International Journal of Engineering Technology, Management and Applied Sciences

www.ijetmas.com March 2016, Volume 4, Issue 3, ISSN 2349-4476

A Photoelectrochemical Solar Cell Properties of $Cd_{1-x}Mn_xS$ Thin Film as an Active Photoanode

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Abstract:-

The $Cd_{1-x}Mn_xS$ ($0.0 \leq x \leq 1.0$) thin films were deposited on ITO coated glass substrates. Photoelectrochemical studies are carried out using 1M NaOH–1M Na_2S–1M S electrolyte. The power output curves were obtained for all the PEC cells under a steady illumination intensity of 20 mW/cm^2. A 100 W tungsten filament lamp was employed to illuminate the cells. Upon illumination of the interface with a light of 20 mW/cm^2, an open-circuit voltage of the order of 305 mV and a short-circuit current of 467 uA/cm2 have been developed (for x = 0.6) resulting energy conversion efficiency and fill factor 0.385% and 0.53% respectively.

1. Introduction

Photoelectrochemical (PEC) cells of various designs have been used to convert solar energy into suitable forms for more efficient use [1-6]. It is an alternative to the commercially available solid state junction photovoltaic cells for the direct conversion of sunlight into electrical energy [7-8]. Photoelectrochemical (PEC) cells have been widely studied for solar as well as non-solar applications. Cadmium chalcogenides in the form of single crystals, sintered pellets and polycrystalline materials have been employed in PEC cells [9]. The efficiency and stability of PEC cells are strongly dependent on the preparation conditions of the photoelectrodes, electrolytes and on experimental conditions [10].

In this paper, a simple and easy method was successfully used to synthesize crystalline $Cd_{1-x}Mn_xS$ films. The films were prepared on ITO coated glass substrates These films have excellent adherence and mechanical stability. The power output measurements are studied and reported.

2. Experimental details

All the chemicals used for the deposition were analytical grade. The $Cd_{1-x}Mn_xS$ ($0.0 \leq x \leq 1.0$) thin films were deposited on ITO coated glass substrates procured from Blue star (Mumbai). A photoelectrochemical solar cell was fabricated using a standard three electrode configuration with $Cd_{1-x}Mn_xS$ thin film as an active photoanode of area 1×1 cm^2, graphite as counter electrode and standard calomel electrode (SCE) as a reference electrode. The redox electrolyte used was aqueous 1M polysulphide (NaOH + Na_2S + S). A 100 W tungsten filament lamp was used as a light source. To prevent heating of the cell, water lens was interposed between the lamp and the cell. The distance between the photoanode and counter electrode was kept 0.3 cm. The power output curves for various cell configurations were recorded under constant illumination intensity 20 mW/cm^2. The illumination intensity was measured with a (Meco) Lux meter.

3. Result and discussions

Photovoltaic output characteristics were studied under light intensity of 20 mW/cm^2. Typical photocurrent versus photovoltage characteristics of n- $Cd_{1-x}Mn_xS$ / polysulphide under light illumination

is shown in Fig. 1. It is found that both the I_{sc} and V_{oc} increases with increase in composition parameter 'x' attain a maximum values at x = 0.6 and then decrease with further increase in 'x'. We attribute the observed improvement to the increased short circuit current of the cell due to the increased photoelectrode absorption, decreased band gap of CdS and decrease in effective series resistance of a cell. These results are analogous to those reported by Mahapatra and Roy [11] and Deshmukh et.al. for mixed materials.

The photovoltaic efficiency (η %) was calculated from the relation [12]

$$\eta = \frac{I_{sc} \times V_{oc} \times ff}{P_{input}} \times 100 \quad (1)$$

where Pinput is the power density of incident radiation.

The fill factor (ff) was obtained from the formula [13]

$$ff = \frac{V_m \times I_m}{I_{sc} \times V_{oc}} \quad (2)$$

where Im and Vm are values of maximum current and maximum voltage, which can be extracted from the PEC solar cell.

Series resistance R_s and the shunt resistance R_{sh} were calculated from the slopes of the power output curves using the relations [14] and are tabulated in Table 1.

$$\left[\frac{dI}{dV}\right]_{I=0} \approx \frac{1}{R_s} \quad (3)$$

$$\left[\frac{dI}{dV}\right]_{V=0} \approx \frac{1}{R_{sh}} \quad (4)$$

The variation of power conversion efficiency (η) and fill factor with photoelectrode composition is shown in Fig. 2 (a-b). It is observed that both follow similar dependence on 'x'. For higher values of 'x' pinning of Fermi level may decrease V_{oc}. The lower magnitudes of short circuit current for higher values of 'x' may be due to the increased in recombination mechanism not only at the grain boundaries but also at the electrode-electrolyte interface. At higher 'x' values, the role of surface states may also become dominant causing a decrease in both open circuit voltage and short circuit current.

