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Fabrication and characterization of thermal evaporated n-Si/ p-ZnTe thin film heterojunction diodes

Gowrish K. Rao [a,*], Kasturi V. Bangera [b], G.K. Shivakumar [b]

[a] Department of Physics, Manipal Institute of Technology, Manipal University, Manipal 576104, India
[b] Thin Film Laboratory, Department of Physics, National Institute of Technology Karnataka, Surathkal, Mangalore 575025, India

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ABSTRACT

The paper reports the fabrication and detailed electrical characterization of thermal evaporated n-Si/p-ZnTe thin film heterojunction diodes. The heterojunction diodes were prepared by depositing ZnTe films on n-Si substrates. The conduction mechanism, barrier height, space charge density and width of the depletion region were determined by I–V and C–V characteristics of the heterojunction diodes. The bandgap and activation energies of n-Si and p-ZnTe were also determined and a theoretical band diagram of n-Si/p-ZnTe heterojunction was drawn based on Anderson's model.

1. Introduction

Zinc Telluride (ZnTe) is a II–VI semiconductor compound with a direct bandgap of 2.26 eV [1,2]. The material also possess relatively high absorption coefficient of the order 10^6 m^{-1} [2]. As both these properties are highly desirable in optoelectronics, ZnTe has been the subject matter of extensive research over the last two decades. Main focus of such investigations has been on the fabrication of green light emitting diodes [3–6], photodetectors, THz emitters and detectors [3,7] etc. The use of ZnTe buffer layers has also been investigated to obtain higher efficiency in CdTe based solar cells [8]. Besides, ZnTe being a wide band gap material can serve as a window layer in tandem solar cells.

In order to fully incorporate ZnTe in optoelectronics, efforts must be made to integrate ZnTe with the silicon based microelectronics. Such efforts would primarily require a rigorous study of ZnTe–Si heterostructure [9]. The present paper reports one such attempt of preparation and characterization of n-Si/p-ZnTe heterojunction.

2. Experimental details

A sandwich type of arrangement shown in Fig. 1 was used for the heterojunction. Silver was used as contact material as it forms good ohmic contacts with both Si and ZnTe [10]. First a silver back-contact was made on phosphorous doped, n-type, Si (100) substrates. ZnTe films were then deposited on the other surface of the Si substrates by vacuum evaporation method and finally another silver contact was made on top of the ZnTe film by vacuum evaporation. High purity (99.99%) ZnTe ingots were used as source for ZnTe films and molybdenum boat was used to evaporate the source material. Depositions were carried out inside a 12 inch vacuum chamber (HINDHIVAC 12A4D) with a residual pressure of about 10^{-5} torr, and at a rate of about 30 nm/min. The thickness of ZnTe films was around 200 nm and the area of the junction region was around 0.2 cm^2. X-ray diffraction (XRD) patterns of the films were obtained by a Rigaku Miniflex XRD 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 XRD pattern of ZnTe film deposited on Si (100) substrate is shown in Fig. 2. The film shows a strong (111) texture, even though the substrate has (100) orientation. Such type of preferred

* Corresponding author. Tel.: +91 0820 2925624; fax: +91 820 2571071.
E-mail address: rgknitk@gmail.com (G.K. Rao).

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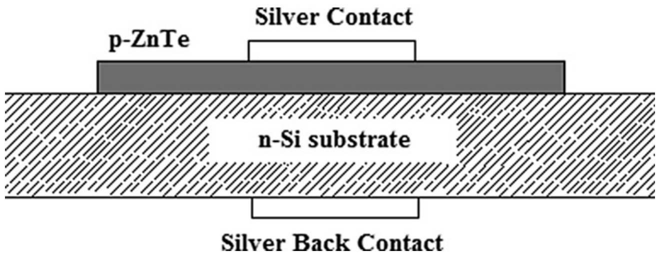

Fig. 1. The schematic diagram of the heterojunction (Not according to scale).

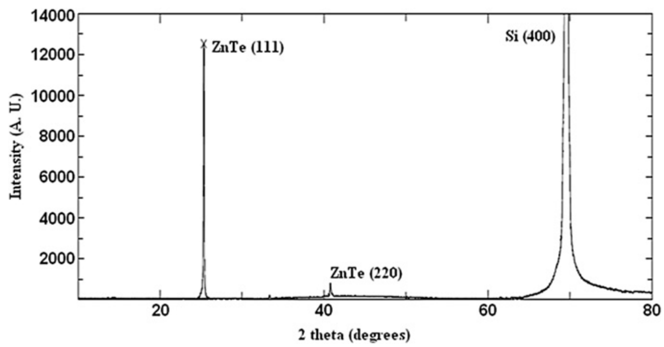

Fig. 2. The XRD pattern of ZnTe film deposited on Si substrate at 300 K.

orientation has been observed even in ZnTe films deposited on amorphous glass substrates and it is mainly due to the iconicity of the bond in ZnTe [10,11]. This indicates that the Si substrate has no effect on the crystal structure of the film. The ZnTe films deposited at room temperature (300 K) were found to be rich in tellurium which makes them p-type [10].

