CHAPTER IV

CHAPTER-IV

Studies on CdS-Electrolyte Junction Solar Cells

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4.1 Introduction

The use of semiconductor electrode as intermediate for solar energy conversion has been recently the subject of intensive research[1-7]. CdS is the large band gap (2.4 eV) semiconductor, for which maximum portion of the solar spectrum goes useless. Eventhough it is well studied and used in ECPV cell, as it gives higher optimum photovoltage. It is n type, direct band gap semiconductor having high absorption coefficient (10^{-4} to 10^{-5} cm^{-1}). CdS films prepared by different techniques have been employed in the ECPV cell[9-11]. Freshly prepared CdS films were annealed in vacuum as described in chapter 3 to improve the overall efficiency of the ECPV cell.

In this chapter, the electrical characterisation of the ECPV cell, formed of the configuration, F-doped SnO_2-CdS/NaOH-Na_2S-S/C were discussed. This includes current-voltage (I-V) characteristics of the cell in dark and under illumination. Both, as prepared and vacuum annealed CdS films were used as the photoanodes in ECPV cell.

4.2 Experimental

Thin, uniform cadmium sulphide films were deposited on conducting glass (F-doped SnO_2) substrates by chemical bath deposition technique and annealed in vacuum as described in chapter III. The conducting glass substrates with 85-90% transparancy and 20-25 $\Omega/\square$ cm resistance were used.

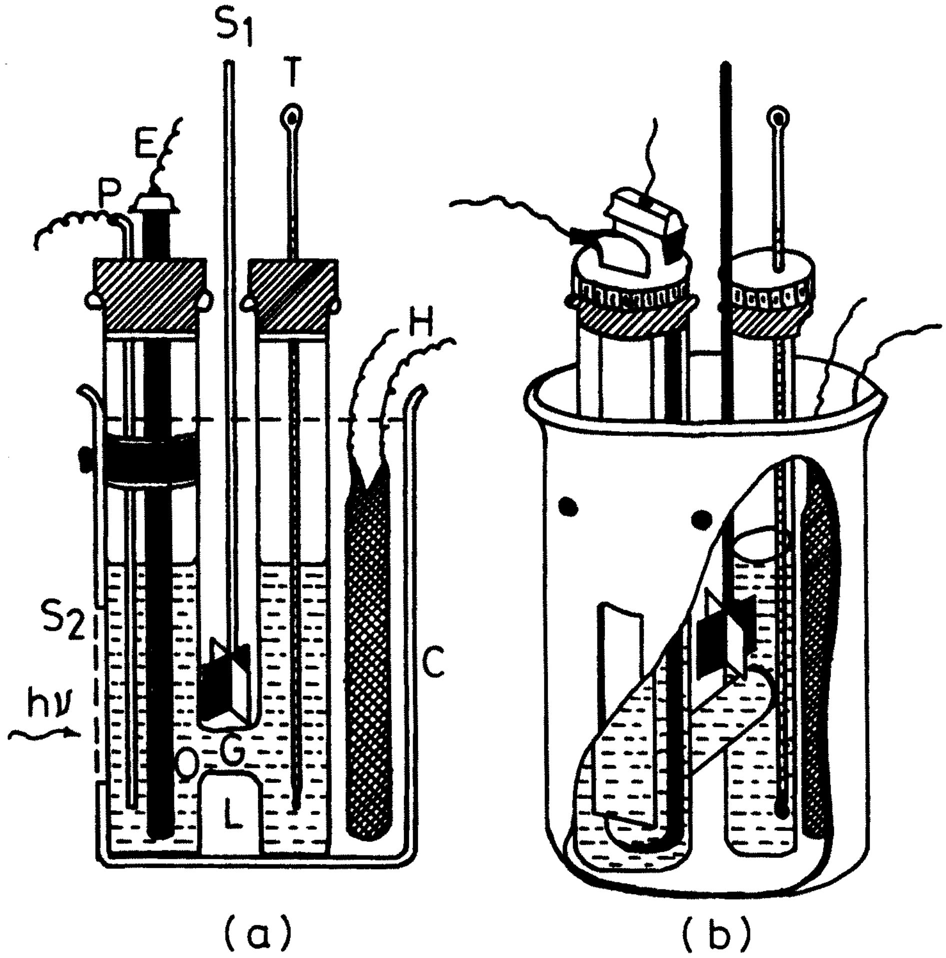
4.2.1 Formation of the ECPV cell :

