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Electrical Properties of Zn/Te Heterostructure Thin films for Switching Application

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ABSTRACT

A semiconductor made by binary composite is a mixture of two fundamentals as of the periodic table like; Zinc Telluride (ZnTe) is a cluster of II-VI composite semiconductor which is a combination of Zinc (Zn) from Column II and Tellurium (Te) from Column VI. ZnTe is an important semiconductor which shows energy band gap of 2.26eV. It is usually a p-type semiconductor. Zn/Te is promising material for purely green light-emitting diode. Column II-VI of periodic table the semiconductors without difficulty doped by n-type impurities other than resist p-type impurities doping.

Keywords: Thermal evaporation, Vacuum unit, Four point probe method

INTRODUCTION

Mainly outstanding immunity of Zinc telluride is that it can be without difficulty doped by p-type impurities but resist doping of n-type impurities [1]. It is therefore a relatively confront to attain n-type doping of Zinc Telluride. Recent literature shows that success of low resistivity growth (around 0.1-0.3 $\Omega\cdot$cm) n-type Zn/Te layers had been achieve using MOCVD (100) ZnTe by means of the exploit of triethyl aluminium as doping [2]. The results might be cheering in the athe variety of optoelectronic devices base research for ZnTe thin films. The crystal structure of Zinc telluride is cubic like diamond. Zinc telluride is an important semiconductor for growth of various Semiconductor devices as blue LEDs, solar cells, laser diodes, component of microwave generators, Solar cells and PIN diode structures, etc. [1,2]. In present work P-type Zn/Te of different thickness hetero structure has deposited on silicon substrate of N-type which has dimensions of 1×1 cm^2. The p–n junction is structure for generally semiconductor devices which works as a diode and p–n junction hypothesis serve as groundwork of the physics of semiconductor devices [3]. By combination of two p and n junctions with an additional p type semiconductor, it can structure the p–n–p bipolar transistor, which had made-up in 1947 and have an extraordinary bang on electronic industry [4]. The combination of three p–n junctions to shape p–n–p–n arrangement and creates a switching mechanism known as thyristor [2,3].

In current work thin films of P-type Zn/Te of various thickness has deposited on N-type clean silicon substrate with the deposition rate 8 Å/s. The N-type silicon (Si) substrate was cleaned by the Solution of RCA in ratio of 5:1:1 of DI water, Hydrogen peroxide and Ammonium hydroxide to remove ionic, metallic and oxide native particles contamination and rinse the silicon wafer by the DI water and dry in spin rinse dryer [5]. The annealing process was done for enhance the crystallinity and plane morphology of the thin films. So thin films have kept at without annealing, annealing at 200°C and 300°C to examine the effect of recrystallization at a certain temperature. It has experimented with the purpose of decreases in resistivity exponentially as the temperature increases. Electrical properties were measured using four point probes. The distance between object and source at the time of deposition of thin films in vacuum coating was 30 cm [4,5].

EXPERIMENTAL DETAILS

Materials and methods

P-type Tellurium (Te) has been purchase from Koch-Light laboratories, Colebrook Berks England and Zinc (Zn) has been purchase since Sigma Aldrich laboratories. Single

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crystal N-type silicon wafer substrate was Grade prime CZ have diameter 3 inch, thickness was 380+/-25 µmicron, orientation <100>, Resistivity was 1-10 Ω·cm and surface was particular side polished [6].

Synthesis

The Zn/Te heterostructure thin film has deposited by thermal evaporation scheme on correctly clean substrate of silicon with the dimension of 1 × 1 cm^2 to begin with dirt-free the chamber and tungsten boat through acetone [7]. The Zinc (Zn) and tellurium (Te) powder with purity of 99.99% placed in a tungsten boat and start pumping unit and starts create high vacuum in chamber. Subsequent to 10^{-5} mbar vacuum the Te intense obliquely with temporary current gradually to electrodes and Te with different thickness (200 nm, 500 nm, 750 nm and 1000 nm using thickness ratio 1:1) have been deposited on silicon. Thickness of materials on substrate has been controlled by means of crystal monitor ("Hind Hivac" Digital Thickness Monitor Model–DTM–101).

Characterization

Structural characterization has been done through X-ray diffraction unit manufactured by Panalytical (Xpert-Pro) & and electrical properties have been considered by four point probe setup manufactured by OMEGA [2,8]. The outside morphology of films have been analysed through scanning electron microscopy. Mobility is measured by Ecopia HMS-3000 Hall measurement system.

