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Effect of deposition current on crystallites size of electrodeposited CdSe thin films

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ABSTRACT

CdSe semiconductor thin films have been successfully synthesized onto stainless steel and FTO glass substrates by electrodeposition technique. Aqueous solutions containing precursors of Cd and Se have been used to obtain good quality films. The optimized films have been characterized for their structural and morphological properties. X-ray diffraction (XRD) studies show that the films are polycrystalline in nature with hexagonal crystal structure. Effect of deposition current on crystallites is shown. Scanning electron microscopy (SEM) studies show that the film surface is smooth, uniform and compact in nature.

KEYWORDS

Cadmium selenide;
XRD;
SEM;
PEC.

INTRODUCTION

Solar energy is the radiant light and heat from the Sun that has been harnessed by humans since ancient times using a range of ever-evolving technologies. The need for non-conventional energy resources is considered to be potential driving force for the power requirements of the 21st century. Solar energy is one of the most abundant, non-pollutants, inexhaustible and democratic source of energy. It is available everywhere on the earth in quantities that vary only modestly, while it needs to be considered for electrical energy conversion. The II-VI binary semiconducting compounds, belonging to the cadmium chalcogenide family (CdS, CdSe, CdTe), are considered to be very important materials for its potential applications in photovoltaic[1-5], photoelectrochemical (PEC) solar cells[6], optoelectronic devices[7], thin film transistors[8,9] and gamma ray detectors[10]. The major attention has been given to the investigation of electrical and optical properties of CdSe thin films in order to improve the performance of the devices and also finding new applications. II-VI compounds, especially CdS, CdSe, CdTe, Cd1-xZnxS etc. are of great interest because they are potential candidates in many practical applications like photovoltaic solar cells.

Cadmium selenide (CdSe) is one of the well known II-VI semiconductor materials having cubic and hexagonal crystal structure is considered to be a potential candidate for photoelectrochemical solar cell conversion, light emitting diodes, and thin film transistors (TFTs.)[11-13] because of the compatibility of its band gap (1.7 eV) with the solar spectrum[14,15].

In this paper, nanocrystalline CdSe thin films are deposited on stainless steel by using electrodeposition technique. X-ray diffraction, scanning electron microscopy and Photoelectrochemical techniques are used to characterize the CdSe thin films. Effect of deposition current on crystallites of CdSe thin films is shown by using photoelectrochemical (PEC) characterization using cell configuration n-CdSe /1M (NaOH+Na2+S)/ C are investigated.

EXPERIMENTAL DETAILS

Preparation of CdSe thin films by electrodeposition technique

The n-CdSe thin films were synthesized by using simple and inexpensive electrodeposition technique. All chemicals were of analytical reagent grade and used without further purification. All the aqueous solutions were prepared using distilled water. For electrodeposition of CdSe thin films, a conventional three electrode cell was used. Stainless steel substrates were used as cathode. The stainless steel substrates were first mirror-polished by a fine grade polish paper, and then washed with liquid detergent followed by drying in the alcohol vapors. Before using as a substrate, in order to remove the oily substances from surface, cleaned substrates were etched in 25% HCl for 20 seconds and then ultrasonically cleaned with double distilled water. Electrodeposition was carried out on the unit area (1 cm2) of the substrates by using the cadmium acetate and selenium dioxide as a precursor sources for Cd and Se at potentiostatic mode in an unstirred bath. The anode and cathode were kept fixed at a distance of 0.4 cm apart throughout the experiment. After deposition, the films were rinsed in doubly de-ionized water and used for further investigations.

First we were optimizing the solution concentration and then deposition current (at optimized solution concentration). Both the solution concentration (0.125M) and deposition current (1mA) were optimized by using photoelectrochemical (PEC) characterization technique. PEC solar cell was fabricated using a two electrode configuration, comprising n-CdSe thin film as a photoanode, graphite as a counter electrode and SCE as a reference electrode. The redox electrolyte was 1M polysulphide (NaOH-Na2S-S). The cell was illuminated with 500W tungsten filament lamp for the measurement of short circuit current (Isc) and open circuit voltage (Voc). In order to improve the PEC performance of CdSe thin films we prepared the films and further studied for same characterizations.

Optimized preparative parameters were characterized by X-ray diffraction and scanning electron microscope (SEM) technique etc. The structural characterization of CdSe thin films were carried out by using Philips X-ray diffractometer (model PW-3710, λ=2.2897Å for Cr-Kα radiation). The morphology of the films was studied by using a scanning electron microscope (JEOL-JSM-6360, Japan). The photoelectrchemical characterization investigation were carried out by using cell configuration n-CdSe /1 M (Na_2S–S–NaOH)/C.

