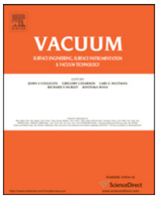
Vacuum 84 (2010) 1216–1219

Contents lists available at ScienceDirect

Vacuum

journal homepage: www.elsevier.com/locate/vacuum



Fabrication and characterization of n-$CdSe_{0.7}Te_{0.3}$/p-$CdSe_{0.15}Te_{0.85}$ solar cell

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PACS:
61.10Nz
68.37.Hk
81.15.Ef
89.30.Cc

Keywords:
Hot wall deposition
$CdSe_xTe_{1-x}$
Solar cell

ABSTRACT

Hot wall deposited $CdSe_xTe_{1-x}$ where $0 \le x \le 1$ thin films for solar cell applications have been prepared from a compound synthesized by direct reaction of high purity Cd, Se and Te elements. Crystal structure and composition of the films were analyzed by X-ray diffraction, scanning electron microscope and EDAX. X-ray diffraction studies carried out on pseudo-binary system revealed that the films are polycrystalline in nature with $CdSe_{0.7}Te_{0.3}$ film exhibiting hexagonal structure and $CdSe_{0.15}Te_{0.85}$ film exhibiting cubic zinc blende structure. The type of conduction was determined by Hall studies. A novel solar cell with structure n-$CdSe_{0.7}Te_{0.3}$/p-$CdSe_{0.15}Te_{0.85}$ has been fabricated and the efficiency was found to be 3.13%.

1. Introduction

The cadmium chalcogenide $CdSe_xTe_{1-x}$ has received much attention as it is used in devices such as solar cells, photoconductors, solar control applications and thin film transistors [1–3 and references therein]. CdSe and CdTe form a solid solution over the entire composition range and the band-gap and lattice parameters can be varied by changing the relative amount of chalcogenides in the compound $CdSe_xTe_{1-x}$. In the case of $CdSe_xTe_{1-x}$, the crystal structure and band-gap can be tailored by changing the concentration of Se and Te, so that the visible solar energy can be suitably harnessed for maximum conversion to electrical energy. $CdSe_xTe_{1-x}$ thin films have been prepared in the past by several techniques such as thermal flash evaporation, electrophoresis, electrodeposition, slurry painting, two source evaporation of CdSe and CdTe, three source elemental evaporation, thermal evaporation and hot wall deposition technique [3–7].

Among the different techniques available for preparation of thin films, hot wall deposition has gained importance recently, because, it is a simple and an economically viable technique and is a technique where deposition takes place under conditions very close to thermodynamical equilibrium. Schikora et al. [8] have claimed that hot wall deposited CdTe films on GaAs substrates show superior luminescence properties when compared to molecular beam epitaxy (MBE) and metal oxide chemical vapour deposited (MOCVD) films. Pal et al. [9] have fabricated ZnTe/CdSe solar cells by the hot wall deposition technique and studied the I-V, C-V characteristics and spectral response. As a continuation of our previous work presented on the synthesis and characterization of $CdSe_xTe_{1-x}$ [10–12], in this paper we present a brief method of preparation of $CdSe_{0.7}Te_{0.3}$ and $CdSe_{0.15}Te_{0.85}$ thin films, their structural properties, fabrication of a n-$CdSe_{0.7}Te_{0.3}$/p-$CdSe_{0.15}Te_{0.85}$ thin film solar cell and its characteristics. The importance of choosing these two compositions is due to the fact that $CdSe_xTe_{1-x}$ shows a sharp transition from the properties of CdSe to those typical of CdTe in the composition region $x \approx 0.3$ or $x < 0.2$ it will be p-type and for $x > 0.2$ it will be n-type. By choosing the same group of elements for any device applications, the junction problems can be avoided effectively. Although, research studies are ongoing on this ternary compound by the authors and various other groups, there is no report available on solar cells fabricated using hot wall deposited $CdSe_xTe_{1-x}$/$CdSe_xTe_{1-x}$ ternary thin films.

