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Effect of the zinc composition on the formation of ternary alloy $Cd_{1-x}Zn_xTe$ thin films

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Abstract

Polycrystalline thin films of the alloy $Cd_{1-x}Zn_xTe$ deposited by RF magnetron sputtering technique on corning glass substrate and subsequently annealed in vacuum, were found to be very homogeneous, nearly stoichiometric and single phase but only at low zinc content ($x<0.4$). We will present the effect of Zn composition and post deposition annealing on the alloy formation. It is found that a weak concentration in Zn is more favourable to the formation of the ternary $Cd_{1-x}Zn_xTe$. Samples with high Zn contents are found to be more oxidized and impoverished on tellurium after annealing. Correlation with the results obtained from calculations of phase diagram using an associated solution model is carried out.

Keywords: $Cd_{1-x}Zn_xTe$; Thin films; CdTe; ZnTe

1. Introduction

The ternary compounds $Cd_{1-x}Zn_xTe$ (CZT), are II–VI semiconductors which have an interest in many applications because of the tenability of their physical parameters, such as lattice parameter and band gap, with composition x. Those ternary semiconducting alloys

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are used in a variety of solid-state devices; such as solar cells, photo detectors and light-emitting diodes because their corresponding band gap is tenable from 1.49 to 2.26 eV by controlling stoichiometry. In fact p-ZnTe/i-CdTe/n-CdS solar cells were fabricated by different authors [1,2] using sequential metalorganic vapour phase epitaxy of ZnTe and CdTe layers on CdS substrats, and obtained cell efficiencies up to 13%, under air mass one (AM1) illumination. This led to an increasing interest in the development of wide band gap absorbers based on the alloys of ZnTe and CdTe, with a variety of advantageous properties. A 10% efficient top cell based on $Cd_{1-x}Zn_xTe$ with energy gap 1.7 eV and about 80% sub-gap transmission coupled with a 12–15% $CuInS_2$-based bottom cell configuration, can produce a combined cell efficiency of 15–20% [3].

A continuous series of CdTe/ZnTe solid solution can be prepared both in bulk and in thin film forms [4,5] because they display an unlimited solubility in each other. Thin films of $Cd_{1-x}Zn_xTe$ were prepared by a variety of techniques, such as two source vacuum evaporation in coaxial tubes [6] molecular beam epitaxy [7], chemical vapour deposition [8] and two-stage process [9]. All These methods of film preparation have their inherent advantages and disadvantages. All this increasing interest of the use of $Cd_{1-x}Zn_xTe$ alloys, demands an extensive characterization of all physical properties related to the structural as well optical properties relevant for the applications mentioned above. With this idea in mind, in this work, we present a detailed study of the structure of $Cd_{1-x}Zn_xTe$ alloys thin films prepared by sequential RF-sputtering of CdTe and ZnTe layers followed by a post deposition annealing.

2. Experiment

A set of $Cd_{1-x}Zn_xTe$ thin films were prepared in a sputtering system equipped an RF magnetron source from advanced energy products, with a maximum output power of 600 W. We used a CdTe and ZnTe pressed target 99.999 at% purity (Cerac). As working gases, we used Ar 99.999 at%. Films were deposited on corning glass, degreased and ultrasonically cleaned.

The glass substrates were maintained at ambient temperature during the growth, keeping the deposition rate of CdTe constant at 250 Å/min. The rate of deposition of ZnTe was varied to obtain films of different compositions. Film deposition was performed after a system base pressure of 3×10^{-6} Torr was reached. The total working gas pressure in the vacuum chamber was 2×10^{-2} Torr. Before deposition, the targets were pre-sputtered for 15 min. The films were subsequently annealed at 300 °C for 2 h and then at 350 °C for 30 min.

X-ray photoelectron spectroscopy (XPS) analyses were performed with a Leybold Heraeus LHS. The samples were excited with 1253.6 eV energy MgK X-ray line and a spectrometer pass energy of 50 eV. The crystallographic structure of the samples was studied by X-ray diffraction (XRD) by means of a Siemens D 5000 system with CuKα radiation.

3. Results and discussion

The surface morphology of the CZT layers is shown by the scanning electron microscopy (SEM) images reported in Fig. 1. The $Cd_{1-x}Zn_xTe$ thin films grown on glass substrates have good morphology and adhered well to the substrate surface. Particularly,