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Optimization of Preparative Parameters for the Electrode position of Cdse Films for Photo electrochemical Solar Cell Applications

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ABSTRACT

The experimental results on the optimization of reaction parameters such as bath temperature, deposition time and pH dependence of structural, optical and morphological properties CdSe nanocrystals in the electro-deposited films. The depositions were carried out on two different substrates viz. stainless steel strips and fluorine doped tin oxide (F.T.O.). The growth process and characterization of CdSe crystals are determined by UV–Vis spectroscopy, X-ray powder diffraction (XRD) and scanning electron microscopy (SEM). Also, the influence of reaction conditions on the photoelectrochemical (PEC) of CdSe nanocrystals photoanodes in combination with graphite as a counter electrode and polysulphide as a redox couple was studied systematically. This demonstrates that low reaction temperature and acidic bath are favourable for the formation of high quality CdSe films to explore them in PEC cells.

Keywords: XRD, SEM, PEC, Thin Films, CdSe

INTRODUCTION

Thin film science is a reasonably early and ever rising concept in the field of nanotechnology [1]. Since last decade thin film technology have been widely studied for the deposition of films of various chalcogenides due to their direct applications in various fields such as photovoltaic [2], surface engineering [3], metallurgical coating[4], magnetic science[5], telecommunications [6], optoelectronic devices [7], radiation detectors [8], laser materials[9], thermoelectric devices, solar energy converters for energy harvesting purposes. Be it in the past or the present, energy has played very vital role in the social and economic progress of the man. Besides, the rising population, intense industrialization and rapidly changing life styles have increased energy demands extremely. Off late, about 80 % of energy consumed is belongs to the natural sources and any major changes in this energy consumption scenario is not foreseen in the near future. Instead, the global energy demand is expected to increase by up to 60 % and CO_2 emission by 70 % by 2020 [9] which, put pressure on an already stressed energy system. Therefore, it is of great importance to develop new alternative sources like bio-fuels, wind, hydroelectric and solar energy. As the energy influx of Sun on the planet earth is about $4.3x10^{20}$ J per hour energy from the Sun dwarfs all other sources, whether they are conventional or non-conventional ones. In addition, it does not have any kind of environmental hazards, since there is no concern of release of hazardous waste and toxic gases associated with access of solar energy. Thus, among all above discussed applications of semiconductor thin films, now days; more emphasis is given to photovoltaic or solar energy conversion technology foe energy harvesting purposes.

Nonetheless, effect of post annealing of optimized electrodeposited CdSe photoanodes have been not studied widely. In view of this, CdSe, a binary chalcogenide semiconductor, is having energy band gap around 1.04 eV with high absorption coefficient, which makes it a suitable candidate as a sensitizer in PEC cells is studied systematically.

METHODOLOGY

To prepare CdSe thin films all of A. R. Grade chemicals (supplied by Sharad Chemicals, Pune) such as $(CH_3COO)_2$ $Cd.2H_2O$, SeO_2, EDTA, $(CH_2(OH)CH_2(OH))$ and Ethylene glycol. All the solutions with optimized concentration and volume were prepared in Ethylene glycol (CH_2 (OH) CH_2(OH). For the electrodeposition of CdSe firstly the 10 ml of 0.01 M $(CH_3COO)_2$ $Cd2H_2O$ was peprepared in ethylene glycol. Secondly, the 1 ml 0.01 M solution of EDTA is prepared under constant stirring and then added to the first bath. Further, 10 ml of 0.005 M SeO_2 prepared and then added to the reaction bath for the final deposition.

As Electrodeposition technique uses electrically conducting stainless steel strips of a size 1x 4=4cm^2 and fluorine doped tin oxide (F.T.O.) coated glass substrates for the deposition of thin films. It requires smooth and clean substrate to have uniform and adhesive electrodeposition of films [32-35]. The metallic and glass substrates were washed using Labolene solution and tap water. Also the substrates were etched subsequently by 25% dilute Hydrochloric acid for 20 to 30 seconds and cleaned with the help of ultrasonication. Finally the substrates were dried in the vapors of alcohol for the final deposition.