2. Experimental technique

Compounds, $CdSe_{0.7}Te_{0.3}$ and $CdSe_{0.15}Te_{0.85}$ have been synthesized by direct reaction of high purity elemental Cd, Se and Te. Stoichiometric amounts of the elements Cd, Se and Te according to the composition are taken in a quartz ampoule, which is evacuated to a vacuum of 10^{-4} m bar and then sealed. The sealed ampoule is heated at a rate of 100 °C per hour up to 1200 K for $CdSe_{0.7}Te_{0.3}$ and 1123 K for $CdSe_{0.15}Te_{0.85}$. The ampoules are maintained at these temperatures for four hours and then cooled slowly to room temperature to avoid thermal cracks in the alloy and in quartz ampoule. During the course of heating and cooling,

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doi:10.1016/j.vacuum.2009.10.028

quartz ampoule is rotated continuously by placing it in a rotating furnace to ensure homogeneity in the molten mixture. Synthesized source materials CdSe$_{0.7}$Te$_{0.3}$ and CdSe$_{0.15}$Te$_{0.85}$ have been used to prepare thin films by the hot wall deposition technique. The detailed deposition technique is already explained in our previous article [13].

The hot wall deposition technique is a low cost, convenient and scalable technique that can be used to deposit films under conditions very close to thermodynamic equilibrium with minimum loss of material. It is one of the methods that has contributed significantly to the preparation of epitaxial films with bulk-like properties [14]. The main feature of the hot wall system is the heated linear quartz tube, which serves to enclose and direct the vapour from the source to the substrate. The hot wall arrangement used in the present study consisted of a quartz tube of length 65 mm and diameter 10 mm with one end open and the other end closed. Kanthal wire was wound closely along the length of the quartz tube, which acts as wall heater. The quartz tube is charged with the prepared CdSe$_x$Te$_{1-x}$ source material. The substrate is held at a distance of less than 1 mm above the open end of quartz tube acting as a "lid" almost closing the tube. The whole arrangement is placed inside a vacuum chamber in which a pressure of 10^{-5} m bar is achieved prior to the deposition. CdSe$_{0.7}$Te$_{0.3}$ thin films have been deposited onto well cleaned glass substrates with wall temperature around 770 K and CdSe$_{0.15}$Te$_{0.85}$ films have been deposited with wall temperature around 665 K. Due to radiation from the hot wall, the substrate temperature automatically raised to 350 K during the deposition of CdSe$_{0.7}$Te$_{0.3}$ and to 342 K during the deposition of CdSe$_{0.15}$Te$_{0.85}$.

The structure of the deposited films was analyzed using an X-ray diffractometer (JOEL8030, Japan) fitted with monochromatic CuKa radiation. Hall effect measurements was carried out by the Van der Pauw's method at room temperature. The Hall coefficient and the carrier concentration were evaluated using the formulae.

$$\text{Hall Coefficient}(R_H) = (V_\text{H} \times t)/(I \times B) \tag{1}$$

Where V$_\text{H}$ is the Hall Voltage, t is the thickness of the film, I is the current and B the magnetic Induction.

$$\text{Carrier concentration}(n) = 1/(R_\text{H} \times e) \tag{2}$$

Where n is carrier concentration and e is the electronic charge.

A solar cell with n-CdSe$_{0.7}$Te$_{0.3}$/p-CdSe$_{0.15}$Te$_{0.85}$ structure was formed on a glass substrate by the hot wall deposition technique. Solar cell characterization was carried out by illuminating the cell with a tungsten lamp. The intensity of light was measured using Suryamapi (Suryamapi is a light intensity measuring equipment calibrated in mW/cm^2, manufactured by CEL, India) and the current and voltage by an optical power meter and a Keithley Electrometer respectively. The fill factor and the efficiency were calculated using the formulae [15].

$$\text{Fill Factor}(FF) = (V_\text{max} \times I_\text{max})/(V_{oc} \times I_{sc}) \tag{3}$$

$$\text{Efficiency}(\eta) = (V_\text{max} \times I_\text{max}) \times 100/(P_\text{in} \times A) \tag{4}$$

P$_\text{in}$ is incident power, A is area of the cell. P$_\text{max}$ = V$_\text{max}$ × I$_\text{max}$ was determined by computing the I-V product at various points along the curve and the point where the product is maximum corresponds to the V$_\text{max}$ and I$_\text{max}$ values. Fill factor gives the squareness of the I-V curve and it indicates the extent of deviation from ideal output. It is well known that the photovoltage versus photocurrent plot is perfectly rectangular in an ideal case. The fill factor also explains how well the junction is formed and, for an ideal cell, the value should lie between 0.6 and 0.8.

