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Room temperature electrodeposition of CdTe thin films in acidic aqueous medium

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Abstract

Electrodeposition is a low cost alternative and a very important technique to deposit either metals or semiconductors. This method allows the deposition of required quality thin film or coating over any conducting substrate with precise control over the deposition parameters. In this paper, efforts have been made to fabricate CdTe thin films from aqueous electrolytic bath at room temperature. To do this, cyclic voltammetric study of each component was carried out and the potential was selected which can lead to the deposition of CdTe films without the external thermal energy in form of increased bath temperature. It will be shown that the growth of this compound semiconductor is possible by combining under and over potential deposition techniques for two individual species. The surface morphology of the films was imagined by using scanning electron and atomic force microscopy. The optical study of the films was done by using spectrophotometer in the wavelength range of 200-1000 nm.

Introduction

Over the years the demand for materials with superior magnetic, electronic or opto-electronic properties has been increased. One of the main criteria in designing or developing any new material or composites is to look at its final cost. In this regard, many low cost techniques have been approached which not only provide financial edge to the developed materials but also add exciting new features which can help them to be readily accepted amongst the wide community of researchers.The list of such low cost techniques contains dip-coating, spin-coating, doctor blade, chemical bath deposition and electrodeposition (ED) methods [1-5]. As it can be seen that all these techniques are wet-chemical routes and hence sometimes can be regarded as dirty or hazardous environment. Amongst these listed techniques, ED method provides relatively superior control over the deposition conditions [6]. One can easily control the thickness, stoichiometry and adhesively of the film by carefully selecting the applied potential.

ED is a three electrode technique in which, working electrode (WE), counter electrode (CE) and reference electrode (RE) are used to govern the chemical reactions inside the electrolytic bath. A variety of materials can be deposited by using this simple and effective technique. Researchers have successfully deposited metal, semiconductor and alloys by using this route [7]. As it is known that the demand of

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photoelectric and photovoltaics materials is increasing day by day, we opted for the fabrication of CdTe from this route. CdTe is a direct band gap material and this gap is ideal to absorb nearly 99% of incoming photon radiation. Moreover, high bond energy of this compound makes it suitable for the space solar cell applications [8]. One of the most important parameters which affect the electrical and optical properties of CdTe films is its stoichiometry. In general, Te-rich CdTe thin films are preferred because of its p-type conductivity and ease of external contact fabrication.

In this study, we have tried to deposit stoichiometric CdTe thin films from highly acidic aqueous medium. The cyclic voltammetric study is carried out in detail to claim the potential of perfect stoichiometry (PPS) for aqueous medium. We will show that the combination of under potential deposition (UPD) and over potential deposition (OPD) is necessary to grow required quality CdTe thin films. Usually, higher temperature of either 80 or 90 ^{o}C [9] is applied to achieve the good quality of the film, however, this high temperature creates hazardous environment especially with cadmium in the bath. Hence this study is an effort to achieve the same quality CdTe films at room temperature.

Experimental

All the chemicals were purchased from Sigma Eldritch and were used without further purification. Cadmium sulphate ($CdSO_4$. $8H_2O$) was used as a cadmium precursor and Tellurium dioxide (TeO_2) was used as a tellurium source. Concentrated (35%) solution of HCl was used to adjust the pH of the solution. The F:SnO_2 glass (FTO)with area 0.5 cm^2 was used as WE and CE was platinum mesh of the area 4 cm^2. The potentials mentioned throughout the manuscript are vs. Ag/AgCl standard reference electrode. The study was carried out at room temperature (25±2^{o}C). The surfaces of grown CdTe thin films were characterized by using scanning electron microscopy (SEM) and Atomic force microscopy (AFM) tools. The band gap of CdTe thin film was roughly obtained byabsorbance data measured by using spectrophotometer.

Results and Discussion

Cyclic Voltammetric Study: The cyclic voltammetric study is the first step to carrying out any electrodeposition experiment. This analysis gives a best idea about the suitable potential which needs to be applied to deposit the thin films on substrates. The Cyclic Voltammogram (CV) for FTO in 0.2 M $CdSO_4.8H_2O$ solution is shown in Fig.1. The CV of cadmium system is straightforward and a single cathodic peak was observed at -0.5 V vs. Ag/AgCl. Moreover, a closed loop at extreme negative potential confirms the 3-dimensional nucleation and growth of cadmium species on FTO electrode. During the anodic scan, one can notice one broad dip almost at -0.6 V and a small dip at +0.55 V. The broad dip can

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be assigned to the dissolution of loosely attached Cadmium species in the solution and a small dip denotes the stripping out of well deposited cadmium layer. Hence, for ED of cadmium from aqueous medium, one needs to apply -0.5 V vs. Ag/AgCl. The CV of 0.05 M TeO_2 at FTO electrode in acidic aqueous solution is shown in Fig.2.It can be seen that the CV for tellurium system is of complex nature compared to cadmium one. A coupled peak and dip at -0.25 V can be observed along with the broad dip at +0.5 V. The simple meaning of the coupled peak is that the deposition of tellurium under layer and dissolution of tellurium species take place at the same potential. The broad dip at +0.5 V shows the dissolution of well-deposited tellurium under layer. This analysis gives an overall idea about the growth processes that will occur as and when a selected constant potential is applied. One also can get hint that the tellurium deposition will start from lower negative potential and cadmium requires litter more negative potential. To deposit these species together as CdTe, one needs to apply the potential which will favor the kinetics of both the species. Hence, in this study a constant potential of -0.4 V was applied which is overpotential for tellurium growth and under potential for cadmium growth.

