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Photo-voltaic Study of Hg Doped ZnS Thin Films

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ABSTRACT

The polycrystalline Hg- doped ZnS thin films were prepared on a clean glass and stainless steel substrates by chemical bath deposition technique. Preparatory parameters such as deposition time, temperature and pH of the reaction mixture were kept at their optimized levels as discussed earlier. As-deposited films were made use as an active photoelectrode in a photoelectrochemical cell with polysulfide (1M) as an electrolyte and impregnated graphite as the counter electrode. As fabricated photoelectrochemical (PEC) cells are then used to study their characteristics viz. current-voltage in dark and power output under 20 mWcm^{-2} constant illumination intensity. The quantum conversion efficiency and fill factors are calculated from these studies.

Keywords: pseudo-binary MZS, CBD, PEC cells.

1. INTRODUCTION

Photo-voltaic has emerged as a fast developing field due to the global search for an alternative source of power generation. The solar energy is a gift of nature to the mankind, which is abundant, non-polluted and can be sensed and harnessed effectively by means of photo-voltaic devices. Although photo-voltaics is a direct means for detection and conversion of electromagnetic solar radiations into an electrical energy. Many researchers have been working on the development of semiconductor materials, which capture a large fraction of the ultraviolet, visible and near infrared regions of the electromagnetic spectrum and for the electrolytes, which are suitable for better stability.

Chalcogenides, in general because of their potential as an efficient absorbers in the visible and near IR regions of solar radiations, have attracted more and more researchers in the field of detection and photoelectrochemical conversion. These materials show a good deal of a wide range of photon energy [1] -[2]. Low fabrication cost, ease inoperation and relatively no lattice mismatch, are the great advantages of PEC cells over the thin films solid solar cells to have better and efficient solar energy conversion devices [3].

To understand the importance of solid state parameter we deposited the $Hg_x Zn_{1-x}S$ thin films by inexpensive, simple and easy to operate chemical bath deposition method. The Photoelectrochemical performance of these cells has been studied and presented in this paper.

2. EXPERIMENTAL PROCEDURE

2.1 Preparation of thin film electrodes

$Hg_x Zn_{1-x}S$ ($0 \le x \le 1$) thin films were deposited on glass (Blue Star, Mumbai) and high quality stainless steel substrate using chemical bath deposition method. For this purpose, $HgCl_2$ (1M), $ZnSO_4.7H_2O$ (1M) and CS $(NH_2)_2$in appropriate proportions were taken in a reaction bath. TEA was added to form a bound complex. Sodium hydroxide and aqueous ammonia were added to this reaction mixture to adjust the pH of the reaction and to increase the film adherence to the substrates. The deposition parameters viz. temperature, speed of mechanical churning, time of deposition, pH etc. was kept constant at their optimized values as reported earlier [4] -[5].

2.2 Fabrication of $Hg_x Zn_{1-x}$ S photoelectrochemical cells

The photoelectrochemical (PEC) cells were fabricated for different electrode material compositions, as an active photoelectrode and polysulfide as a suitable redox couple in an H-shaped corning glass cuvette set. An impregnated graphite rod acts as a counter electrode which is placed behind the active photoelectrode at a distance of 2mm. The current–voltage characteristics in dark and under illumination were studied and examined at room temperature. The cells are illuminated by the light of 20 mW/cm^2 intensity and photo-voltaic power output curves were obtained for all these cells. A potentiomateric arrangement was used for measurement of current – voltage at various applied bias potentials. Current - voltage characteristics were obtained by using Digital picometer of $3\frac{1}{2}$digits, SES Instrumentation Pvt. Ltd. and classic (999N1) digital multimeter were used for the measurement of current and voltage respectively.

3. RESULTS AND DISSCUSSION

3.1 Physical properties

The as-grown films are thin, uniform, mechanically hard and adherent to the substrate support. It is seen that the layer thickness decreased monotonically with composition parameter as shown in figure 1.