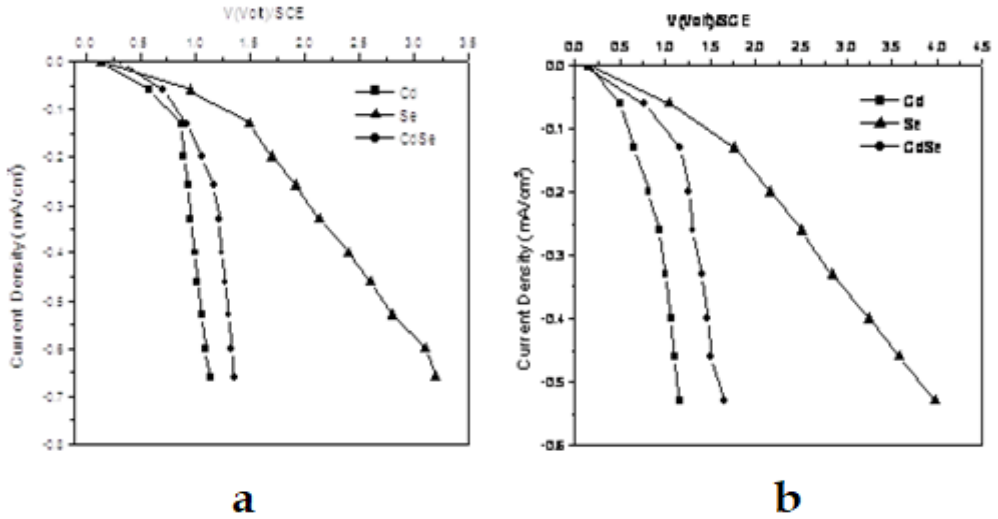
RESULTS AND DISCUSSION

Optimization of deposition potential:

Initially, the elementary depositions of Cd and Se were separately carried out with their optimized concentrations, volumes and deposition potentials, respectively. The current versus voltage (w.r.t SCE) curves (polarization curves) were plotted for examining the deposition potentials. Similarly, electrodeposition of CdSe thin film was carried out with suitable bath compositions and different polarization curves were obtained for CdSe thin films at various bath temperatures. The so obtained polarization curves for Cd and Se and CdSe are shown in figure 1 and the respective deposition potentials for various bath temperature are tabulated.

Table 1: Deposition Potentials for various bath compositions

Sr. no.	Bath Composition	Bath temperature (℃)	Deposition potential for SS (min)	Deposition potential for FTO (min)
1	$(CH_3COO)_2Cd2H_2O$ (0.01M)	30	-0.93	-1.77
2	SeO_2 (0.005M)	30	-2.56	-2.80
3	$(CH_3COO)_2Cd2H_2O$ (0.01M, 10ml) + EDTA (0.1M, 1 ml) + SeO_2 (0.005M, 10 ml)	30	-1.78	-1.80
4	$(CH_3COO)_2Cd2H_2O$ (0.01M, 10ml) + EDTA (0.1M, 1 ml) + SeO_2 (0.005M, 10 ml)	40	-1.86	-1.42
5	$(CH_3COO)_2Cd2H_2O$ (0.01M, 10ml) + EDTA (0.1M, 1 ml) + SeO_2 (0.005M, 10 ml)	50	-1.20	-1.41
6	$(CH_3COO)_2Cd2H_2O$ (0.01M, 10ml) + EDTA (0.1M, 1 ml) + SeO_2 (0.005M, 10 ml)	60	-1.17	-1.40
7	$(CH_3COO)_2Cd2H_2O$ (0.01M, 10ml) + EDTA (0.1M, 1 ml) + SeO_2 (0.005M, 10 ml)	70	-1.15	-1.42
8	$(CH_3COO)_2Cd2H_2O$ (0.01M, 10ml) + EDTA (0.1M, 1 ml) + SeO_2 (0.005M, 10 ml)	80	-1.10	-1.33



a b

Fig. 1: Cathodic polarization curves for Cd and Se and CdSe on a) SS b) FTO

It is observed from Table.1 that, as the bath temperature increases, the potential required for deposition of films increases which further leads towards the increase in the grain size during deposition. The rise in the temperature beyond 40℃ causes the dissociation of the complex and causes the rise in concentration of simple ions [36]. It leads to the discharge of ions at a low potential. Thus, increase in temperature of the bath enhances the rate of diffusion and raises the motilities of ions and along with the conductivity of the bath [37]. As a result of this, in the present case, temperature of 40℃ is considered to be the optimized temperature.

Optimization of deposition time though thickness measurement:

To optimize the deposition time for the deposition of films, depositions were carried out for various time intervals. The plot of thickness Vs time is shown in the figure 2 (a and b) and the corresponding data is shown in Table 2.

Table 2: Thickness measurement

Sr. No.	Deposition time (min.)	Thickness (SS) µm	Thickness (FTO) µm
1	20	1.31	1.01
2	25	2.63	1.54
3	30	4.41	1.99
4	35	5.09	3.32
5	40	4.69	3.15

