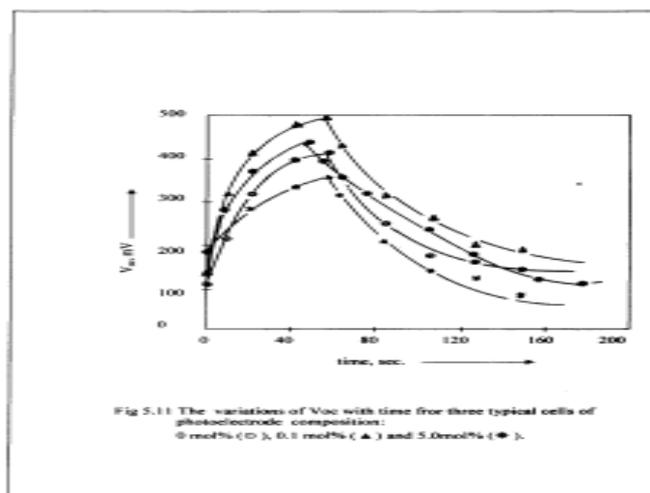


Fig. 4: The variations of V_{oc} with time. 0 mol % (o), 0.1 mol % (▲) and 5 mol % (*).

The plots of $\log I_0 / T^2$ vs. $1/T$ deviate from the linearity showing Poole – Frenkel type conduction mechanism [9, 10]. Fig. 4 shows the speed response characteristics for three typical cell configurations. A relatively faster rise and slower decay is observed at 0.1 mol% Sb^{3+} doping concentration in CdSe.

Table – I Various ECPV cell performance parameters for the CdSe: Sb electrolyte.

Doping conc. mol%	$R_s \Omega$	$R_{sh} K\Omega$	$\eta \%$	ff %	nd	nl	Φ_B mV
0	800	6.66	0.138	42	6.5	2.90	0.357
0.005	705	7.0	0.135	42	6.0	2.89	0.397
0.01	500	7.5	0.151	46	6.0	2.41	0.437
0.025	550	6.0	0.159	48	5.5	3.38	0.476
0.05	420	10.0	0.187	46	5.0	3.13	0.556
0.075	408	12.0	0.195	48	4.5	3.86	0.595
0.1	312	12.0	0.243	51	4.0	3.18	0.635
0.15	318	10.8	0.187	43	5.0	4.10	0.596
0.2	405	10.6	0.176	45	4.5	2.85	0.596
0.3	605	10.0	0.157	48	5.5	2.39	0.557
0.5	700	10.0	0.135	45	6.0	2.65	0.516
1.0	1600	6.9	0.100	36	6.5	3.09	0.437
2.0	1700	6.0	0.082	36	7.0	3.10	0.398
3.0	1915	5.0	0.076	38	7.5	3.13	--
5.0	2005	4.61	0.060	33	7.5	3.62	--

4. Conclusions

An attempt is made to investigate the various electrochemical properties as a function of the photo electrode doping concentration (Sb^{3+}). The results indicated that the trace addition of antimony modifies the photo electrode properties, which has consequently reflected on the various electrochemical properties of the cell.

Acknowledgement

The authors are thankful Head, Department of Physics, Rajarshi Shahu Mahavidyalaya, Latur for providing laboratory facilities.

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