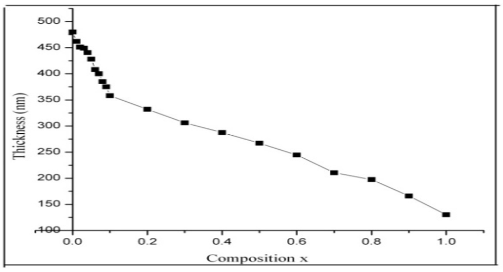

Figure 1: Variation of film thickness with materials composition parameter, x.

The thin film properties of these films viz. structural, optical and electrical transport properties have studied and reported earlier [1] -[2].

3.2 Photoelectrochemical (PEC) studies

3.2.1 Current- Voltage (I-V) characteristics

As deposited $Hg_xZn_{1-x}S$ films were studied for (I-V) charecteristics for the range of ± 0.5 V, in dark and under illumination. Figure (2.a) shows (I-V) characteristics under dark and figure (2.b) under illumination. From these studies it is observed that the forward current increases rapidly with voltage. The increase in current can be attributed to the small contact hight and increase in the tunneling mechanism [6]. The junction ideality factor is calculated using the equation

$$I = I_o\left(e^{\frac{qV}{n\,kT}} - 1\right) \quad (1)$$

Where n is a junction ideality factor, I_o is the reverse saturation current, V is the forward bias voltage and I is the forward current in dark. The junction ideality factor n_L (under illumination) and n_d (in the dark) are determined and tabulated in Table. The values for n_L and n_d are 1.38 and 4.04 respectively, for the electrode having the materials composition x= 0.1. The observed values of these parameters are slightly higher than their ideal / theoretical values, which is a common fact found in many polycrystalline materials [6].

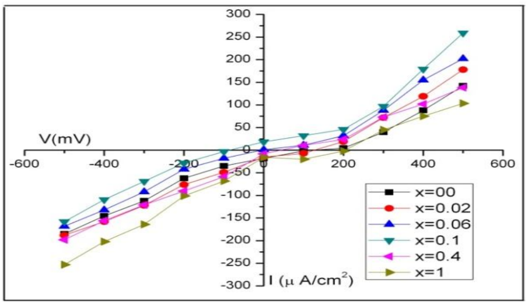

Figure 2 (a): I-V characteristics in dark for some of the typical photoelectrode compositions of $Hg_x Zn_{1-x} S$ thin films.

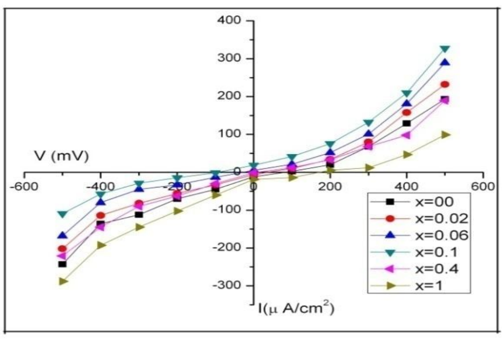

Figure 2 (b): I-V characteristics under illumination for Some of the typical photoelectrode compositions of $Hg_x Zn_{1-x} S$ thin films.

Table Some of the photoelectrochemical performances parameters of $Hg_x Zn_{1-x} S$ thin films.

x	t nm	R_{sh} Ω	R_s Ω	n_d	n_L
0	480	2040	56	6.15	2.46
0.01	462	2200	49	5.98	2.22
0.02	451	2500	43	5.64	1.92
0.04	440.5	2641	39	5.18	1.66
0.06	408	2941	35	4.56	1.55
0.08	385	3265	33.9	4.07	1.46
0.1	358	3269	33	4.45	1.38
0.2	332	1807	60	5.25	1.51
0.4	287.5	1600	68	5.70	1.86
0.6	244.5	1458	76	5.87	1.98
0.8	197.5	1224	89	5.99	2.10
1	130	961	102	6.15	2.34

3.2.2 Power output characteristics

Typical power output characteristics of these as- deposited active photoelectrodes in polysulfide electrolyte under illumination of 20mW/cm^2 are as shown in the figure 3. The V_{oc} and I_{sc} of the electrode increases with as Hg doping in host ZnS and increase upto x = 0.1. We attribute the observed improvements in photopotential and photocurrent mainly to the decrease series resistance band gap and increased photosensitivity. The quantum conversion efficiency (η%) of a cell can be calculated from the relation,

$$\eta = \frac{V_{oc} I_{sc} \times FF}{P_{in}} \times 100 \qquad (2)$$

Where P_{in} is the power density of incident radiation, I_{sc} is short-circuit current and , V_{oc} is open-circuit voltage.
The fill factor was calculated from the relation

$$FF = \frac{V_m I_m}{V_{oc} I_{sc}} \times 100 \qquad (3)$$

Where I_m and V_m are the current and voltage obtained corresponding to a point on these power output curves which gives the maximum area under the curve.

