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Thickness-Dependent Photoelectrochemical Solar Cell Characterization of Cd0.825Pb0.175 S Thin Films

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ABSTRACT

The photoelectrochemical properties on chemically deposited $Cd_{0.825}Pb_{0.175}$ S thin films have been studied to asses its suitability to convert solar energy into electrical energy. The electrode was prepared from an aqueous alkaline medium consisting of Cd^{2+} and Pb^{2+} ions simultaneously in a definite volume stoichiometric proportion. The photoelectrochemical (PEC) cell of the configuration $Cd_{0.825}Pb_{0.175}$ S / 1M (NaOH +Na_2S + S) / C is fabricated to study the current-voltage (I-V) characteristics in dark and under illumination. The photovoltaic power output curves have been obtained under 25 mW/ cm^2 light intensity. The power conversion efficiency (η) and fill factor (ff) are obtained.

Keywords: Photoelectrochemical cell, $Cd_{0.825}Pb_{0.175}$ S electrode, efficiency, fill factor.

I. INTRODUCTION

Ternary semiconductors belonging to II-VI and IV-VI group are gaining much importance due to their wide spectrum utility in various optoelectronic devices such as IR detectors, photoconductive, photovoltaic cells, light amplification, LED's, lasers, PEC cells [1-3] and is an efficient absorbers in visible region of the solar spectrum [4]. Among these groups, the semiconductors CdS and PbS are highly sensitive to light radiations, so due to the practical applications, the study of the photoelectrochemical properties of their mixed thin structures has technical as well as scientific importance. In photoelectrochemical studies, the parameters like resistivity, optical band gap, optical absorption, thermoelectric power and grain size of photoelectrode material has great influence on the open circuit voltage and short circuit current of the cell [5]. The efficiency and stability of PEC cell depends strongly on choice of the material [6], preparation conditions of the photoelectrodes, electrolytes and the experimental conditions which were optimized during the experiment [7-10]. The composite / mixed ternary semiconductor materials efficiency convert solar energy into electrical are [10] due to the fact that properties of the ternary material can be easily tailored to the desired level by changing the composition parameter 'x' with the compositional variation of CdS and PbS in the $Cd_{0.825}Pb_{0.175}$ S, it is possible to alter the optical, electrical and structural properties since these properties depend on the Cd / Pb ratio.

II. EXPERIMENTAL DETAILS

Preparation of photoelectrodes of different thicknesses

The photoelectrodes of $Cd_{0.825}Pb_{0.175}S$ thin films of different thicknesses were deposited on FTO coated glass substrates procured from Sigma-Aldrich (Mumbai). The electrode thickness was increased by repeating the number of depositions.

Construction of photoelectrochemical (PEC) solar cell

The photoelectrochemical (PEC) solar cells were prepared using the $Cd_{0.825}Pb_{0.175}S$ thin films of various thicknesses deposited on FTO glass substrates as photoelectrodes, polysulphide as an electrolyte and graphite as the counter electrode. The configuration of the PEC cell is as below:

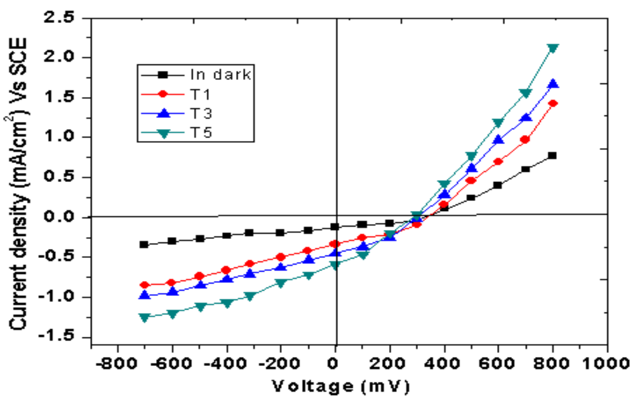
n-$Cd_{0.825}Pb_{0.175}S$ | 1M (Na_2S + S + NaOH) | C

Current-voltage (I-V) characteristics

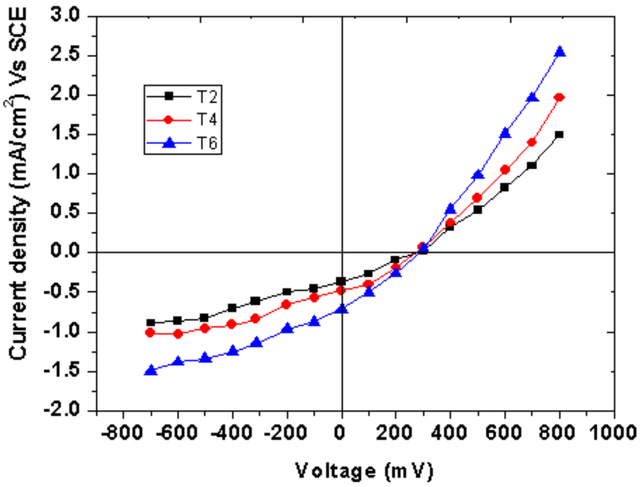
The PEC cell configurations were formed with $Cd_{0.825}Pb_{0.175}S$ thin films with different thicknesses as active photoelectrodes and their current-voltage characteristics in dark and under illumination are studied in order to understand the charge transfer process across the electrode-electrolyte interface. In electrode-electrolyte system, the nature of the charge transfer across the interface is governed by a Butler-Volmer relation