The electrochemical photovoltaic (ECPV) cell was formed as shown in fig. (4.1). It consists of a modified corning glass tube, fixed in a copper calorimeter having glass window of size 2 cm x 0.5 cm epoxied into it, for illuminating the photoanode. The photoanode was positioned with metallic holder in a corning glass tube, at a distance of 1.5 mm from the glass window. A rubber cork with carbon counter electrode was used to air tight the cell. The electrolyte used was 0.1 M ($NaOH - Na_2S - S$) solution. The distance between photoanode and counter electrode was 0.2 cm. The whole assembly was kept in a backlite box (12 cm x 11.7 cm x 7.5 cm). The cell was illuminated by tungsten fillament lamp of 500 W.

4.2.2 ECPV cell properties

i) Dynamic characteristics :

The circuitry used for the study of dynamic I-V characteristics of ECPV cell, is shown in fig.4.2(a). A ten turn potentiometer (5 K) was used to vary the potential applied to the cell. The dark current through the circuit, and the dark voltage applied to the cell; were measured by



P — Photoelectrode E — Counter electrode
G — Modified glass tube T — Thermometer
C — Copper calorimeter H — Heater
L — Liquid O — Electrolyte
S_1 — Stirrer S_2 — Slit

Fig. 4.1 Design of ECPV cell
(a) Schematic diagram
(b) Sectional view

Aplab FET input nanoammeter TFM-13 and Pla digital d.c. voltmeter DPM-10 respectively. The photoanode of the ECPV cell was exposed to light from tungsten fillament lamp by opening the window slit shutter. All the measurements in light were carried out under the same conditions for same photoanode, similar to those in dark.

ii) Photovoltaic output characteristics :

Fig. 4.2(b) shows the circuit diagram to study the photovoltaic output characteristics of the ECPV cell. The short circuit current, I_{sc} and open circuit voltage, V_{oc} were noted by varing resistance R_L.

All above ECPV experiments were carried out at room temperature.

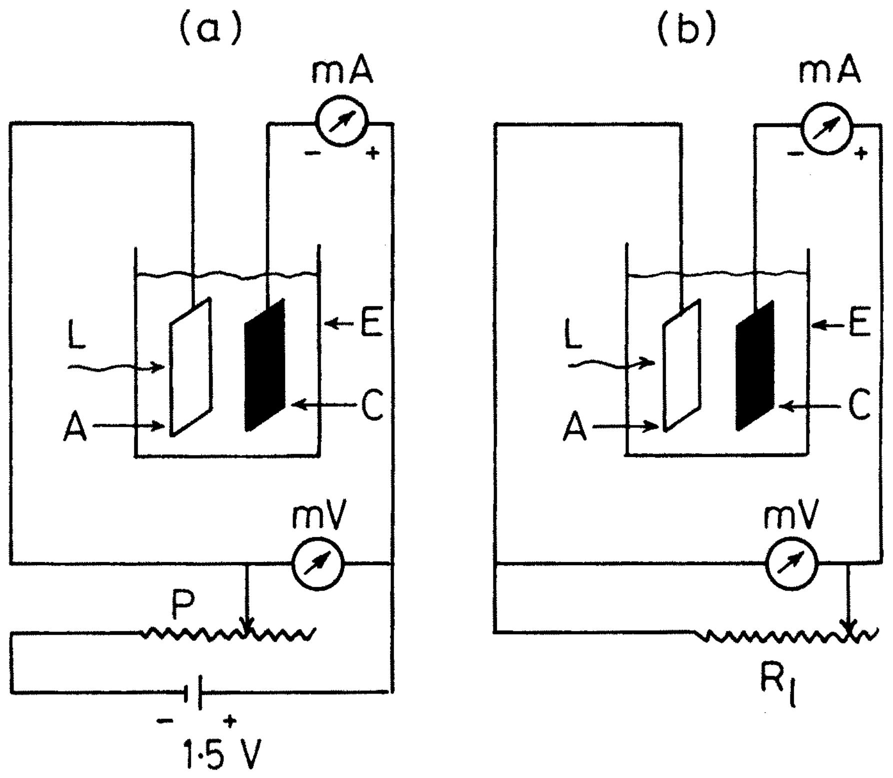
4.3 Results and Discussion

Effect of Annealing on Properties of CdS-electrolyte Junction Solar Cell

4.3.1 Dynamic characteristics of the ECPV cell :

i) Current-voltage (I-V) curve in dark :

In order to investigate the charge transport across the semiconductor-electrolyte interface, the current-voltage (I-V) characteristics was studied both in forward and reverse direction using as prepared and vacuum annealed CdS as photoanode. The nature of the (I-V) curve was shown in fig.4.3.