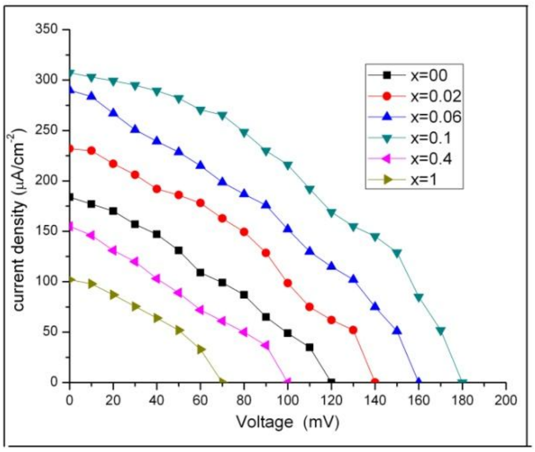

Figure 3: Power output for some of the typical photoelectrode compositions of $Hg_x Zn_{1-x} S$ thin films.

The values of efficiency (η%) , and fill factor (FF %) are calculated from these studies. Series resistance R_S and the shunt resistance R_{Sh} were calculated and listed in a table from slopes of power output characteristics curves using the relation,

$$\left(\frac{dI}{dV}\right)_{I=0} \cong \left(\frac{1}{R_s}\right) \qquad (4)$$

$$\left(\frac{dI}{dV}\right)_{V=o} \cong \left(\frac{1}{R_{sh}}\right) \quad (5)$$

Figure 4 shows the variation of the calculated value of conversion efficiency (η%) and fill factor (FF%) of the electrode composition. The fill factor and conversion efficiency maximum for composition x= 0.1are found to be 37.94% and 0.105% respectively. Efficiency (η%) and fill factor (FF%) follow the same trend of variation as that of the I_{sc}, V_{oc}. Since the efficiency and FF is related to the flat band potential and varies with an energy band gap of material [7] -[9].

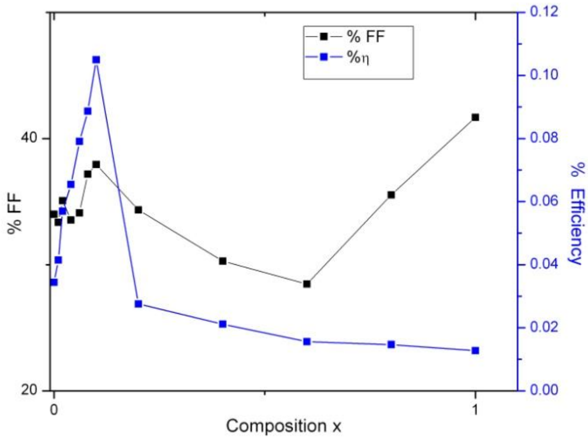

Figure 4: Variation of efficiency and fill factor with composition parameter, x.

4. CONCLUSION

The following conclusions may be drawn from this study:

- The Hg doped ZnS films were deposited onto glass and stainless steel substrate by using simple and inexpensive chemical bath technique. Physical and photoelectrochemical properties of as deposited films have been investigated.
- The physical study shows that the film thickness decreases monotonically with the composition parameter (x).
- As deposited films are n-type polycrystalline in nature and they are photoactive.
- n-Hg_x Zn_{1-x} S in conjuction with polysulfiede electrolyte form an important and interesting class of photovoltaic cells.
- I-V characteristics of as deposited films show that films are of diode in nature.
- The fill factor (FF) and conversion efficiency (η) maximum for composition x= 0.1, are found to be 37.94% and 0.105% respectively.

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