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Substrate Temperature Dependent Properties of Spray Deposited CdTe Thin Films

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ABSTRACT

Semiconducting CdTe thin films have been deposited on amorphous glass substrate using a spray pyrolysis technique. The preparative parameters have been optimized to obtain good quality and stoichiometric thin films. Binary chalcogenides with appropriate bandgap energy have been attracting a great deal of attention because of their potential applications in photovoltaics. CdTe in the form of thin films is prepared at different substrate temperatures by a simple and economical spray pyrolysis technique. The photoelectromical characterization shows that both short-circuit current (Isc) and open-circuit voltage (Voc) are at their optimum values at the optimized substrate temperature of 250^{0}C. The SEM studies reveal the compact morphology with large number of grains.

Keywords: Spray pyrolysis, Cd chalcogenides thin films, PEC Cell, SEM.

INTRODUCTION

Cadmium telluride is a one of the II-VI compound semiconductor and is a potential candidate as a photovoltaic material because of its optimum band gap of (~1.5 eV) and high absorption coefficient in the visible region [1-2]. It has many applications such as photovoltaic cells, laser window, p-n diode, Gamma ray detector etc. [2-5]. The deposition of II-VI semiconductor sulphides and selenides by spray pyrolysis was first investigated by Chamberlin and Skarman [6] and that of cadmium telluride films by Boone et al. [7] and Jordan et al. [8].

Rastogy and Balkrishnan [9] studied electrodeposited CdTe films for their growth structure and composition. R.F. sputtered n-CdTe film has been used to fabricate Schottky barrier junction with Ag metal [10]. K. Vamshi et al. [11] have reported the effect of electric field on CdTe thin films deposited using spray pyrolysis. The chemical spray pyrolysis is a technique for depositing polycrystalline films of oxides, binary and ternary chalcogenides, and superconducting oxide thin films [12]. The II-VI compound semiconductors of the type AX (A= Cd, Zn, Pb etc. and X= S, Se, Te etc.) have widely been studied [13-16]. The properties of Cd-chalcogenide thin films have been studied by other investigators [17-26,30-36].

The present study deals with the preparation of CdTe thin films at various substrate temperatures on preheated glass substrates by a simple and low-cost spray pyrolysis technique. The films have been characterized by photoelectrochemical (PEC), scanning electron microscopy (SEM).

METHODOLOGY

1 Preparation of CdTe thin films

The thin films CdTe were deposited onto a bare glass and the fluorine doped tin oxide (FTO) coated glass substrates at different substrate temperatures. The precursor solution to be sprayed was prepared by appropriate volumetric proportion of aqueous cadmium chloride ($CdCl_2$) and Tellurium dioxide (TeO_2) dissolved in hydrazine hydride, NH_4OH and HCl being used to form clear spraying solution with optimized pH value. Hydrazine hydride served as a reducing agent to obtain Te^{2-} ions [27]. The pH, concentration and the spray rate of the precursor solution were optimized to be 10.5, 0.01 M and 1.5 ml min^{-1} respectively. The films were deposited at various substrate temperatures from 225 to 300°C at the interval of 25°C in order to obtain good quality, stoichiometric and uniform CdTe thin films.

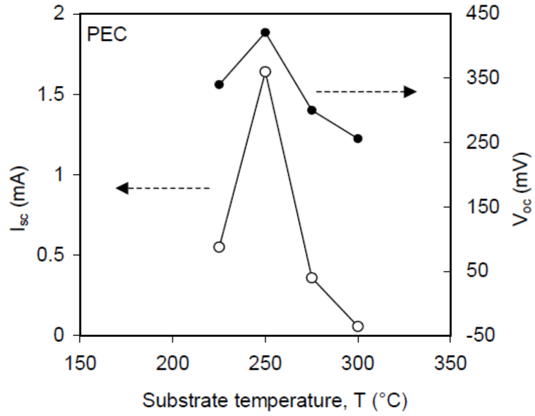
2 Characterization

The PEC cell consisted of CdTe thin film as an active photoelectrode, polysulphide solution (1 M NaOH + 1 M Na_2S + 1 M S) as an electrolyte and graphite as a counter electrode. The short circuit current (Isc) and open circuit voltage (Voc) were measured with respect to the substrate temperature for optimizing the preparative parameters. The surface morphology of the spray-deposited CdTe thin films on glass substrate was carried by SEM model Cambridge Stereos can 250-MK3 assembly and model XL-30 in series with 4000 X magnification.