E — ECPV cell , C — counter electrode ,
A — photoanode, P — potentiometer,
mA — milliammeter, mV — millivoltmeter,
L — light

Fig. 4·2 Experimental circuit diagram for
(a) dynamic characteristics of ECPV cell
(b) photovoltaic output characteristic of ECPV cell .

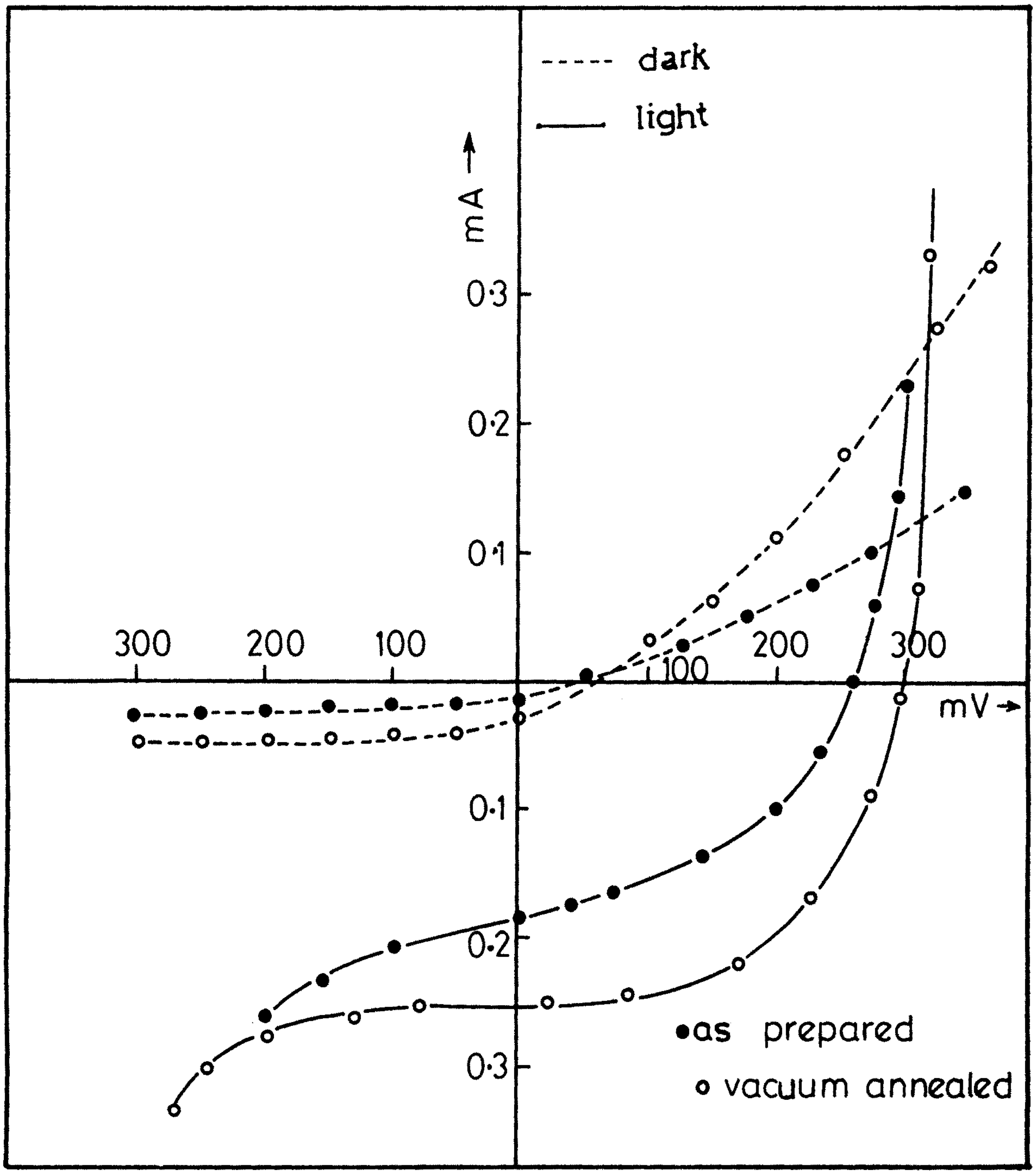


Fig.4·3 Current-voltage characteristics in dark and light of PEC cell formed with as prepared and vacuum annealed CdS film.