MorphologicalStudies: The SEM micrographs of CdTe thin film deposited at -0.4 V vs. Ag/AgCl is shown in Fig. 3. It can be seen that the film grows via granular structures of CdTe crystals and the overall film is compact in nature. However, tiny pinholes were visible and they contribute to the roughness of the film. The overall roughness of 200 nm was observed from AFM analysis as shown in Fig. 4.

Optical Studies: The absorbance data of CdTe thin film were recorded to determine the band gap of the film. The Absorbance data of CdTe film is presented in Fig. 5. It can be observed that the films start absorbing sharp at 1.3 eV. The standard band gap of CdTe is 1.45 eV, however, Cd or Te rich films can offer different band gaps. It can be seen from the figure that CdTe films absorb from NIR to UV-region and hence these films can find suitable applications in photoelectric devices.

Conclusion

In conclusion, a facile and low cost route of room temperature electrodeposition was explored to deposit CdTe thin films from aqueous electrolytic bath. The cyclic voltammetric study revealed that the co-deposition of Cd and Te is possible by using UPD and OPD approaches. The selected potential of -0.4 V

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was found to be suitable to satisfy this approach and to deposit compact and photoactive CdTe thin films. The surface analysis study showed that the granular CdTe films can be deposited via this route with an average roughness of 200 nm. The band gap of CdTe film was found to be around 1.3 eV which suggests either Cd or Te-rich film formation. This is a preliminary study and hence improvements can be done by changing the applied potential, bath temperature and post treatments to fabricate the photoelectric devices out of these films.

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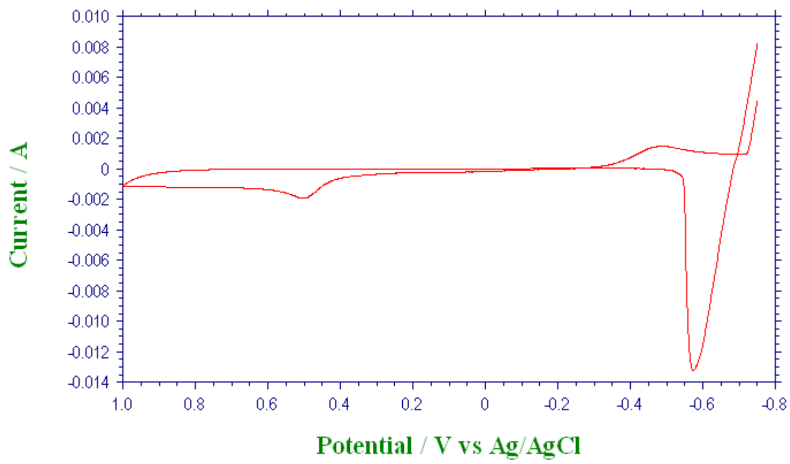

Figure 1 Cyclic Voltammogram of 0.2 M $CdSO_4.8H_2O$ in aqueous medium at room temperature. Sweep rate= 50 mV/sec

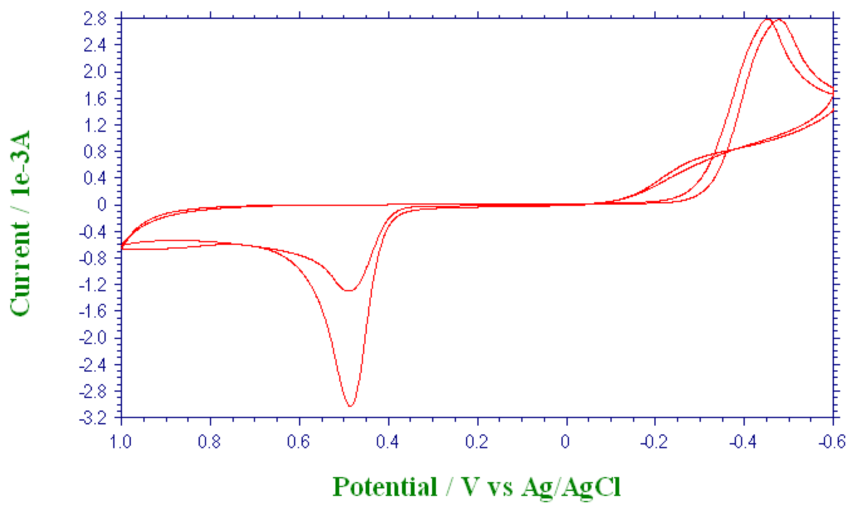

Figure 2 Cyclic Voltammogram of 0.05M TeO_2 in acidic aqueous medium at room temperature. Sweep rate= 50 mV/sec

