Applied Surface Science 255 (2008) 2143–2148

Contents lists available at ScienceDirect

Applied Surface Science

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

Formation of ZnTe by stacked elemental layer method

K.C. Bhahada [a,*], B. Tripathi [a], N.K. Acharya [b], P.K. Kulriya [c], Y.K. Vijay [a]

[a] Department of Physics, University of Rajasthan, 10 Vigyan Bhawan, Jaipur 302 004, India
[b] Applied Physics Department, M.S. University of Baroda, Vadodara 390001, India
[c] Inter University Accelerator Centre, New Delhi 110 067, India

ARTICLE INFO

Article history:
Received 9 March 2008
Received in revised form 1 July 2008
Accepted 1 July 2008
Available online 12 July 2008

PACS:
77.80Bh
72.80Ey
73.20Hb
81.10Fq
77.20+y

Keywords:
Thin film of ZnTe
SHI
XRD
Optical bandgap
AFM

ABSTRACT

Zn–Te bilayer thin films have been deposited on well-cleaned glass substrate using vacuum thermal evaporation technique under a vacuum of 5×10^{-5} Torr. These bilayer films have been modified by Swift heavy ion (SHI) irradiation, vacuum thermal annealing (VTA) and rapid thermal annealing (RTA). Characterization of ZnTe bilayer thin films have been performed by X-ray diffraction, optical reflectance, atomic force microscopy (AFM) and X-ray fluorescence (XRF) measurements. Irradiated ZnTe bilayer thin films have been obtained in cubic phase, Optical band gap values have been found in between the range of ZnTe compound. Increased surface roughness has been observed in irradiated films, compositional analysis has been confirmed by XRF measurements.

1. Introduction

Zinc telluride (ZnTe) is an important semiconductor material for the development of various modern technologies of solid-state devices (blue light emitting diodes, laser diodes, solar cells, microwave devices, etc.) [1,2]. It is a direct band gap semiconductor having band gap 2.26 eV at 300 K and zinc-blende structure with lattice constants of 6.1037 Å [3].

A variety of methods have been developed for the preparation of ZnTe thin films such as physical vapor deposition under vacuum, molecular beam epitaxy, organo-metallic chemical vapor deposition, solution growth, spray pyrolysis, etc. [2,4–6]. The choice of the deposition method may be based on quality of the films required for specific applications.

A well-defined composition of Zn–Te can be formed in thin film form by stacked elemental layer (SEL) [7] deposition and their intermixing. The stacked elemental layer deposition method has been used for CdTe by Curz and de Avillez [7] and copper indium diselenide thin film by Carter et al. [8]. It is particularly suitable for deposition of compound semiconductor thin films, as it provides good control of composition. This method has been used as a promising method for producing highly efficient CdTe/CdS solar cells as reported by Ohshita [9].

Thermal annealing and ion irradiation can perform the mixing of bilayer. Ion beam mixing has been widely used for its several advantages over solid-state reaction such as lower processing temperature and high spatial selectivity. The ion beam mixing (IBM) with high energy swift heavy ions (SHI) in the range of ≥100 MeV can be explained first by Coulomb explosion and the second is by thermal spike model. The mixing in insulator/insulator systems has been explained by the Coulomb explosion model (CSM), where because of the lack of charge carriers; a charge accumulation takes place, which finally explodes causing mixing [10].

In cases of metal/semiconductor systems or metal/metal systems IBM can be explained with thermal spike model (TSM). In thermal spike model (TSM) assumes that the energy deposited initially in the electronic subsystem in 10^{-15} to 10^{-14} s gets subsequently transferred to the atomic subsystem via electron–phonon (e–ph)

* Corresponding author. Tel.: +91 141 2702457; fax: +91 141 2707728.
E-mail address: kcbhahada@gmail.com (K.C. Bhahada).

0169-4332/$ – see front matter. Crown Copyright © 2008 Published by Elsevier B.V. All rights reserved.
doi:10.1016/j.apsusc.2008.07.068

coupling in 10^{-13} to 10^{-12} s, results in a rapid rise in the lattice temperature up to, 10^4 K (thermal spike). The material within a few nanometers from the ion path melts for duration of 10^{-12} to 10^{-11} s. The molten state then quenches at a very fast rate of, 10^{14} K s^{-1}, forming latent tracks and this induces inter-mixing in bilayer or multi-layer systems [10].

The stack elemental layer deposition method in case of Al–Sb films recently used Mangal et al. [11] and suggested that vacuum thermal annealing and rapid thermal annealing can be used for mixing of bilayer and preparation of semiconductors thin films. The isochronal heat treatment of bilayer results in the interdiffusion and reaction between the elements accompanied by consequent nucleation and growth [8].

In this paper, we present the method of preparation of Zn–Te bilayer thin film and characterization by XRD and optical reflection spectra.