It was found that the I-V curves in dark, for both photo-anodes were not passing through origin, which means that even external voltage was zero. The ECPV cell gives some voltage. The polarity of the voltage was -ve towards the photoanode. The origin of this voltage was attributed to the difference between the two half cell potentials in ECPV cell.[12] It was found that the forward current increases rapidly with applied bias. The increase of forward current can be attributed to the small contact barrier height and increase in tunneling mechanism.[13-14] Current in reverse bias does not saturate but increases slowly with an applied bias.

A symmetry factor β of 0.5 corresponding to a symmetrical barrier yields a symmetrical I-V curve. This means that the interface cannot rectify with varing potential. If $\beta \neq 0.5$, then I-V curve would not be symmetrical one and interface has rectifying properties. This is known as Faradic rectification.[15] The non symmetrical nature of I-V curve fig. (4.3) for as prepared and vacuum annealed CdS film in forward and reverse direction shows that the junctions formed were rectifying one and identical to a Schottky-barrier junction.

The current-voltage (I-V) characteristics in dark for as prepared and vacuum annealed CdS film show that the dark current (I_d) increases after annealing. This increase in dark current, after annealing was attributed due to better crystallinity as well as due to the formation of sulphur vacancies, giving rise to additional donor level.[16,17]

ii) Current-voltage characteristics in light :

The dynamic I-V curve of the ECPV cell was also recorded when the cell was exposed to white light source. The nature of the I-V curve for the ECPV cell using as prepared and vacuum annealed CdS photoanode was shown in fig. (4.3). It was found that I-V curve in light was shifted in fourth quadrent which shows that the ECPV cell was the generator of electricity. It was also observed that, for vacuum annealed CdS photoanode in the ECPV cell, the shift of I-V curve in fourth quadrent was more than as prepared CdS photoanode; hence more electricity can be generated by using vacuum annealed CdS photoanode.

4.3.2 Photovoltaic output characteristics of the ECPV cell

The ECPV cell, when exposed to light, works as a generator of electricity. The characteristics of this generator were measured in turns of voltage and current. The circuit diagram to study the photovoltaic output characteristics is shown in fig. 4.4. The voltage and current drawn from ECPV cell were

