Materials Science in Semiconductor Processing 59 (2017) 23–28

Contents lists available at ScienceDirect

Materials Science in Semiconductor Processing

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

CdTe films grown using a rotating sublimate vapor effusion source in glancing angle deposition mode

L.G. Daza[a,*], R. Castro-Rodríguez[a], E.A. Martín-Tovar[a], A. Iribarren[a,b]

[a] Department of Applied Physics, CINVESTAV-IPN, Unidad Mérida, 97310 Mérida, Yucatán, Mexico
[b] Instituto de Ciencia y Tecnología de Materiales, Universidad de La Habana, Zapata y G, Vedado, La Habana 10400, Cuba

ARTICLE INFO

Keywords:
Cadmium telluride
Thin films
Columnar structure
Glancing angle deposition
Structural properties
Surface topographical properties

ABSTRACT

Thin films of CdTe were deposited on glass substrates using a rotating sublimate vapor effusion source combined with glancing angle deposition substrate mode. The samples were prepared with different incident deposition flux angles of α=0°, 40°, 50° and 60° using substrate rotation of 55 rpm in the opposite direction to the source which was in turn rotated at 40 rpm. The Scanning electron and atomic force microscopy images showed that the sample with α=0° and without substrate rotation presented dense columnar structures with variable shapes and dimensions. However, the sample with substrate rotation presented dense coalesced columnar structures with uniform shapes. When the substrate is simultaneously tilted and rotated the columnar forms is more individuality defined. The X-ray diffraction measurements demonstrated that all samples crystallized in the CdTe-cubic phase structure, which exhibits a diffraction peak with full width at half-maximum of the (111) Bragg reflection of 390.4arcsec corresponding to a crystallite size of ~75 nm for the sample with α=50°. The crystallite size decreased as α increased. The apparent absorption edge shifting towards lower wavelength regions for samples grown at α=50° and 60° was attributed to light scattering by the columnar structures. The optical band gap for all samples presented an average value of ~1.5 eV.

1. Introduction

Cadmium telluride (CdTe) is a semiconductor of the II–VI family with a direct band gap of 1.5 eV at room temperature and a large absorption coefficient (10^5 cm^{-1}) [1]. It has attracted a lot of interest because it is a promising thin-film photovoltaic material, due to its high stability, and lower production cost [2–5]. However, one major problem associated with the fabrication of a CdTe solar cell is the difficulty of producing CdTe films with high crystallinity. Polycrystalline CdTe films have been deposited by several techniques including electro-deposition [6], close-spaced sublimation (CSS) [7,8], molecular beam epitaxy [9], thermal evaporation [10] and sputtering [11]. Additionally CdTe nano-arrays have been produced with chemical bath deposition and electrochemical deposition [12,13]. In the CSS method the source and the substrate are separated by small distance in a controlled atmosphere. It is an inexpensive technique for depositing polycrystalline films, this is due to its simple configuration and cheap materials [14] and it also presents a high rate of deposition [15].

Glancing Angle Deposition (GLAD) is a recent and useful technique to grow nanostructured materials at low cost, which consist of tilting the substrate against the vapor flux. Initially, the nuclei are randomly formed on the substrate, and they produce self-shadowed regions where the vapor flux cannot reach the surface of the substrate, which in turn favours the creation of a nano-array pattern. By Controlling the substrate rotation as well as the vapor flux incidence angle, substrate temperature and incidence rate, among other parameters, it is possible to obtain three dimensional nanostructures such as nano columns, Zig-zag, nanohelix, nanosprings and many others [16–18], which enhance the contact area for certain materials. This also produces changes in the optical and structural properties of the deposited materials, that could result beneficial for certain applications such as: optoelectronic and photocatalytic devices [18,19] Furthermore, the aforementioned structures could be integrated into a solar cell, which makes them very attractive for a wide variety of applications [19,20].

In this paper micron thick CdTe films were prepared using the GLAD technique but with a Rotating Sublimate Vapor Effusion (RSVE) source, we report the effects of this deposition method on the morphological, structural and optical properties of the films.

2. Experimental setup

We use a new version of source sublimation in the CSS technique,

* Corresponding author.
E-mail addresses: luisgermandaza13@hotmail.com, luis.daza@mda.cinvestav.mx (L.G. Daza).

http://dx.doi.org/10.1016/j.mssp.2016.09.042
Received 12 July 2016; Received in revised form 15 September 2016; Accepted 30 September 2016