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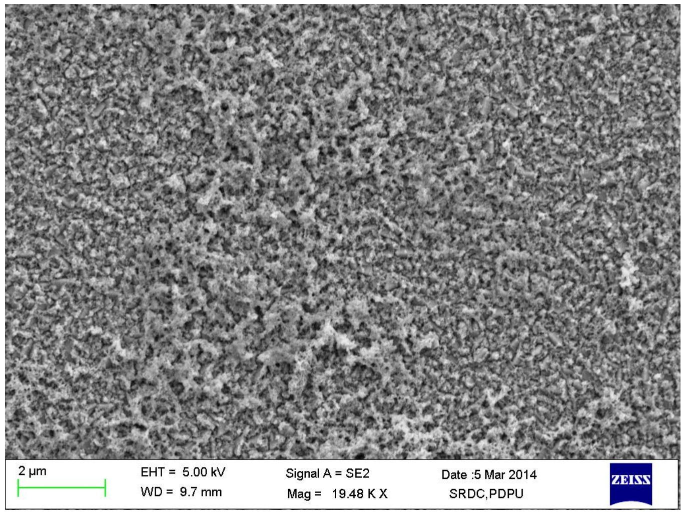

Figure 3 SEM micrograph of CdTe thin film deposited at -0.4 V vs. Ag/AgCl

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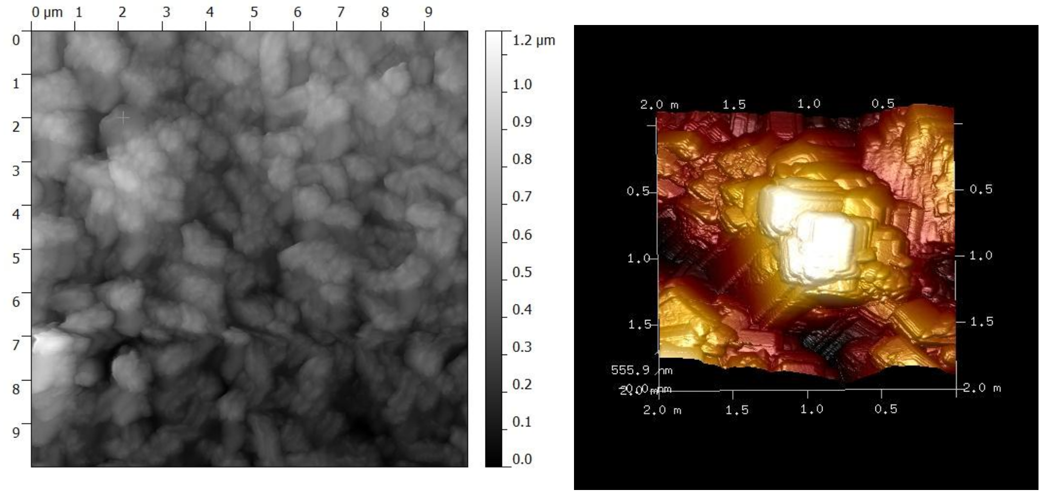

Figure 4 AFM analysis of CdTe thin films; Surface topography (on left) and roughness analysis (on right)

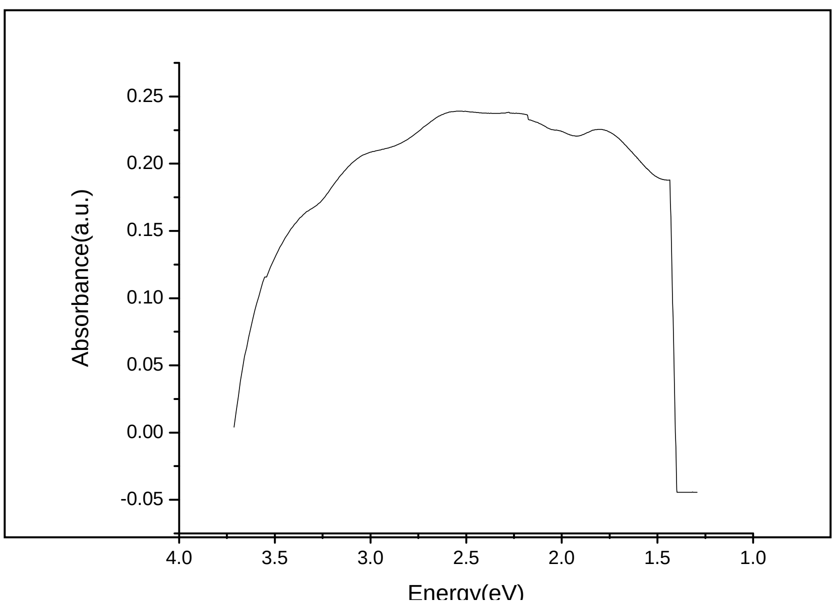

Figure 5 Absorbance spectra for the Electrodeposited CdTe thin film