RESULTS AND DISCUSSION

It is recognized that the technologies involved in the energy efficiency and solar energy could alleviate the environmental and energy crisis manifested by global heating through greenhouse effect and fast depletion of conventional energy sources respectively. These problems could be partly remedied by the use of semiconductor solar cells. Although there have been both academic advances and market growth in photovoltaic technology in recent years, there remains a need for increased efficiency, lower cost processing and increased process yields. Photovoltaic energy generation is currently dominated by bulk crystalline Si solar cell technology.

Cadmium selenide films have been formed according to the following overall reaction:

$$\mathbf{(CH_3COO)_2Cd.2H_2O \rightarrow Cd^{2+} + (CH_3COO)_2^{\ 2-} + 2H_2OSeO_2 + H_2O \rightarrow H_2SeO_3} \quad (1)$$

$$\mathbf{H_2SeO_3 + 4H^+ + 6e^- \rightarrow Se^{2-} + 3H_2O} \quad (2)$$

In the chemical reaction, first step is the reduction of H2SeO3 to selenium ion on the surface of the stainless steel substrate, which is at once followed by successive reduction process given by,

$$\mathbf{Cd^{2+} + Se^{2-} \rightarrow CdSe} \quad (3)$$

Several factors influences the performance of the produced semiconductor electrode, including cathode surface before the electrolysis, composition of the so-

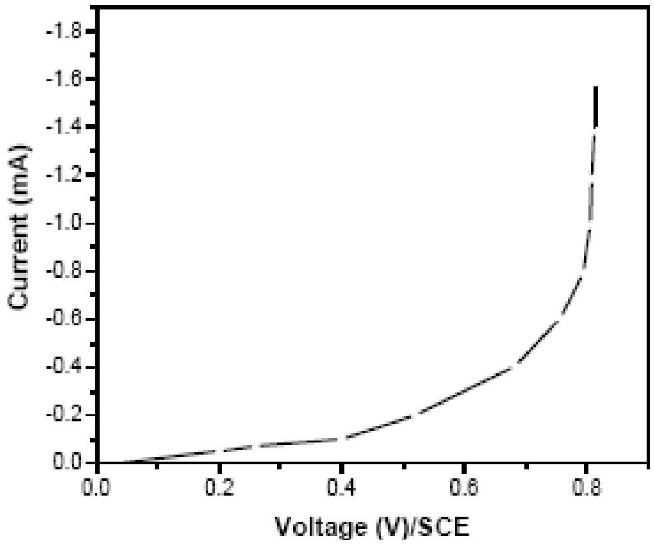

Figure 1 : CdSe thin films in aqueous medium. it is observed that deposition potential of CdSe thin films 0.8V/SCE .

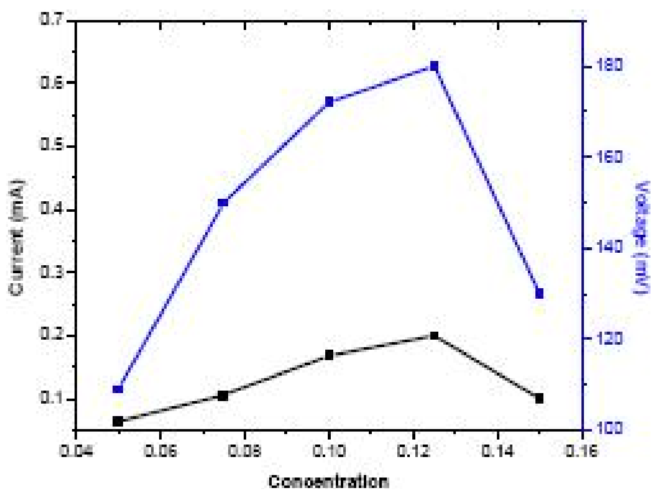

Figure 2 : Variation of I_{sc} and V_{oc} with concentration of solution for CdSe thin film /1M NaOH-1M Na_2S-1M S/C PEC solar cell

TABLE 1 : Optimized preparative parameters for electrodeposited CdSe thin film

1	Deposition potential	-0.82 V/SCE
2	Bath composition	0.125 M $(CH_3COO)_2.Cd.2H_2O$+0.125 M SeO_2
3	pH of the bath	3.72
4	Deposition time	30 minutes
5	Deposition current	1mA

lution, plating current density, pH of the electrolytic bath, deposition time. The deposition potential is obtained from polarization curve is as shown in following Figures 1.