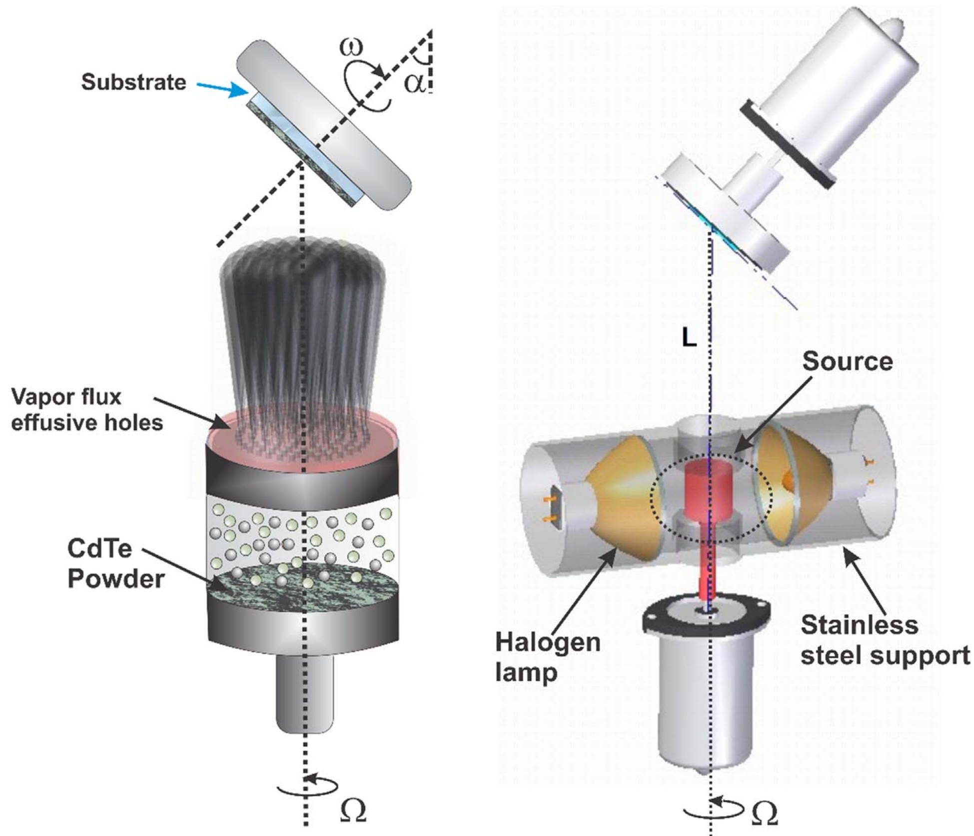

Fig. 1. Experimental setup with GLAD method combined with sublimate vapor effusion source. Side left show the source with the schematic flux of the effusion holes and on the bottom right the schematic setup of the system.

based on a RSVE source, which consisted in a cylindrical graphite container with 85 effusion holes symmetrically distributed at the container cap, each one with a diameter of ~1.5 mm. It can be rotated from Ω=0–100 rpm and placed at a distance range of 2–10 cm from the substrate. The CdTe powder was placed in the container. The pressure within the cavity was close to ~10^5 Pa and it was calculated assuming an ideal gas behavior ($PV=nk_BT$), where V=39.76 cm^3 is the volume of the RSVE container, $T=T_{RSEV}$=973 K, n the numbers of moles and k_B is the Boltzmann constant. The experimental system and source are schematized to left in Fig. 1.

The experiment was carried out in a vacuum chamber evacuated at ~10^{-3} Pa. 0.5 g of a polycrystalline CdTe powder (99.99% pure of SPI supplies) was used as a source material. Corning 2947 glasses were used as substrates, which were cleaned through ultrasonic agitation in acetone, isopropanol, and distilled water. The temperature was kept at 300 and 700 °C for the substrate and source respectively. α is the angle formed between the rotation axes of the substrate and the source respectively as can see in side left of Fig. 1, and ω is the angular rotation speed of the substrate.

The source is heated through radiation emitted by two halogen lamps as shown in right of Fig. 1. The distance (L) between the effusion holes and the substrate was 40 mm. The substrate was rotate at 55 rpm in the opposite direction to the RSVE which in turn was rotated at 40 rpm. A sample was deposited without substrate rotation with α=0° (SA-0) to be compared with the film prepared with substrate rotation and α of 0° (SA-1), which was in turn compared to samples grown at different GLAD angles of 40° (SA-2), 50° (SA-3) and 60° (SA-4). The deposition time was 2.5 min for each sample.

The morphological analysis was studied by atomic force microscopy (AFM) with a Q-Scope 250 of Ambios Technology with Si tips auto probe in the topography contact mode. Field emission scanning electron microscope (FESEM) was employed to obtain morphological and cross-sectional images of the CdTe films employing a JEOL 7600F instrument. The X-ray diffraction (XRD) data was obtained by a D5000 Siemens X-ray Diffractometer with a beam under of $CuK\alpha$ filtered monochromatic radiation (λ=1.5418 Å) by 40 kV with 35 mA and aperture diaphragm of 0.2 mm. The diffractograms were registered in the step scan mode with a beam incidence angle of 1° and recorded in 2θ=0.02° steps with a step time of 10 s in a 2θ range of 15–75°. The Optical measurements were carried out using a UV–vis Agilent 8453 spectrophotometer with a 0.1 nm resolution, in the range of 300–1100 nm. The optical band gaps were calculated only with direct transitions.

3. Results and discusion

Surface and cross section FESEM images of the samples are shown in Fig. 2. The surface SEM image for the sample SA–0 shows a morphology composed of CdTe structures with variable dimensions and shapes. Additionally the corresponding surface SEM image for SA-1 shows that the substrate rotation induces coalescence effects in the CdTe structures, displaying more uniformity in dimensions and shapes. Samples SA-2, SA-3 and SA-4 show that when the GLAD mode when is combined with RSVE source it produces fissures on their surface, and by doing this the structures begins to create separations and voids from each other. The sample SA-4 shows an improvement of the structures mentioned before. From analyzing the surface SEM images we obtained the average dimensions of the CdTe structures (D_{SEM}), which are summarized in Table 1. It was found a D_{SEM} size of ~148 nm for the SA-0 sample and an increasing up to ~193 nm for SA-1. Additionally, we observed a decreasing in the sizes of these surface structures for the films SA-2, SA-3 and SA-4 respectively. From the cross section images it is seen that the GLAD mode combined with RSVE source favours the formation of long and well defined three