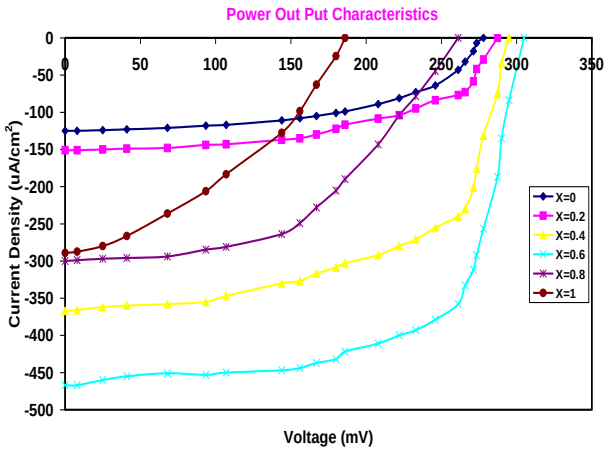

Fig.1: Plots of photovoltaic power output characteristics of $Cd_{1-x}Mn_xS$ ($0.0 \leq x \leq 1.0$) thin films.

www.ijetmas.com March 2016, Volume 4, Issue 3, ISSN 2349-4476

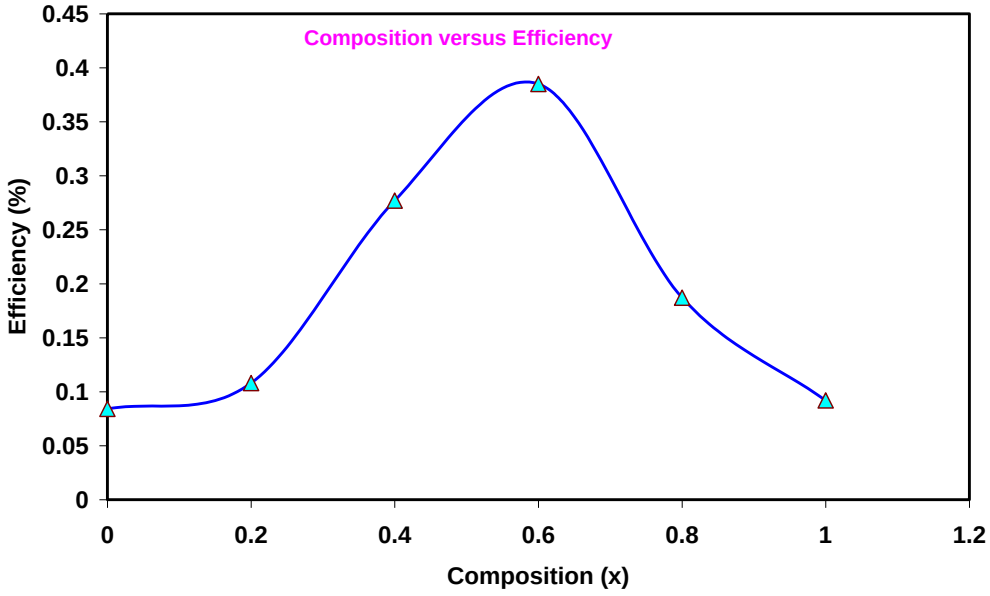

Fig.2 a: The variation of η with photoelectrode composition (x).

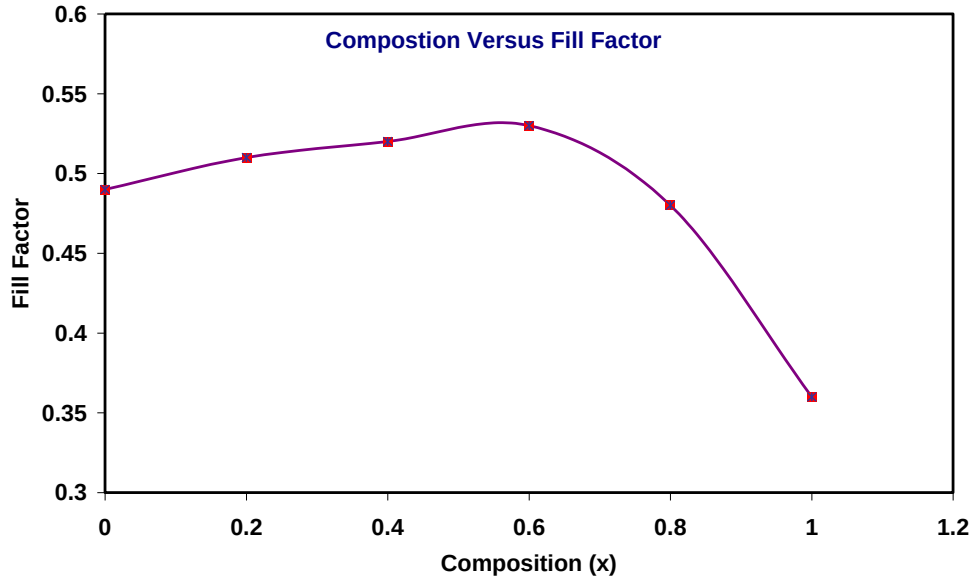

Fig.2 b: The variation of ff with photoelectrode composition (x).

Table 1: Photoelectrochemical performance parameters of chemical bath deposited $Cd_{1-x}Mn_xS$ ($0 \leq x \leq 1$) thin films.

Composition	V_{oc} (mV)	I_{sc} (µA)	η%	ff	Crystallite size from SEM (nm)
X=0	275	125	0.084	0.49	150
X=0.2	280	151	0.108	0.51	320
X=0.4	292	367	0.277	0.52	435
X=0.6	**305**	**467**	**0.385**	**0.53**	**510**
X=0.8	260	300	0.187	0.48	340
X=1	174	294	0.092	0.36	235

4. Conclusions

A photoelectrochemical solar cell was fabricated using a standard three electrode configuration with $Cd_{1-x}Mn_xS$ thin film as an active photoanode. . It is found that both the I_{sc} and V_{oc} increases with increase in composition parameter 'x' attain a maximum values at x = 0.6 and then decrease with further increase in 'x'. An open-circuit voltage of the order of 305 mV and a short-circuit current of 467 uA/cm2 have been developed (for x = 0.6) resulting energy conversion efficiency and fill factor 0.385% and 0.53% respectively.

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