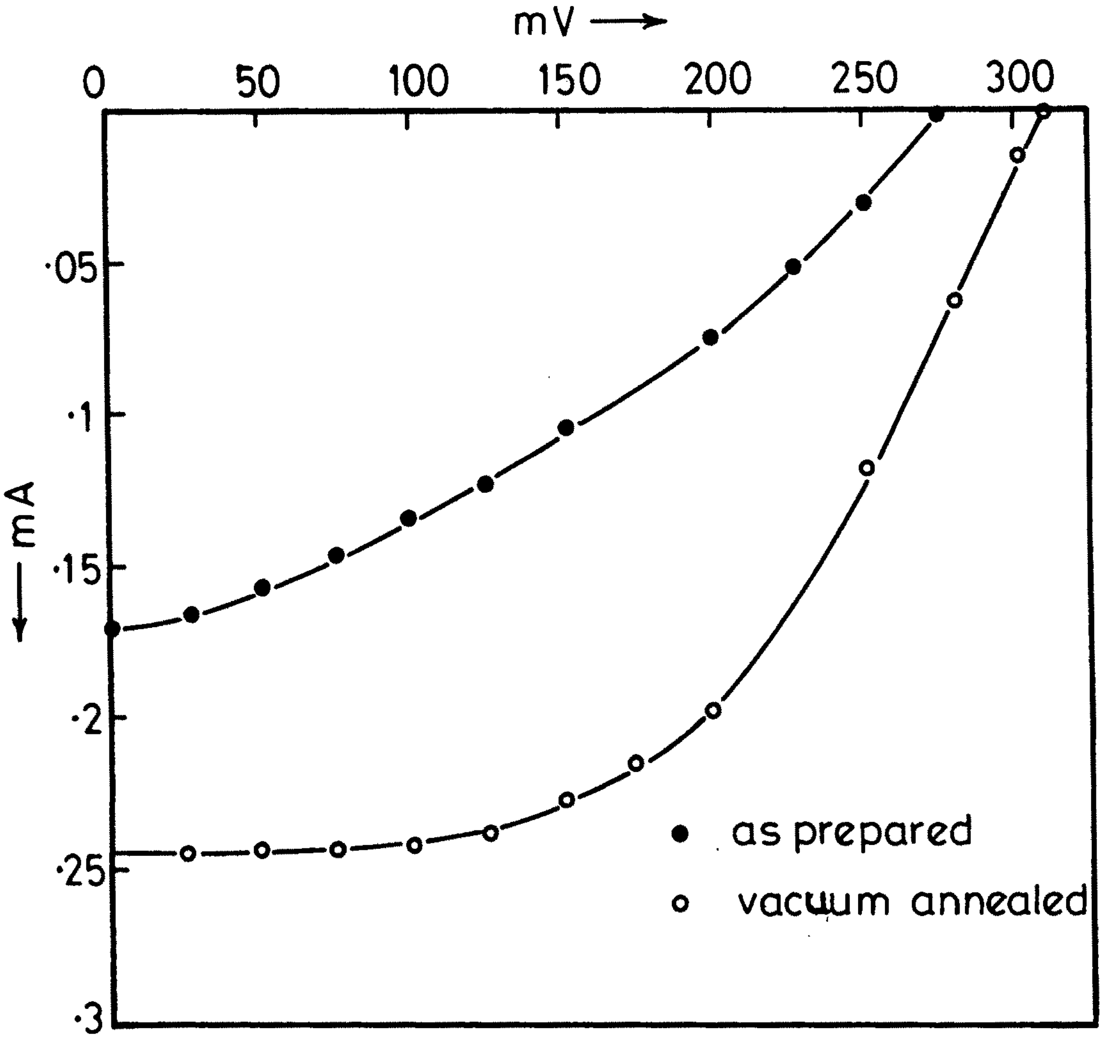


Fig.4·4 Photovoltaic power output caracteristics of as prepared and vacuum annealed CdS photoanode.

dependent on load resistance R_L in the closed circuit. When $R_L = 0$, the current flowing through the circuit was maximum, denoted by I_{sc}. The short circuit currents for as prepared and vacuum annealed CdS photoanodes were recorded and they were found to be 0.17 and 0.24 mA/cm^2 respectively. Thus the short circuit current of vacuum annealed CdS photo anode was found to be greater than as prepared CdS photo anode.

When R_L is infinite, the current flowing through the circuit was zero, while the voltage drop across R_L was maximum, called as open circuit voltage (V_{oc}). The open circuit voltage for as prepared and vacuum annealed CdS photoanodes were recorded and they were 275 and 320 mV respectively. Thus the open circuit voltage for vacuum annealed CdS photoanode was greater than as prepared CdS photoanode.

For other values of load resistances, the magnitudes of I and V were recorded, for both photoanodes, to yield the I-V curve. The nature of the I-V curve for typical ECPV cell using both photoelectrodes are shown in fig.4.4. The area under the curves gives the total power available from the ECPV cell. The maximum power available from the ECPV cell was found at a point on I-V curve where the product IV was maximum. The values of I and V corresponding to this point were denoted by I_m and V_m respectively. The values of I_{max}, V_{max} and P_{max} were recorded from both the I-V curves, drawn for as prepared and vacuum annealed CdS photoanode. The photovoltaic parameters namely, maximum power output (P_m), efficiency (η) and fill factor (ff) were calculated for as prepared and vacuum annealed CdS photoanodes and they were 20 μw, 0.02%, 42 and 40 μw, 0.04%, 52 respectively.

It was found that the magnitudes of both I_{sc} and V_{oc} of vacuum annealed CdS photoanode ECPV cell are larger than as prepared CdS photo anode which can be understood as follows.

During the annealing of CdS film the sulphur from top layer gets removed resulting in sulphur vacancies. This leads to diffusion of loosly bound sulphur atoms along the grain boundries, towards the surface, conversly, sulphur vacancies may be assumed to diffuse into the interior of the film. This gives rise to the additional doner levels in the film causing decrease in resistance. The increase in I_{sc} can also be partly due to increase in crystallinity in the CdS film.[16,17]

The explanation for the large magnitude of V_{oc} can be understood on the basis of removal of sulphur atoms from the grain boundries and generation of sulphur vacancies in the film.[16,17]

The energy conversion efficiency of the cell depends on spectral distribution of the light source, internal cell resistance and depth of light penetration into the film. The efficiency of the ECPV cell formed with as prepared CdS film was found to be less than vacuum annealed CdS film.

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