$$I = I_0\left\{\exp\left[(1-\beta)\frac{V_f}{RT}\right] - \exp\left[-\beta\frac{V_f}{RT}\right]\right\} \qquad (1)$$

the magnitude of the symmetry factor (β) decides the nature of the junction formed [10-12]. The symmetry factor (β) is therefore calculated for each junction. From the observed magnitude of β, it is clear that the junction is formed are of the rectifying Schottky type [11]. Fig. (a-b) shows the current-voltage curves for PEC solar cell with $Cd_{0.825}Pb_{0.175}S$ thin films with different thicknesses. It is found that the current increased rapidly with electrode thickness whereas the reverse saturation current (I_0) decreased this may be partly attributed to: i) the reduced surface traps with increase in the thickness and ii) reduction in the path shortening through the micro pores in the electrode structure[13-15]. The junction ideality factor (n_d) is a measure of the junction quality and is determined from I-V characteristics in dark under forward bias condition. Using famous diode equation junction ideality factor can be calculated as



(a)



(b)

Figure 1(a-b). I-V characteristics of $Cd_{0.825}Pb_{0.175}S$ thin films of different thicknesses.

Power output characteristics

Photovoltaic output characteristics of $Cd_{0.825}Pb_{0.175}S$ films with different thicknesses under 25 Mw/cm^2 are shown in Fig. c. The short circuit current (I_{sc}) and open circuit voltage (V_{oc}) were measured as a function of the photoelectrode thickness. It is found that both short circuit current (I_{sc}) and open circuit voltage (V_{oc}) increased almost linearly up to a photoelectrode thickness of 2.75 µm and deviated from linearity for higher thicknesses. The power output curves were analysed to give the power conversion efficiency (η %), fill factor (FF %) and series (R_s) and shunt (R_{sh}) resistances. It is seen that the efficiency, fill factor and shunt resistance increased with the thickness of photoelectrode where as series resistance decreased.

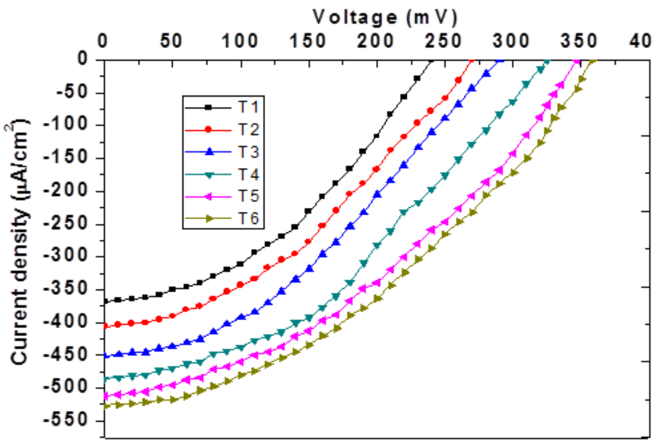


Figure 2c. Photovoltaic power output characteristics for thickness dependent $Cd_{0.825}Pb_{0.175}S$ thin films.

The increase in η can be correlated to: First, the thicker films have increased solar photon absorbing volume contributing to the increased short circuit current and second, the increased photoelectrode thickness increases the electrical conductivity and in turn decreases series resistance of a cell [16-21]. The increased in V_{oc} can be correlated to the increased flat band potential and reduced reverse saturation current [22-30]. The enhancement in the efficiency and fill factor is direct consequences of the short circuit current (I_{sc}) and open circuit voltage (V_{oc}). It is seen that an optimum performance with conversion efficiency of 0.245% has been delivered by a photoelectrode of thickness about 2.75 μm.

III. CONCLUSION

The n- $Cd_{0.825}Pb_{0.175}S$ thin films can be deposited on to conducting FTO-coated glass substrates using simple chemical bath deposition technique. As-deposited $Cd_{0.825}Pb_{0.175}S$ thin films are n-type polycrystalline and photoactive. The results indicated that for composition parameter $Cd_{0.825}Pb_{0.175}S$ the efficiency and fill factor were increased to 0.245% and 48.5% respectively. The observed enhancement is due to increased open-circuit voltage, improved grain quality and improved photoelectrode absorption

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