The I–V curves of n-Si/p-ZnTe heterojunction at different ambient temperatures are shown in Fig. 3. The heterojuntion shows the rectifying behaviour similar to a typical p-n junction diode. The conduction mechanism in a heterojunction diode usually follows the model proposed by Sze and Crowell [12]. According to this model, the conduction occurs mainly due to thermionic emission and the forward current varies with the voltage according to the equation,

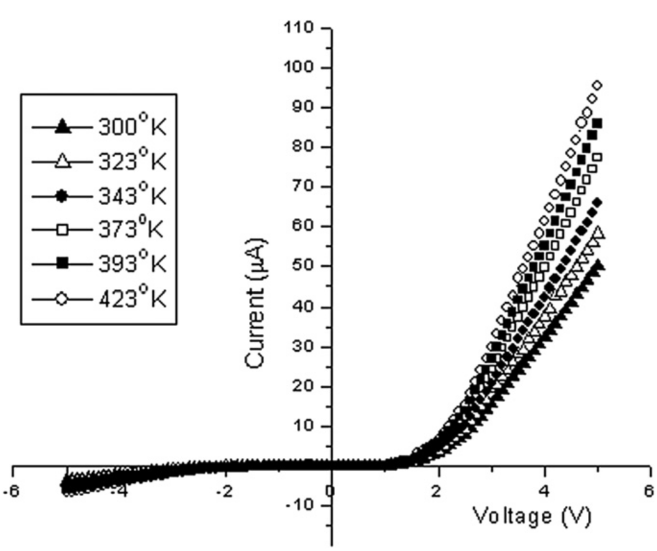

Fig. 3. The I–V curves of n-Si/p-ZnTe heterojunction diodes at different ambient temperatures.

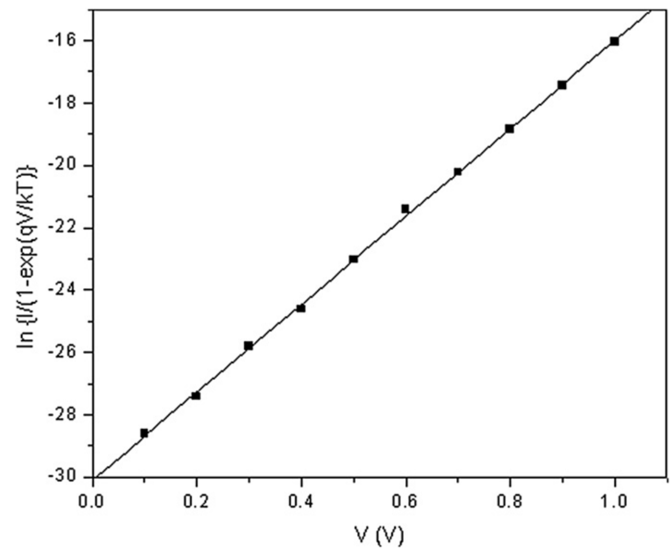

Fig. 4. The variation of ln(I/(1-exp(-eV/kT))) with voltage for n-Si/p-ZnTe heterojunction diode.

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

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 graph of ln(I/(1-exp(-qV/kT))) vs. V, drawn for low forward bias voltages, (Fig. 4) was found to be linear, suggesting that the thermionic emission is the dominant conduction mechanism at low voltages. The diode ideality factor 'n', determined from the slope of the graph, was found to be about 2.63. This means that the junction is non-ideal mainly due to high rate of recombination at the depletion region. Other researchers have also reported this kind of non-ideal behaviour supporting our observation [1]

In the case of thermionic emission, saturation current I_s is given by [13],

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

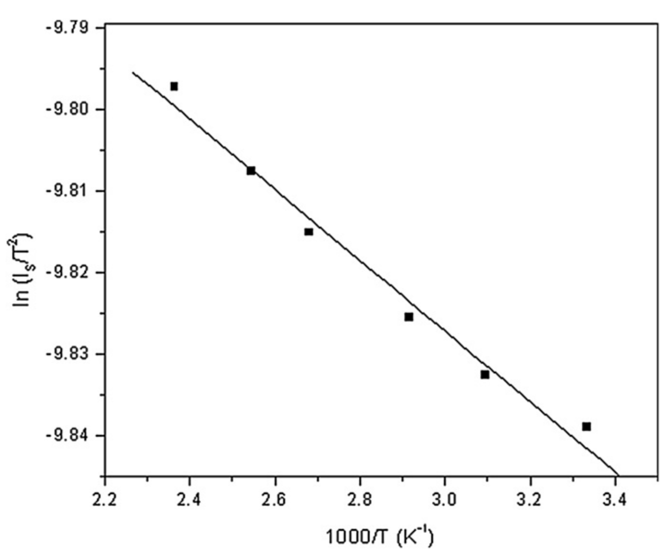

Fig. 5. The variation of ln(I_s/T^2) with $1/T$.