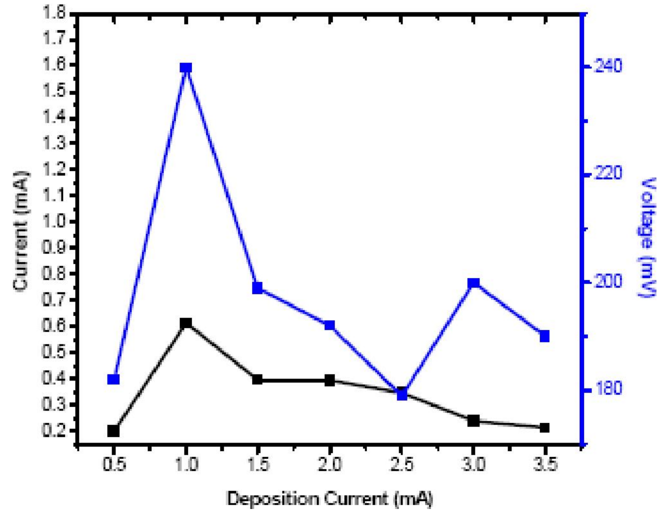

Figure 3 : Variation of I_{sc} and V_{oc} with deposition current at constant concentration of solution for CdSe thin film /1M NaOH-1M Na_2S-1M S/C PEC solar cell

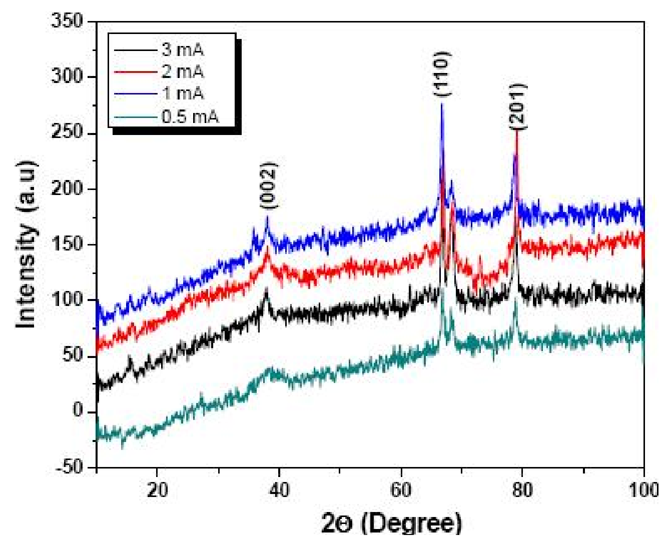

Figure 4(a) : XRD pattern of CdSe thin film deposited on stainless steel substrate

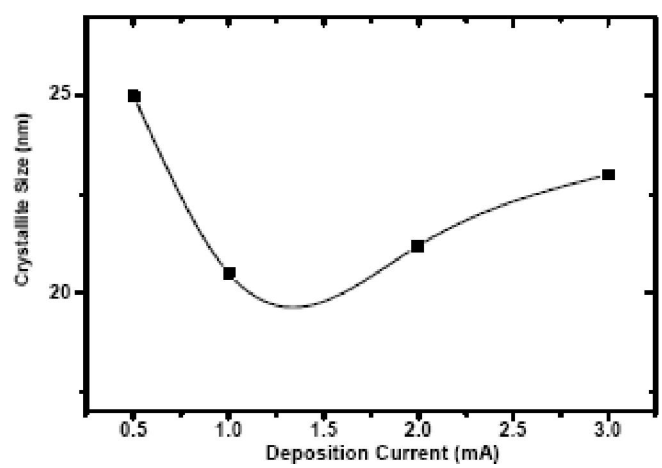

Figure 4(b) : Variation of crystallite size with deposition current of CdSe thin film deposited on stainless steel substrate

TABLE 2 : Comparison of the observed and standard'd' values of CdSe thin films at optimized preparative parameters on stainless steel substrate.

Sr. No.	Observed 'd' (Å)	Standard 'd' (Å)	(hkl) planes
1	3.48	3.51	(002)
2	2.07	2.15	(110)
3	1.79	1.80	(201)

Optimization of preparative parameters of photoactive semiconducting electrode by PEC method is new, reliable and unique technique in thin film technology. In order to demonstrate the potential use of electrodeposited CdSe thin films in conversion of light into electrical power and photoactivity of the films deposited on the stainless steel substrate were studied in aqueous electrolyte of 1M polysulphide (NaOH+Na2S+S) solution and shows cathodic behaviour of photovoltage, indicating that the films are of n-type. The optimization of solution concentration and deposition current has done by using photoelectrochemical (PEC) technique as shown in Figures 2 and 3 respectively, where the solution of pH kept constant (3.72). The deposited CdSe thin films were directly used as photoanode and graphite was used as a counter electrode, in an photoelectrochemical cell filled with polysulphide electrolyte to measure the short circuit current (I_{sc}) and open circuit voltage (V_{oc}) for CdSe photoanode. The optimized preparative parameters for CdSe film deposition are listed in TABLE 1. From TABLE, it is concluded that we got better quality film of CdSe at 1 mA deposition current and 0.125 M concentration.

