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Thickness dependent properties of electro-chemical-photovoltaic (ECPV) cells formed with chemically deposited CdS films

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Abstract. Thin polycrystalline cadmium sulphide photoelectrodes of various thicknesses have been deposited on polished stainless steel substrates by a chemical bath deposition technique. The electrochemical photovoltaic (ECPV) cells were formed with these photoanodes. Short circuit current (*Isc*) and open circuit voltage (*Voc*) are recorded under 100 mW/cm^2 light intensity. It is found that *Isc* increases with increase in thickness of the photoanode whereas *Voc* remains more or less constant. The other cell parameters, maximum power output (*Pm*) and efficiency (η) are found to improve with increasing thickness, while fill factor (f.f.) varies slightly with the photoanode thickness. The semiconductor-liquid space charge region capacitances in the dark were measured. The variation of $1/C^2$ versus applied reverse bias V is nonlinear. The deviation from straight line behaviour is attributed to the existence of surface states and degeneracy of states. The flat band potential is determined from the extrapolation of the $(1/C^2) - V$ plot to the voltage axis, and is found to vary with the thickness of the photoanode.

Keywords. Electrochemical photovoltaic cells; chemically deposited CdS films; photoanode; short circuit current; open circuit voltage; fill factor.

1. Introduction

Over the last fifteen years problems of energy have emerged with tremendous force and potential. One of the ways predicted to minimise this problem is conversion of visible light into electrical energy by the formation of a heterojunction between a direct bandgap semiconductor and an aqueous polysulphide elctrolyte. Recently, cadmium sulphide thin films have gained interest among researchers, due to their possible applications in semiconductor devices (Bube 1960). It is well known that semiconductor-liquid junction cells consisting of CdS films as photoanode, show photovoltaic effect. Several attempts have been made to improve the performance and solar energy conversion efficiency of these electrochemical photovoltaic cells (Pandya and Chopra 1981; Lokhande and Pawar 1983; Pawar and Deshmukh 1984). One of the most important parameters which controls the solar energy conversion efficiency of the photovoltaic cell is the thickness of the photoanode. Chih Tang Sah (1982), studied the effect of thickness on the efficiency of the silicon solar cell and have shown that the efficiency increases as thickness reaches the optimum value and decreases with further increase in thickness. However, little attention was paid to the effect of photoanode thickness on electrical properties of cadmium sulphide photovoltaic cells. The present paper describes the effect of photoanode thickness on various electrical parameters of a photovoltaic cell formed with CdS photoanode.

2. Experimental details

Thin films of cadmium sulphide were deposited by controlled, precipitation chemical bath deposition technique (Pavaskar *et al* 1977; Shikalgar and Pawar 1979), on plane ultrasonically cleaned glass and stainless steel substrates. The basic ingradients used were AR grade cadmium sulphate, thiourea and 14 N ammonia solution. The deposition time and temperature were 30 minutes and 85°C respectively. The speed of rotation of the substrates was 75 r.p.m. and the rate of addition of thiourea was 0·7 ml/minute. After 30 minutes the films were removed and washed several times with double distilled water and then with ammonium nitrate to make them free from sulphate radicals. Thickness of the film was increased by treating the first layered films with a fresh quantity of reactants. After each deposition the films were washed with double distilled water and ammonium nitrate.

Employing films of different thicknesses as the photoanodes, carbon as the counter electrode and 1M-NaOH-1M Na_2S-1MS as an electrolyte, the electrochemical cell was formed in a specially designed corning glass test tube. The distance between photoanode and counter electrode was kept equal to 1·5 mm. The current–voltage characteristics were recorded by a potentiometric arrangement using a digital voltmeter DPM-10 and a Aplab FET input nanoammeter. The cells were illuminated with 100 mW/cm^2 intensity by a 500 W tungsten filament lamp to analyse the photovoltaic power output characteristics.

To determine the semiconductor-liquid space charge capacitance, the distance between photoanode and counter electrode was made as large as possible (4·5 cm in this case). The space charge capacitance was measured under reverse biased condition by using digital display capacitance meter VCM-13A.

3. Results and discussion

3.1 *I–V characteristics*

The current voltage (*I–V*) characteristics in dark were studied for all the cells formed with diverse thickness of photoanode. The nature of the curve is more or less similar. Figure 1 shows the curves for three typical cells. It is seen that for forward bias, current increases rapidly as the thickness of the photoanode increases. The junction ideality factor determined from log *I* versus *V* plot for all the cells lies between 2·51 and 2·30 which indicates that the junctions are non-ideal and there is no systematic variation of ideality factor with thickness of the photoanode. The photovoltaic power output characteristics for three typical cells are shown in figure 2. The nature of the power output curves becomes more rectangular as the thickness of the photoanode increases. This is attributed to the decreased series resistance of the cell which is mainly due to the decrease in resistance of a photoanode with increase in thickness. This is similar to the results reported by Wolf and Rauschenbach (1963) for solid state solar cells. The variation in electrical parameters of a cell with photoanode thickness is given in table 1. It is seen that *Isc* increases with increasing thickness of the photoanode whereas *Voc* remains almost constant. This increase in *Isc* with the thickness is attributed to the increased solar photon absorbing volume of the photoanode. The dependence of f.f. on thickness is significant (which) as it reflects the condition that change in thickness (does

