Study of different parameters in nanocrystalline CdSe based photoelectrochemical cells

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Use of nanostructures in photoelectrochemical solar cells has potential to provide high conversion efficiency. Films of CdSe nanocrystals of different size have been prepared on titanium substrate by pulsed electrodeposition. These are used as photoelectrode in photelectrochemical cells and photovoltaic effect is studied. It is observed that photoelectrodes prepared with 1:1 duty cycle give best performance. Increase in open circuit voltage and short circuit current with the incident light intensity is observed to be logarithmic and linear respectively.

(Received June 01, 2010; accepted August 12, 2010)

Keywords: Nanocrystalline CdSe Thin film, Pulse electrodeposition, Photoelectrochemial solar cells

1. Introduction

Solar power has a great potential as source of renewable energy, which explains the intense research activity in this field [1]. In photoelectrochemical (PEC) solar cells, light energy may be converted into electrical and/or chemical energy [2]. The performance and effectiveness of a solar cell device mainly depend upon its design and the properties of the photovoltaic (PV) materials included especially the light absorbers and their connections to the external circuit. The choice of the charge mediator involved may also be crucial.

Repots are available that the use of nanostructures in solar cells may enhance the efficiency and performance [3]. In PEC cells the junction formation is quite easy and polycrystalline films also work very well. Use of nanocrysllites have potential to provide high conversion efficiency since large area is available to absorb photons, the photo-generated carriers have to travel over a short distance and the effective band gap can be tuned to absorb a particular photon energy-range [3-4]. Cadmium selenide (CdSe) having band gap 1.7eV is a good candidate for PV. In present work CdSe nanocrystalline films of different crystal size have been prepared by pulsed electrodeposition method and their performance in PEC cells with sulfide/polysulfide electrolyte has been studied.

2. Experimental methods

2.1 Preparation of photoelectrodes

Pulse electrodeposition technique is use to prepare CdSe nanocrystal films on titanium substrate. We have taken 0.5M $CdSO_4$ and 0.1M SeO_2 for preparing the electrolyte solution **[5].** For pulsed voltage, we have used an ON-OFF machine which is based on the operation of IC-555 in astable mode. The output of 555 is square wave whose time period is controlled by external resistances. Different duty cycles of ON-OFF machine were used for preparing five samples of nanocrystalline thin films. The electrolyte solution was kept at 80ºC during the deposition process. The current density was 7 mA/cm^2. In this way five samples of nanocrystalline CdSe films with different duty cycles as 1:0, 1:1, 1:2, 1:3 and 1:4 have been obtained. These were dried in air for 24 hours

2.2 Photovoltaic study

Electrolyte solution for PEC solar cell was prepared by 1M NaOH, 1M Na_2S & 1M S **[6].** A graphite rod was used as a counter electrode and CdSe films prepared previously were used as photoelectrode. For illumination of photoelectrode a 50Watt tungsten lamp was used. It was placed at a fixed distance of 10 cm. from photoanode and the light intensity was 6000 lux. A potentiometer was connected in series with PEC cell. Varying the resistance of potentiometer, voltage and current were measured. Same process was repeated for all five samples, and I-V characteristics were plotted and solar cell parameters- Open circuit voltage (Voc), Short circuit current (Isc), fill-factor (ff) . & Efficiency (η) were determined. In order to study the effect of intensity, the distance between the lamp and solar cell was varied from 10 to 100 cm and Voc and Isc were measured for the solar cell with photoelectrode prepared from 1:1 duty cycle.

3. Results

Fig. 1 shows the I-V characteristics of solar cells with different photoelectrodes. The solar cell parameters with different samples are given in Table I. The variation of Voc and Isc with the duty cycle of pulse electro-deposition of photoelectrode are shown in Fig2 and the variation of ff and efficiency are showing Fig3.

The effect of intensity was studied only for CdSe photoelectrode prepared with duty cycle 1:1 since this sample gave best performance. Fig 4 shows the variation of Voc and Isc with the incident light intensity. The intensity dependence of short circuit current is nearly linear and the open circuit voltage increases as logarithmic function of light of intensity.

