



Studies on vacuum deposited p-ZnTe/n-ZnSe heterojunction diodes

Gowrish K. Rao *, Kasturi V. Bangera, G.K. Shivakumar

Department of Physics, National Institute of Technology Karnataka, Surathkal, Mangalore 575 025, India

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ABSTRACT

p-ZnTe/n-ZnSe heterojunction diodes were prepared by vacuum deposition and a detailed electrical characterization of the heterojunction was performed. The *I*–*V* and *C*–*V* characteristics of the heterojunction diodes were studied to determine the conduction mechanism, barrier height, space charge density and thickness of the depletion region in the heterojunction. The bandgap and activation energies of n-ZnSe and p-ZnTe were also determined and a theoretical band diagram of p-ZnTe/n-ZnSe heterojunction was drawn based on Anderson's model.

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1. Introduction

Zinc Telluride (ZnTe) is a II–VI semiconductor compound which has many attractive potential applications in the field of optoelectronics. ZnTe has a direct bandgap of 2.26 eV [1,2] which falls in the pure green region of the electromagnetic spectra. The direct bandgap of ZnTe makes it a highly suitable material for the fabrication of optoelectronic devices such as green light emitting diodes [3–6], photo-detectors, THz emitters and detectors [3,7]. Since there is only a small valence band offset of 0.1 eV between ZnTe and CdTe, ZnTe can be used as a back contact material to obtain higher efficiency in CdTe based solar cells [8].

Heterostructures involving ZnTe have attracted considerable attention of late. The main focus is on the study of the electrical properties of such heterostructures. Studies are being done on p-ZnTe/n-ZnSe heterostructure with the intention of utilizing them in optoelectronic devices. This kind of heterostructure is known to have high valence band offset which is useful for forming ohmic contacts [9]. Although there are reports on the fabrication of p-ZnTe/n-ZnSe heterostructures, in most of them higher end techniques like epitaxy have been utilized to obtain the heterostructure [10,11]. The present work concentrates on the fabrication of p-ZnTe/n-ZnSe heterostructure by simple and cost effective vacuum evaporation technique and on their detailed electrical characterization.

2. Experimental details

ZnSe and ZnTe films were deposited on well cleaned glass substrates by vacuum evaporation method, inside a 12 in. vacuum chamber (HINDHIVAC 12A4D). 99.99% pure ZnSe and ZnTe ingots (Aldrich) were used as source materials and molybdenum boats were used to evaporate these source materials, by resistive heating. Silver contacts were made, by vacuum evaporation, on both sides of the heterojunction. The depositions were carried out in a residual pressure of about 10^{-5} Torr, at a rate of about 30 nm/min. X-ray diffraction (XRD) patterns of the films were obtained by a Rigaku Miniflex XRD unit. The compositions of the films were determined by JEOL (JSM 5800) energy dispersive analysis (EDS) unit. Keithley Multimeter (2002) and SourceMeter (2400) were used for current and voltage measurements and Wayne Kerr precision component analyser was used for measuring the capacitance.

3. Results and discussion

The electrical properties of vacuum deposited thin films depend heavily on the composition of the films which in turn depends on the deposition parameters. In our previous study [12] it was found that the substrate temperature, maintained at the time of deposition, can vary the composition of the ZnTe films to a large extent. The ZnTe films deposited at the room temperature were rich in Tellurium and those deposited at 553 K were nearly stoichiometric. However all the films were found to be p-type. The variation of composition of the vacuum deposited ZnSe thin films as a function of substrate temperature is given in Table 1.

* Corresponding author.

E-mail address: rgknitk@gmail.com (G.K. Rao).

Table 1

The Zn:Se ratio for ZnSe films deposited at different substrate temperatures.