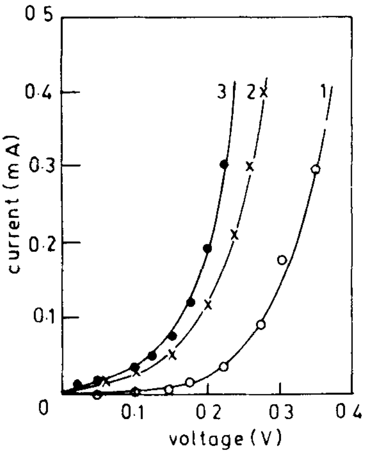

Figure 1. Current voltage characteristics in dark for three typical cells, formed with different photoanode thicknesses, (1) 0·405 μm (2) 1·43 μm and (3) 2·415 μm.

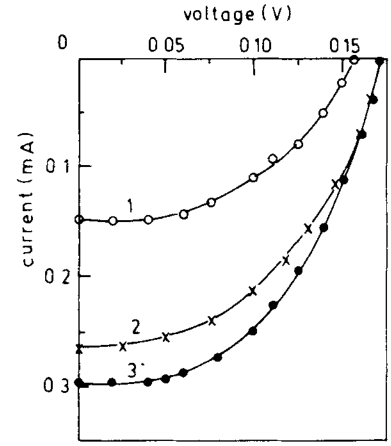

Figure 2. Power output curves for three cells of photoanode thickness, (1) 0·405 μm. (2) 1·43 μm. and (3) 2·415 μm.

Table 1. Some electrical parameters of ECPV cells formed with CdS photoanode of different thicknesses.

Thickness of the photoanode (μm)	*Isc* mA	*Voc* mV	*Pm* = *Im*·*Vm* mW	*Rs* Ω	*Rsh* Ω	f.f. %	η %	Junction ideality factor
0·4058	0·15	155	11·0	416·66	6000	47.4	0·0110	2·390
0·8928	0·23	150	14·5	331·53	5216	42·0	0·0145	2·360
1·438	0·265	170	22·0	270·24	4016	48·8	0·0220	2·517
2·415	0·31	170	25·3	220·24	3601·4	48·0	0·0253	2·305

significantly) alters the injection levels. This is similar to (that of) the results reported by Chih *et al* (1982) for silicon solar cells.

3.2 *C–V characteristics*

In order to characterize the semiconductor-liquid junction the capacitance-voltage measurements were carried out. The measured space charge layer capacitance is found to decrease with increased reverse bias. The variation of $1/C^2$ versus V is depicted in figure 3, for two typical cells of different photoanode thicknesses. It is obvious from the figure that variation of $1/C^2$ with V is nonlinear and is indicative of graded junction. This deviation from linearity is due to the presence of surface states and degeneracy of states as explained by Cardon and Gomes (1978) and Aruchamy *et al* (1982). The capacitance (is found to) increases slightly with thickness of the photoanode which may be due to the reduction in the shortening effect between electrolyte and substrate *via*

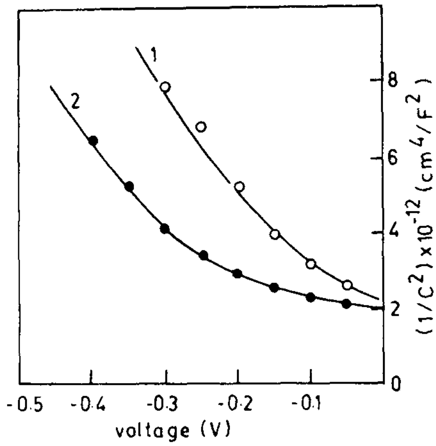

Figure 3. Mott-Schottky plots for two cells of various thicknesses, (1) 0·405 μm. and (2) 2·415 μm.

pin holes. The flat band potential is determined by extrapolating the $1/C^2$–V plot to voltage axis and found to increase with the thickness of the photoanode.

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References

Aruchamy A, Aravamudan G and Subba Rao G V 1982 *Bull. Mater. Sci.* **4** 483
Bube R H 1980 *Photoconductivity of solids* (New York: Wiley) pp. 88
Cardon F and Gomes W P 1978 *J. Phys.* **D11** L 63
Chih Tang Sah C T, Yamakawa K A and Lutweck R 1982 *IEEE Trans. Electron Devices* **29** 903
Lokhande C D and Pawar S H 1983 *Mater. Res. Bull.* **18** 1295
Pandya D K and Chopra K L 1981 in *Vacuum surface thin solids films* (eds.) K L Chopra and T C Goel (Delhi: Vanity Books) p. 258
Pavaskar N R, Menezes C A and Sinha A P B 1977 *J. Electrochem. Soc.* **124** 743
Pawar S H and Deshmukh L P 1984 *J. Mater. Chem. Phys.* **10** 83
Shikalgar A G and Pawar S H 1979 *Thin Solid Films* **61** 313
Wolf M and Rauschenbach H 1963 *Adv. Energy Convers.* **3** 455