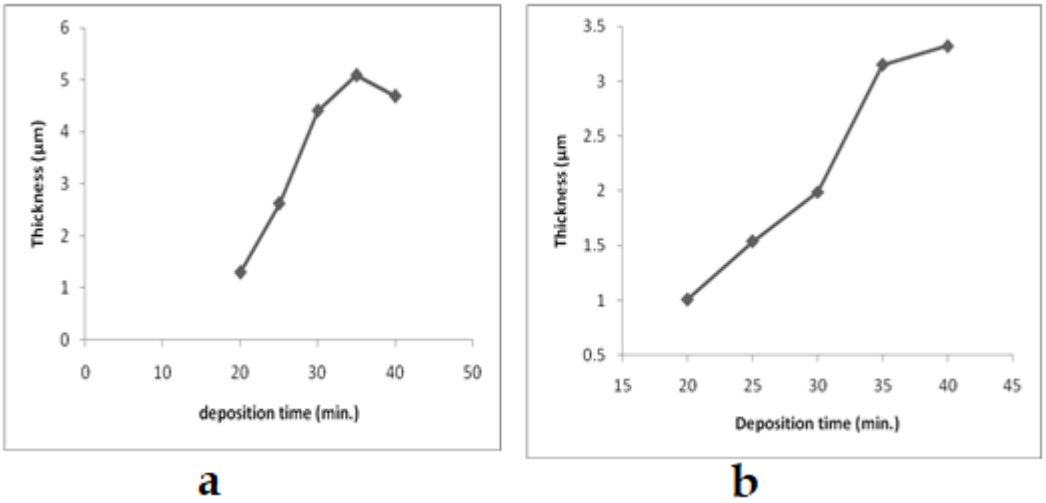


Figure 2(a): Change of Thickness with different deposition time on SS substrates
(b): Variation of Thickness with deposition time on FTO coated glass substrates

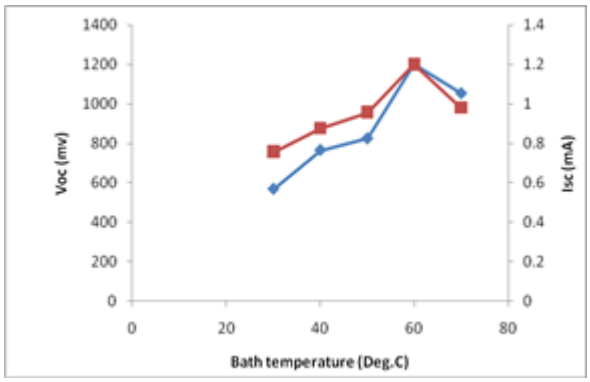


Figure 3: Variation of Isc and Voc with temperature of bath taken on SS substrates

Thus, as discussed earlier, the further electrodeposition of CdSe films were carried out for the deposition time of 35 min and deposition potential obtained for the bath temperature of 40℃ is used to obtain good adherence and appearance.

The X ray diffraction analysis for CdSe films on to SS and FTO glass substrates were recorded within the span of angle b etween 10° to 100° using Philips, PW 1710 diffractometer. Optical absorption studies were carried out by using UV- VIS- NIR spectrometer. (Hitachi, Japan, Model no. 330). JEOL, JXA – 840 reflection scanning electron microscope with EDAX arrangement model was to study the surface morphology and elemental composition for the annealed and as-deposited CdSe films. The Photovoltaic properties of the CdSe / 0.1 M polysuphide/graphite (2 x 4 x 0.3=2.4 cm^3.) PEC cells were studied systematically. The photovoltaic parameters such as current density, I_{sc} and open circuit voltage V_{oc} were recorded at different load resistance R_L. Fill factor and power conversion efficiency (η) of the electrodeposited CdSe material were also measured for the fabricated PEC cells.

Effect observed of Bath Temperature onto Photoelectrochemical Properties

The variation in Isc and Voc is studied for photo electrodes deposited at different bath temperatures and the variations are depicted in figure 3. From the curves, it is observed that, Isc increases initially with bath temperature. However, it attains its maximum value at particular temperature and then starts to decreases with further rise in temperature. This is in agreement with the earlier reports in the literature. The relatively observed higher value of Isc can be attributed to shifting of the materials towards stoichiometry. However, the observed decrease in the Isc may be attributed to the increase in the deposition rate as a result of more thermal energy supplied to the ions of electrolyte due to large temperature of bath. Thus, in present case, at a particular value of the temperature, the composition of the material formed is stoichiometric giving good results of the CdSe based PEC performance. In addition, From the fig.3 similar trend is observed for Voc for the CdSe based PEC cells.

Similarly, the effect of temperature of bath on the PEC properties of photoelectrode CdSe by using different substrates is studied by using the photoelectrodes prepared from the electrolytic bath of different temperatures.

CONCLUSION

In the present study, for the electrodeposition of the CdSe films various preparative parameters such as bath temperatures, pH, deposition time and deposition potential were optimized to obtain good quality films. In addition, the as-deposited films were annealed at three different temperatures to study their structural and optical properties to decide their suitability for photoelectrochemical cell applications. The results presented in the work illustrate the influence of reaction time, pH and bath temperature including the effect of annealing on the photovoltaic performance of CdSe based PEC cells.

Conflicts of interest: The authors stated that no conflicts of interest.

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