4. Discussion

It is seen from the Fig.1 and also from Table I that the cell performance improves and parameters increase with duty cycle from 1:0 to 1:1, but with duty cycle 1:2 it shows poor performance of PEC cell. However as further increases the off time of duty cycle, these parameters increase again. The best result obtained for CdSe with 1:1 duty cycle at an intensity of 6000 Lux using 1M polysulfide as the redox electrolyte. The parameters of the cell are obtained as **Voc** - 260 mV. **Isc** - 82 μA, **F.F.** - 0.36 and **η%** - 0.326%.

The I-V curve is displaced along the current axis, as a function of intensity of incident light hence intensity dependence of short circuit current is linear and the open circuit voltage increase as logarithmic function of light intensity.

The studies show that comparatively large nanocrystals of CdSe give better results in PEC solar cells. As the size of nanocrstsal further decreases first the performance is very poor, but then improves gradually for still smaller CdSe particles. Such observation may be explained as follows:

Improved performance for 1:1 duty cycle can be attributed to larger surface area available for absorption of photons in case of nanoparticles. This causes increase in photo generated electron hole pairs, whose separation gives photovoltaic effect. For duty cycle 1:2 perhaps the surface states become dominate and so the photo generated charge carriers are captured by them reducing photovoltaic effect. For duty cycles 1:3 & 1:4, still smaller CdSe crystals will be deposited on titanium electrode where quantum size effect is considerable. This increases the oscillator strength and hence the absorption co-efficient. But higher energy is required to produce photogenerated charge carriers. Investigation of spectral response may be able to show this fact.

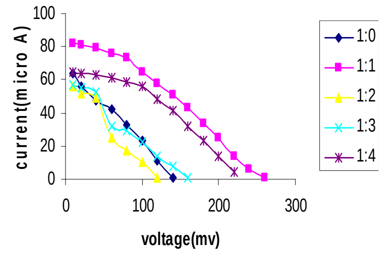

Fig. 1. I-V characteristic of PEC Cells with CdSe film prepared with different duty cycles.

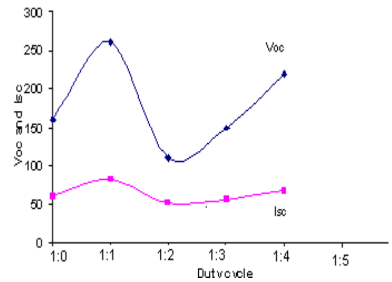

Fig. 2. Effect of duty cycle on Voc & Isc of CdSe nanocrystal based PEC Cell.

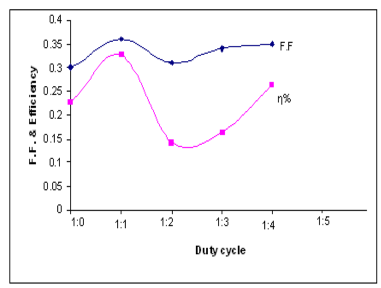

Fig. 3. Effect of duty cycle on ff. and η of CdSe nanocrystal based PEC Cell.

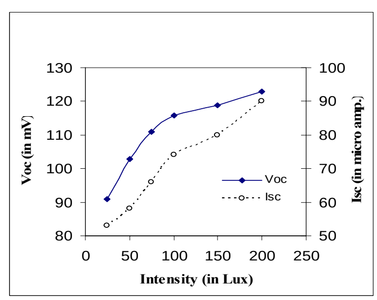

Fig. 4. Effect of incident light intensity on Voc & Isc of CdSe nanocrystal based PEC Cell.

Table 1. Solar cell parameters for different photoelectrodes.

S. N.	Duty cycle	Open circuit voltage (Voc)	Short circuit current (Isc)	Fill-Factor (F.F.)	Efficently (%)
1	1:0	160	61	0.30	0.226
2	1:1	260	82	0.36	0.326
3	1:2	110	51	0.31	0.143
4	1:3	150	57	0.34	0.163
5	1:4	220	68	0.35	0.263

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