Substrate temperature (K)	Zn:Se
300	0.89
373	0.95
423	1.00
473	1.07
523	1.13

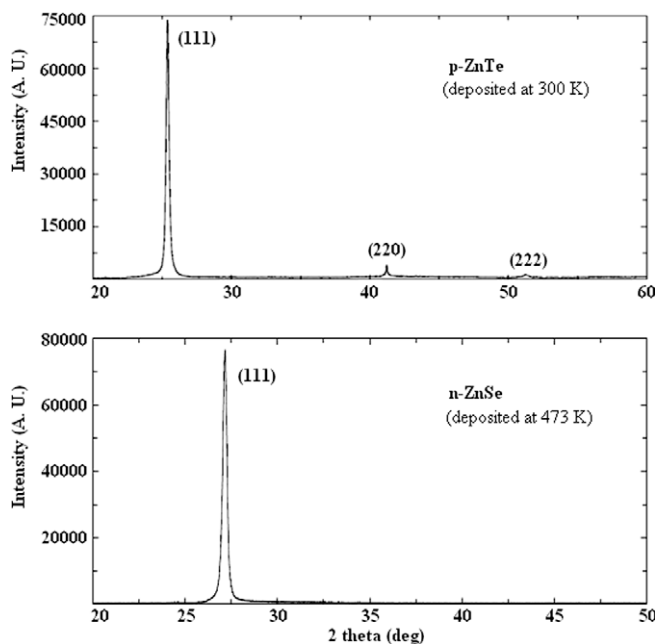
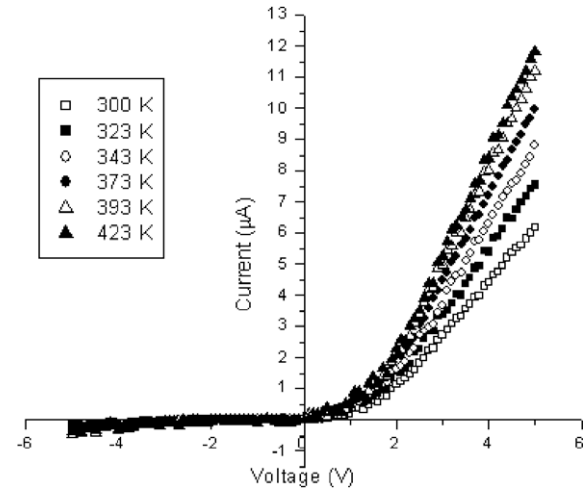
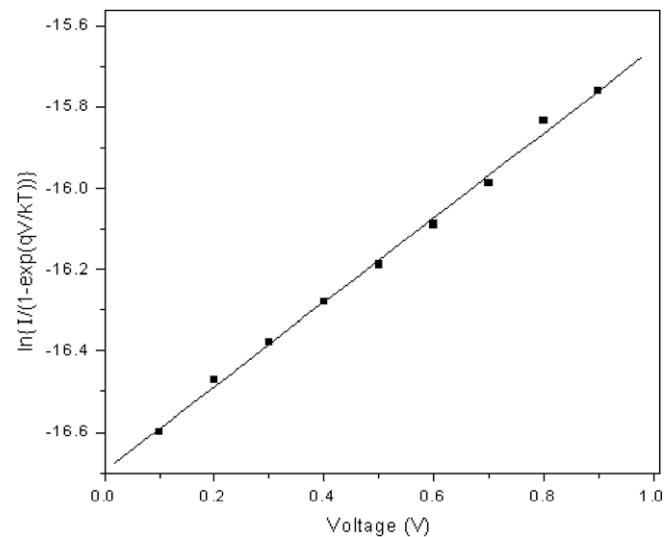
The films deposited at room temperature were rich in Selenium and stoichiometric films were obtained at about 423 K. Good n-type conductivity was observed in ZnSe films deposited at 473 K. Hence all ZnSe films, used for the heterojunction, were prepared at a substrate temperature of about 473 K. The XRD patterns of ZnTe and ZnSe films are shown in Fig. 1. Both the films show cubic structure with a strong (1 1 1) texture.

Fig. 2 shows the I - V curves of p-ZnTe/n-ZnSe heterojunction at different ambient temperatures. The heterojunction shows the rectifying behavior similar to a typical p-n junction diode. The conduction mechanism in a heterojunction diode usually follows the model proposed by Sze and Crowell [13]. According to this model, the conduction occurs mainly due to thermionic emission and carrier diffusion and the forward current varies with the voltage according to the equation,

$$I = I_s \exp\left(\frac{qV}{nkT}\right) \left\{ 1 - \exp\left(\frac{-qV}{kT}\right) \right\} \quad (1)$$

where I_s is the reverse saturation current, k is Boltzmann's constant, n is the diode ideality factor, T is the temperature and q is the elementary charge. In the present case, the variation of $\ln(I/(1 - \exp(-qV/kT)))$ with V , for low forward bias voltages, (Fig. 3) was found to be linear, suggesting that the thermionic emission and carrier diffusion are the dominant conduction mechanisms at low voltages. The diode ideality factor ' n ' was found to be about 2.84.

In the case of thermionic emission, saturation current I_s is given by [14],

**Fig. 1.** The XRD patterns of p-ZnTe (deposited at 300 K) and n-ZnSe (deposited at 473 K) films.**Fig. 2.** The I - V curves of p-ZnTe/n-ZnSe heterojunction diodes at different ambient temperatures.**Fig. 3.** The variation of $\ln\{I/[1 - \exp(-eV/kT)]\}$ with voltage for p-ZnTe/n-ZnSe heterojunction diode.

$$I_s = AA^*T^2 \exp\left(\frac{-\phi_b}{kT}\right) \quad (2)$$

where A is the device area, A^* is the Richardson's constant and ϕ_b is the barrier height. The variation of $\ln(I_s/T^2)$ with $1/T$ was found to be linear for p-ZnTe/n-ZnSe heterojunction as shown in Fig. 4. This observation further indicates that the conduction mechanism operating in the heterojunction is thermionic emission. The barrier height ϕ_b , calculated from the slope of the graph, was found to be 0.73 eV.

For higher forward bias voltages, Eq. (1) can be approximated as,

$$I = I_s \exp\left(\frac{qV}{nkT}\right) \quad (3)$$

In such a case, the graph of $\ln(I)$ vs. V must be linear. However the graph of $\ln(I)$ vs. V drawn for p-ZnTe/n-ZnSe heterojunction was not perfectly linear (Fig. 5) indicating the possibility of a different type of conduction mechanism at higher voltages. A plot of I vs. V^2 , drawn for higher bias voltages (Fig. 6), was found to make a bet-

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