2. Experimental details

The bilayer structures of Zn–Te have been prepared by vacuum thermal evaporation at pressure 10^{-5} Torr in HIND HI VACCUM system. The high purity Zn (99.99%) shots (1–2 mm size) and Te (99.99%) granules placed in two different boats in vacuum system. The glass substrate was placed in the substrate holder above the boats carrying the materials. The Zinc layer was first deposited and later tellurium layer deposited to get bilayer of Zn–Te system. In order to get the desired stoichiometry, the thickness of elemental layers must be adjusted; for a ZnTe film, the number of atoms in Zn and Te layers must be identical; this leads to the following relation-ship between thickness of elemental layers: $t_{Te}/t_{Zn} = 2.22$. In present work, three different set of thickness; 500–1110 Å, 1000–2220 Å and 1400–3100 Å of Zn–Te bilayer thin films have been deposited. For mixing of these bilayers three different methods such as vacuum thermal annealing, rapid thermal annealing and SHI irradiation. The vacuum thermal annealing has been performed for one an hour at pressure 10^{-5} Torr for different constant temperature. For vacuum thermal annealing we have placed the radiation heater inside the vacuum chamber and put the sample over it. The radiation heater takes 10 min to raise the temperature from room temperature to 373 K. The sample then annealed at this constant temperature 373 K for one an hour. Similarly these samples were also annealed at 413 K and 443 K for one an hour. The rapid thermal annealing has been performed by 1000 W halogen lamp for 20 s.

Swift heavy ion irradiation was carried out at Inter University Accelerator Center (IUAC), New Delhi using 15 UD Pelletron facilities. Material science beam line was used for irradiation of the samples. The vacuum in the target chamber is generally maintained up to 10^{-6} Torr. The samples have been mounted on the ladder which have four faces and can slide vertically and rotate also (clock and anticlockwise). The samples were irradiated uniformly at room temperature over an area of 1 cm $\times$ 1 cm by scanning the ion beam with electronic magnetic scanner. The Ni^{7+} ion beam of 100 MeV energy with beam current 1.5 pnA at the fluences of 1×10^{12}, 5×10^{12} and 1×10^{13} ions/cm^2 have been used for irradiation. The angle of incident during the irradiation was normal with respect to the sample.

Characterizations of these bilayer thin films have been performed by X-ray diffraction, optical reflectance, atomic force microscopy and X-ray fluorescence (XRF) measurements.

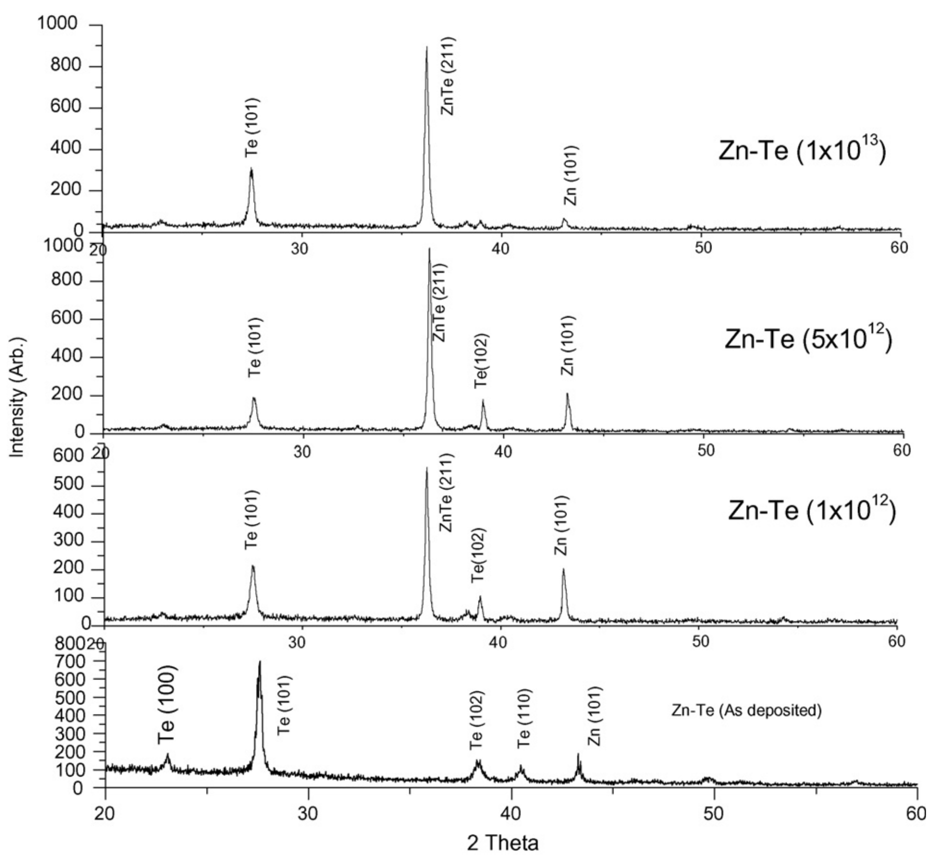

Fig. 1. X-ray diffraction patterns for as deposited and ion irradiated Zn–Te bilayer thin films (1400–3100 Å).