Materials Science in Semiconductor Processing 37 (2015) 93–98

Contents lists available at ScienceDirect

Materials Science in Semiconductor Processing

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

Cadmium(1 − x)zinc(x)telluride thin films deposited by sequential pulsed laser deposition

N. Hernandez-Como [a,*], J. Elizalde [b,1], I. Mejia [c,2], M.A. Quevedo-Lopez [c,2]

[a] Centro de Nanociencias y Micro y Nanotecnologías, Instituto Politécnico Nacional, Av. Luis Enrique Erro S/N, Unidad Profesional Adolfo López Mateos, Zacatenco, Delegación Gustavo A. Madero, México, Distrito Federal C.P. 07738, Mexico
[b] Centro de Investigación en Materiales Avanzados, Unidad Chihuahua, Ave. Miguel de Cervantes 120, Complejo Industrial Chihuahua, Chihuahua, Chihuahua C.P. 31109, Mexico
[c] Department of Materials Science and Engineering, University of Texas at Dallas, 800 West Campbell Road, Richardson, TX 75080, USA

ARTICLE INFO

Available online 23 February 2015

Keywords:
Cadmium telluride
Zinc telluride
Pulsed laser deposition.

ABSTRACT

In this work, sequential pulsed laser deposition was used for the deposition of cadmium zinc telluride (CZT) thin films. CZT is a ternary II–VI compound semiconductor with a tunable band gap between 1.51 and 2.26 eV. In this work, three different CZT film compositions were achieved at room temperature by sequential deposition of nanometric layers with a precise number of laser shots on the cadmium telluride (CdTe) and zinc telluride (ZnTe) targets. XPS, XRD and UV–vis transmittance techniques were used to characterize the CZT films. The atomic content of zinc ranged from 60% down to 13%. This represents an enlargement of the lattice constant from 6.19 to 6.41 Å, and a band gap decrement from 1.94 to 1.55 eV. In addition, the CZT film resistivity can be modulated between the CdTe (4.1×10^7 Ω-cm) and ZnTe (2.8×10^5 Ω-cm) values. Our results demonstrated that the sequential pulsed laser deposition can be used to obtain several CZT film compositions with precise control of its stoichiometry and can be extended to the production of other ternary compounds.

1. Introduction

Cadmium zinc telluride ($Cd_{1-x}Zn_xTe$ or CZT) has been used as a gamma ray, neutron and X-ray detectors [1], as well as for graded band gap solar cells [2]. For such applications, a thick CZT film (> 1 μm) is required to absorb most of the incoming photons. Nowadays, the research of Cd and Te-free thin film solar cells has gained attention, leaving CZT based solar cells out of the picture [3]. As a thin film (< 100 nm), CZT can still be used for the fabrication of electronic devices such as: diodes and thin film transistors (TFTs). In thin film electronics, there is still a quest for a reliable p-type material towards the fabrication of complementary metal-oxide-semiconductor (CMOS) devices. Recently, p-channel TFTs based on zinc telluride (ZnTe) thin films have been demonstrated [4,5]. This achievement place the ZnTe as an emerging candidate for the fabrication of p-channel TFTs, similar to tin oxide (SnO) and copper oxide (Cu_2O) [6]. Because CZT can vary its optical and electrical properties between cadmium telluride (CdTe) and ZnTe, it can also be applied to the fabrication of TFTs, heterojunction diodes and photodiodes.

In this work, pulsed laser deposition (PLD) is used to obtain CZT films with different film compositions. A novel approach to obtain a ternary compound from two targets

* Corresponding author. Tel.: +52 55 5729 6000x57516.
E-mail addresses: nohernandezc@ipn.mx (N. Hernandez-Como), jose.elizalde87@gmail.com (J. Elizalde), jim081000@utdallas.edu (I. Mejia), mquevedo@utdallas.edu (M.A. Quevedo-Lopez).
[1] Tel.: +52 614 439 1100.
[2] Tel: +1 972 883 5714.