RESULTS AND DISCUSSION

Electrical properties

Zn/Te layers of dissimilar thickness 200 nm, 500 nm, 750 nm and 1000 nm using thickness ratio 1:1 experiential using four point probe method and the energy band gap observed between 2.22 eV to 2.30 eV without annealing. It has been observed that energy band gap decreases as the thickness increases due to the combined effect of the alter in blockade height suitable with change in grain size in thin films and a huge density of dislocation of thickness. Due to the unstructured defects the localize state of valance band is equipped with more electrons, which enlarge the localized states density of band gap and as a result decrease the energy band gap. Without annealing thin films shows the ohmic junction contact at the interface of P-N junction. **Figure 1** shows the important finding of thickness relation with the Energy band gap.

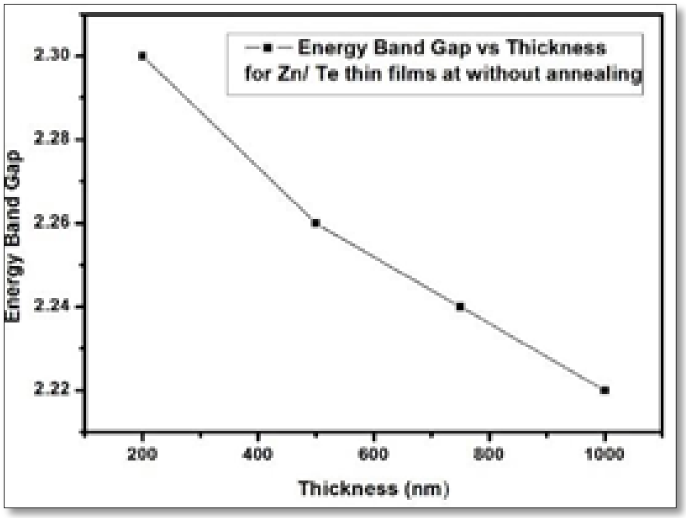

Figure 1. Graph for thicknesses and energy band gap for Zn/Te thin films at without annealing.

After annealing at 200°C and 300°C it is observed that energy band gap increases as the thickness of the thin films increases up to 750 nm. This because of at high temperature communal synthesis of minute grains into bulky grain. So after annealing uniform surface of atoms recrystallize and tellurium partially diffuses into Zinc and make the alloy compound of Zinc Telluride (ZnTe) with junction type Schottky barrier contact. But for the 1000 nm due to the "quantum confinement effect" and higher thickness of the Zn/Te crystal grain particles band gap decreases. "The quantum confinement effect" is experimental that the particle size is excessively little to compare with the electron wavelength. To comprehend the effect the words break as quantum as well as confinement, "confinement" revenue in the direction of confine randomly moving electron motion to restrict its movement in definite energy levels and "quantum" reflect the atomic kingdom of particles. The particle size decreases and reach a Nano scale this reduce the confining dimension make the separate energy levels and this widens up the energy band gap and in the end the band gap energy increase [8,9]. Modify the energy band gap due to the structural muddle otherwise defect at grain boundaries. **Figures 2 and 3** shows the effect of annealing on Zn/Te heterostructure on silicon (Si) substrate.

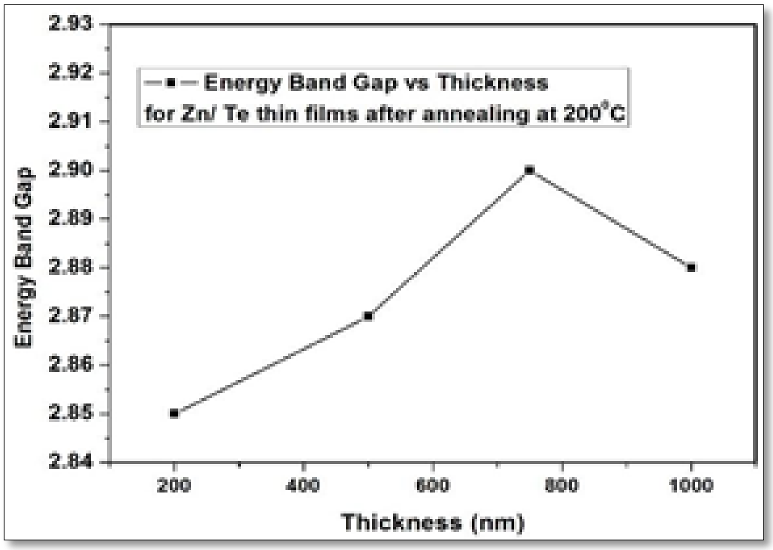

Figure 2. Graph between thicknesses vs. energy band gap of Zn/Te thin films annealed at 200°C.

