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Cadmium Selenide thin film by electrochemical deposition

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Abstract

This review provides information of fabrication of thin film solar cell devices based on Cadmium Selenide (CdSe) by electrochemical deposition technique. For industrial scale applications this technique is useful for reducing the fabrication cost. It has potential to prepare large thin films due to cheap raw material source and equipment capital. This article focuses on various approaches in electrochemical deposition, parameters which affects the electrodeposition and the reaction mechanism. This article is helpful for researchers entering the field to understand the basics of CdSe and its application to photovoltaics.

Keywords : Electrochemical deposition, thin films, optical properties.

Introduction

CdSe is a II-VI semiconductor which is used in solar cells fabrication, LEDs, FETs, biosensors, opto-electronic devices and biomedical imaging. It is a n-type material suitable as a buffer, window or absorber layer in thin film solar cells. It has a bandgap of ~ 1.80 eV and ~ 1.71 eV in the wurtzite crystal phase and zinc blende phase respectively. [1]

The CdSe thin film can be prepared by various methods such as thermal evaporation, pulsed laser deposition,[2] electrochemical deposition[3], chemical bath deposition (CBD) and spray pyrolysis[4].

Among this techniques electrodeposition method is suitable because of its low capital cost, control over the film thickness by changing the deposition time and deposition potential. In this method the material properties such as optical, structural, electrical and morphological properties can be control by varying the parameters like growth temperature of the electrolyte, pH, stirring, concentration of the electrolyte, deposition time and post-deposition annealing temperature. The substrate for thin film growth in this method must be conductive. Substrate can be gold [5], indium-doped tin oxide (ITO)-coated glass[6], stainless steel [7], Fluorine-doped Tin Oxide (FTO), nickel [8] and titanium [9]. Table 1 shows the properties of CdSe.

A few works have been completed to-date on electrochemical deposition of CdSe thin films by three-electrode cell from aqueous and non-aqueous solution in either acidic or basic medium.

Experimental details

In electrochemical deposition the movement of metallic ions in solution takes place towards a cathode in presence of an applied electric field. The ions accept the electron and deposited on the cathode in the form of a neutral atom or molecule. Electrodeposition setup is shown in the Fig.1[10]

This reaction occurs in the successive steps such as ionic transport, discharge, breaking of ions legend bond and deposition of atoms onto the substrate. These steps occur within the range of 1-1000 Å from the substrate. Ions are greater than 1000 Å away from the electrode surface. The movements of ions occur under the influence of potential gradient, current density and concentration gradient. The discharged ions

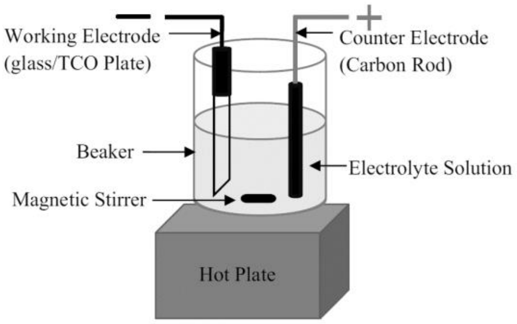

Fig. 1 : Electrodeposition setup for a two electrode system

Table 1 : Properties of CdSe [11]

Sr. No.	Property	Values
1	Melting point	>1541 K
2	Molar mass	191.37 g mol^{-1}
3	Color	Yellow to red (depends on optical band gap & crystal size)
4	Solubility in water	Insoluble
5	Structure	Wurtzite, rock salt and zinc blende
6	Young's modulus:	5.1011 dyn K^{-1}
7	Dielectric constant	10.2
8	Specific heat	0.49 J $g^{-1}K^{-1}$
9	Thermal conductivity at 300 K	0.04 W $cm^{-1}K^{-1}$
10	Electron mobility at 300 K	<650 $cm^2V^{-1}s^{-1}$
11	Max. transmittance (2.5-15m)	71%

approach the electrode leads to the formation of a solid phase of an electrochemical deposited thin film. These atoms deposited either in crystalline phase or disorder amorphous phase.[12]

In this process, grain size and thickness of thin film depends on several factors. The current density controls the rate of deposition of material onto the electrode and temperature of deposition bath controls the crystallite size. The pH of bath play an important role for physical properties of the deposit. [13]

Electrochemical deposition of CdSe in acidic or alkaline bath is as follows :

1. In acidic bath : The deposition potentials for Se and Cd are

   On the anode the electrochemical reaction are as follows:

   $Cd^{2+} + 2e^- \rightarrow Cd$ (-0.403 V) (1)

   $Se^{2-} - 2e^- \rightarrow Se$ (+0.74 V) (2)

   On the cathode the electrochemical reaction are as follows:

   $$SeO_2 + H_2O \rightarrow H_2SeO_3 \quad (3)$$

   $$Cd^{2+} + H_2SeO_3 + 4H^+ + 6e^- \rightarrow CdSe + 3\,H_2O \quad (4)$$

2. Alkaline bath:CdSe thin films can be synthesized by electrodeposition from the cadmium-ethylenediaminetetraacetic acid EDTA complex, and selenosulfate from alkaline bath, which can be described by the following reactions:

$SeSO_3{}^{2-} + 2e^- \rightarrow Se^- + SO_3{}^{2-}$ (5)

$(NH_4)_2\,Cd(EDTA) + (NH_4)_2SeSO_3 + 2e^- \rightarrow CdSe + (NH_4)_2\,(EDTA)^{2-} + (NH_4)_2SO_3$ (6)

[14]

Thin Film Characterization

- UV – visible spectrophotometer is used to determine the optical band gap energy of CdSe nanoparticles
- Cyclic voltammetry is employed to investigate the electrochemical behaviour of CdSe nanoparticles.
- Crystal structure, crystallite size and phase purity of CdSe nanoparticle are determine by XRD.
- SEM is used to find the surface morphology of CdSe nanoparticles.
- Raman spectroscopy is another technique that can be used in determining the crystallinity of CdSe nanoparticles.

Conclusion

In this article, the synthesis of CdSe thin film has been thoroughly discussed. The electrochemical deposition technique is inexpensive and convenient for large scale solar cell manufacturing process. Various characterization instruments can be employed to confirm the physical, electrical and optical properties of CdSe nanoparticles.

We can also conclude that properties of CdSe thin film in alkaline bath are inferior in comparison with the CdSe thin film deposited in acidic bath.

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