http://dx.doi.org/10.1016/j.mssp.2015.02.012
1369-8001/

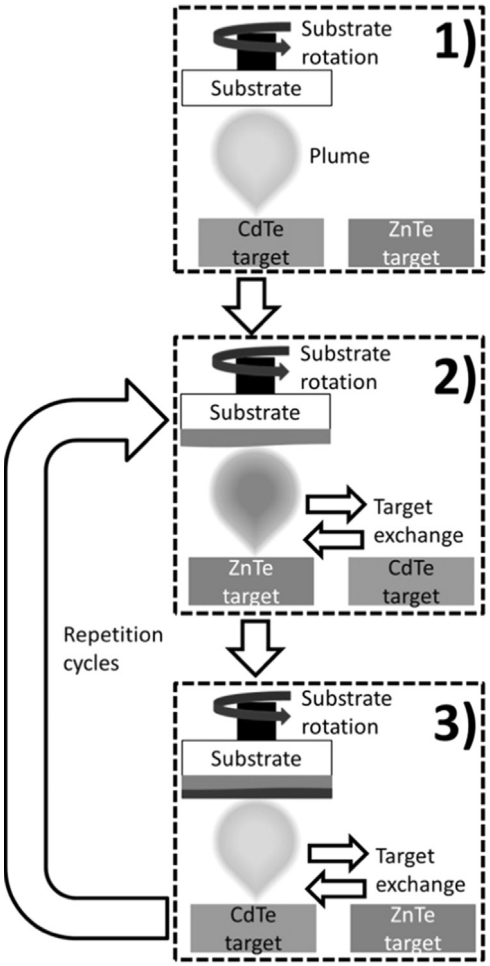

Fig. 1. Sequential pulsed laser deposition: 1) CdTe target ablation, 2) ZnTe target ablation and 3) CdTe target ablation and repetition of step 2 and 3 for a certain number of cycles.

Table 1
Number of laser shots and cycles used to deposit CdTe, ZnTe and CZT films.

Sample	No. of shots		Cycles
	CdTe	ZnTe	
CdTe	10,000	–	1
ZnTe	–	10,000	1
CZT-01	90	27	85
CZT-02	90	63	70
CZT-03	27	90	100

is presented. This method overcomes the implication to create each target with the desired composition, which normally produces a different composition in the deposited films [7]. Our results demonstrated that the sequential pulsed laser deposition can be used to obtain several CZT film compositions with precise control of its stoichiometry. The proposed deposition method can be extended to the production of other ternary compounds.

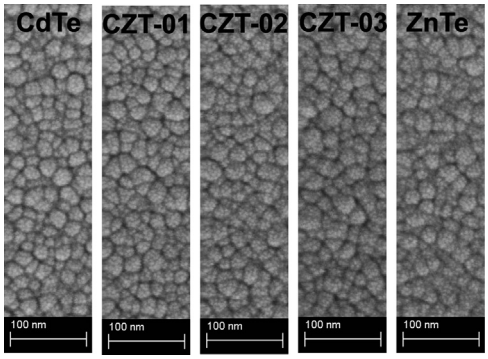

Fig. 2. Morphology of deposited films taken at 500 KX and 15 kV.

2. Experimental details

CZT films were deposited with a Pioneer 180 PLD system manufactured by Neocera Inc. The CdTe and ZnTe targets were purchased from Testbourne Ltd. with a purity of 99.99%. Crystalline silicon wafers (100) with 500 nm of thermally grown SiO_2 and glass slides were used as substrates. Prior to each deposition, substrates were cleaned in acetone, isopropanol and deionized water under sonication and dried in nitrogen. An excimer KrF laser, with a wavelength of 248 nm, and pulse duration of 20 ns was used to ablate the targets. For all the depositions, the laser fluence and frequency were 1.1 J/cm^2 and 6 Hz, respectively. All the depositions were carried out at room temperature. The background pressure was 1×10^{-6} Torr and the deposition pressure was 20 mTorr in argon. Using the three step process as depicted in Fig. 1, CZT films with different compositions were deposited. The objective was to obtain a CZT film by sequentially depositing nanometric layers of CdTe and ZnTe for a certain number of consecutive cycles. With the PLD, the deposition rate of each material can be precisely controlled in the order of angstroms per laser shot. Both CdTe and ZnTe deposition rates were equal to 0.01 nm/shot. CdTe and ZnTe single films were also deposited at the same conditions. In Table 1, the number of laser shots and number of cycles used for each target are presented. According to this table, going from CZT-01 to CZT-03 the amount of Zn should be increased.

The crystal structure was identified using a Rigaku Ultima III X-ray diffractometer with a Cu Kα radiation ($\lambda=0.15406$ nm). A θ–2θ XRD scan was performed for all the measurements with a constant $\omega=1^\circ$ to avoid substrate patterns. The thickness and surface morphology were evaluated with a Zeiss Supra 40 scanning electron microscope (SEM). The root mean square (RMS) roughness of the films was estimated with an atomic force microscope (AFM) Veeco Dimension 5000 SPM. Ultraviolet–visible (UV–vis) transmittance of the films was evaluated using an Agilent 8453 spectrophotometer. The bandgap was calculated by plotting α^2 vs. $h\nu$ (photon energy) and extrapolating the linear portion of the plot to the $h\nu$ axis, as described elsewhere for direct bandgap semiconductors [8]. The absorption coefficient (α) was obtained from the transmittance spectrum. Composition of the CZT films was