RESULTS AND DISCUSSION

1 Deposition of CdTe thin films and effect of substrate temperature on the film formation

TeO_2 was added to a solution of ammonium hydroxide (NH_4OH), which was used as a solvent. TeO_2 takes few hours for complete dissolution. Hydrazine hydrate ($N_2H_4.H_2O$) acts as a reducing agent for Te^{4+} ions and supplies six electrons to convert Te^{4+} to Te^{2-}. Dilute HCl was also added at this stage, which shifts chemical equilibrium in the appropriate direction, thereby avoiding the precipitate formation at a later stage. Solution thus prepared was mixed with aqueous solution of CdTe, which resulted in a slightly milky solution. Furthermore, the pH was well below the desired value required for preparing stoichiometric thin films. Hence the pH was increased by adding few more drops of NH_4OH. Then this clear solution was used as the precursor. The solution was immediately sprayed onto the preheated glass substrates before formation of precipitate. In the spray pyrolysis technique, the clear precursor solution of CdTe was sprayed onto the preheated hot glass substrates, pyrolytic decomposition of solution occurs thereby resulting in well-adherent pale brown CdTe thin films. Every sprayed droplet reaching the surface of the hot substrate undergoes pyrolytic decomposition and breaks into its constituent components. The solvent and other volatile components get evaporate in the form of vapors and the only desired compound containing the required chemical species deposits on the surface of substrate in thin film form. The depositions of CdTe thin films were carried out at various substrate temperatures in the range 225-300°C using 0.01 M solution. It was observed that the lower sub trate temperatures (<225°C) favor non-uniform and easily detachable film formation. The temperature might be insufficient



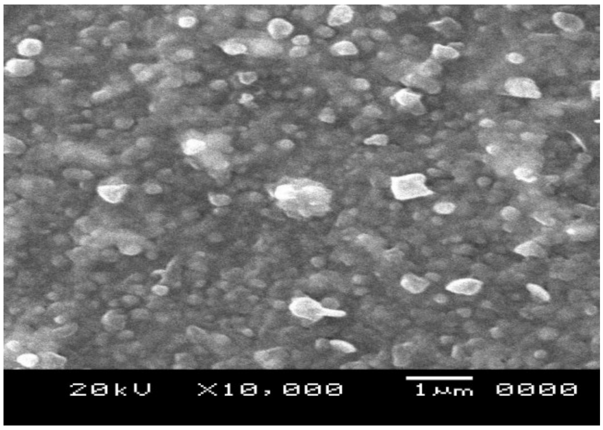


Fig. 1. **Fig. 2.**

Fig. 1. Variation of Isc and Voc with substrate temperature for CdTe thin film based polysulphide PEC solar cell.
Fig. 2. Scanning electron micrographs of spray-deposited CdTe thin films at optimized substrate temperature (T250).

in this case, to decompose the sprayed droplets of the mixed solution. At higher substrate temperatures (>300°C) also the films resulted with non-uniformity and pinholes. This could be due to the higher evaporation rate of the initial ingredients from the surface of the hot substrates. However, the CdTe thin films deposited at intermediate substrate temperatures are uniform and adherent to the glass substrates. The films are faint brown in colour.

2 Photoelectrochemical (PEC) studies

The quantities such as short circuit current (Isc) and open circuit voltage (Voc) of the PEC cell obtained with each CdTe thin film are observed to be comparatively maximum at optimized substrate temperature of 250°C as shown in Fig. 1. The comparatively higher values of Isc and Voc at optimized substrate temperature may be due to the relatively maximum stoichiometry of the compound at that temperature.

3 SEM studies

Fig. 2 shows the surface morphology of the spray-deposited CdTe thin films on glass substrates at optimized substrate temperature of 250°C. The micrograph reveals that the substrate is well covered with large number of densely packed more-or-less spherical grains.

CONCLUSION

The deposition of semiconducting CdTe by spray pyrolysis technique is feasible. The films deposited at optimized substrate temperature 250°C, concentration 0.01 M and exhibiting good photovoltaic activity.

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