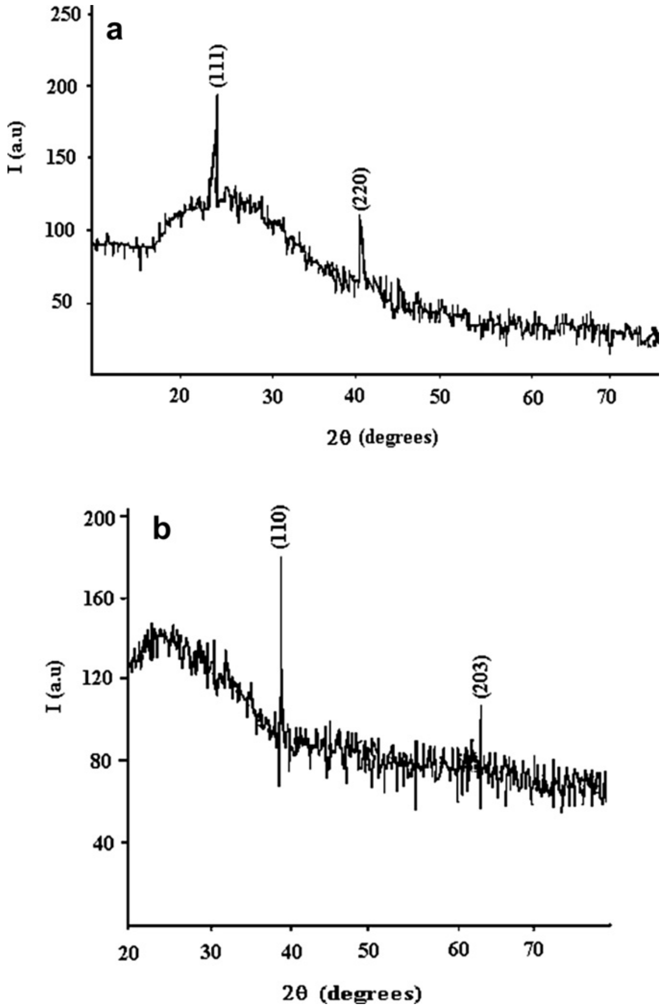

Fig. 1. a) X-ray diffraction pattern of CdSe$_{0.15}$Te$_{0.85}$ thin film of thickness 1455 Å and b) X-ray diffraction pattern of’ CdSe$_{0.7}$Te$_{0.85}$ thin film of thickness 1210 Å.

3. Results and discussion

The X-ray diffraction pattern of CdSe$_{0.15}$Te$_{0.85}$ and CdSe$_{0.7}$Te$_{0.3}$ films shown in Fig. 1 consists of sharp peaks, which indicates that the films are polycrystalline in nature. The CdSe$_{0.15}$Te$_{0.85}$ film is found to exhibit a cubic zinc blende structure with preferred orientation of grains along (111) and (220) directions, but the CdSe$_{0.7}$Te$_{0.3}$ film is seen to crystallize in a hexagonal structure with a preferred orientation along (110) direction. The lattice parameter value ‘a’ of CdSe$_{0.15}$Te$_{0.85}$ film is found to be 6.38 Å, which is in close agreement with ASTM (American Society for Testing and Measurements) data (41-1324 and 41-1325). The lattice parameter values ‘a’ and ‘c’ of the CdSe$_{0.7}$Te$_{0.3}$ thin film are 4.30 Å and 7.08 Å respectively, which are in good agreement with the ASTM data. The grain size, dislocation density and strain of CdSe$_{0.15}$Te$_{0.85}$ and CdSe$_{0.7}$Te$_{0.3}$ thin films have been calculated and are shown in Table 1. The methodology of calculation is fully explained in our previous articles [3,13]. The evaluated values of strain and dislocation density are within the

Table 1
Microstructural parameters.

Composition	Thickness (Å)	Grain size (Å)	Dislocation density (lines/m^2)	Strain
CdSe$_{0.15}$Te$_{0.85}$	1455	105	9.07×10^{15}	12.8×10^{-3}
CdSe$_{0.7}$Te$_{0.3}$	1210	302	1.09×10^{15}	0.967×10^{-3}