A typical X-ray diffraction pattern recorded on stainless steel substrate for CdSe film deposited at 0.125M at room temperature is shown in Figure 4(a). The XRD data are indexed with the help of JCPDS file. The observed'd' values of CdSe films match with standard 'd' values of CdSe which confirms the formation of CdSe. The observed and standard'd' values are listed in TABLE 2. The reflection planes (002) (110), (201), are corresponding to CdSe polycrystalline with hexagonal crystal structure. Figure 4 (b) shows the variation of crystallite size with deposition current. This shows that initially crystal size decreases with increasing deposition current, attempt minimum value at 1 mA deposition current then further increases with increase in deposition current. The SEM micrographs of the CdSe thin films on stainless steel substrate are shown in Figure 5 for different magnifications. The SEM study clearly shows the CdSe thin film exhibits rough surface with compact, dense and non-uniform heterogeneous growth of grains on stainless steel substrate at room temperature. Which clearly show that the result of growth of CdSe grains. Some pits are also observed with springy grains. Grain size is about 80 nm.

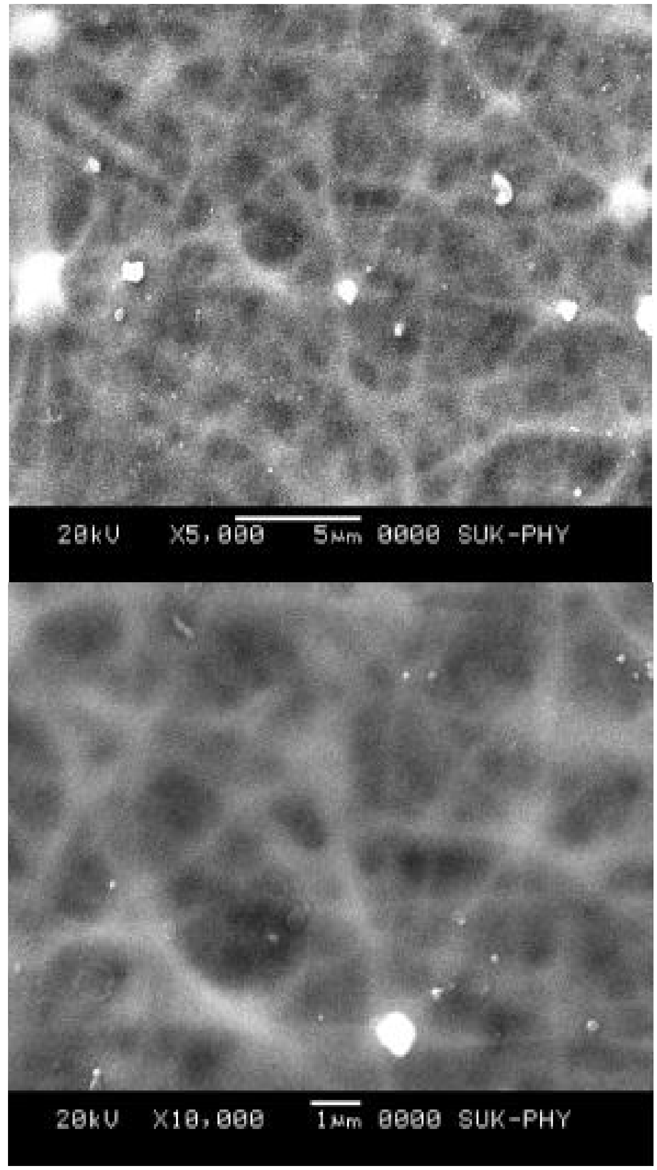

Figure 5 : Scanning Electron Micrographs of CdSe thin film at different magnifications on stainless steel substrate

CONCLUSION

The results of this study clearly demonstrate that the CdSe thin films have been successfully deposited by simple and inexpensive electrodeposition technique and structural, morphological properties and Photoelectrochemical are studied. As deposited CdSe thin films are n-type polycrystalline and photoactive. CdSe photoanode gives a better performance when crystallite size is smallest amount.

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