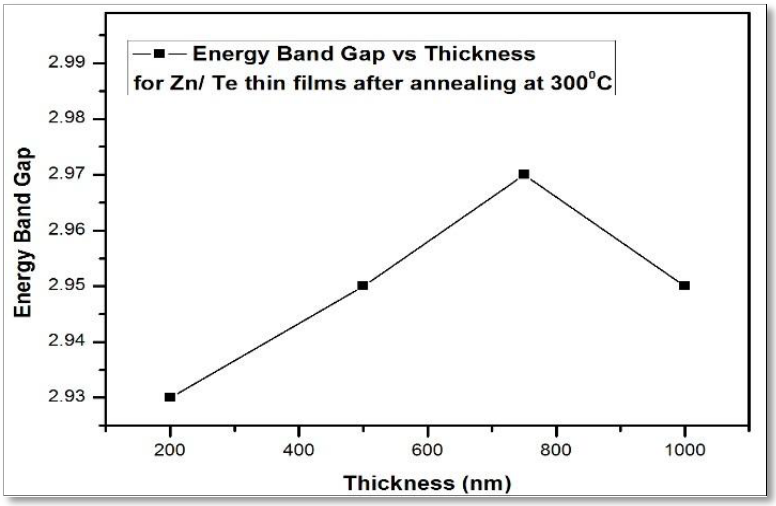

Figure 3. Graph between thicknesses vs. energy band gap of Zn/Te thin films annealed at 300°C.

Electrical I-V measurement

Effect of thickness vs. Voltage-Current (V-I) characterization of prepared Zn/Te thin films were also studied. The measurements were taken at room temperature for without annealing thin films, after annealed at 200°C and 300°C for 500 nm Zn/Te thin films. By **Figure 4** observed that I-V curve is measured at room temperature for without annealed Zn/Te thin films which indicate linear I-V curve with ohmic contact variation at the interface between of Zn/Te and Si substrate contact which shows non-rectifying barrier potential at the interface of P-N junction contact [9]. At ohmic contact current is relative to applied voltage magnitude accordance with ohm's law. I-V curve is obtained Linear at room temperature for without annealed thin films shows ohmic contact with typically metallic nature of Zn/Te thin films. This ohmic behaviour increase with increasing the temperature of films. At 200°C after annealing thin films clearly indicate that the thin films shows nonlinear curves after heat treatment appropriate with granular uniformity and demonstrate Schottky contact at the interface which shows rectifying behaviour of potential barrier between P-N junctions with tunnelling effect. After annealing at 300°C tellurium diffuse in Zinc and readily available Schottky barrier junction in the interface that makes alloy compound of Zinc Telluride (ZnTe). Thin films attained semiconductor nature after heat treatment [10].

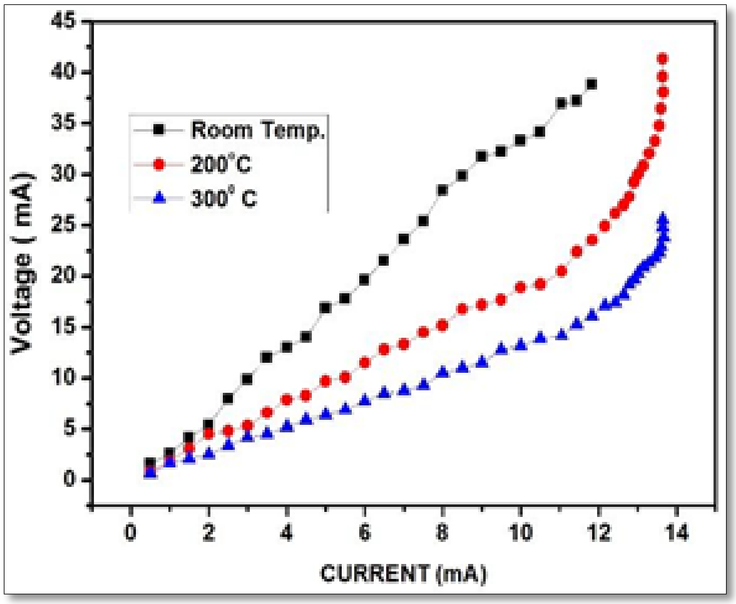

Figure 4. I-V graph of Zn/ Te thin films for without annealed thin films and after annealed at 200°C and 300°C.

Resistivity v/s temperature relation

The effects of thickness and temperature on resistivity of the prepared thin films were studied. The measurement was occupied with remain the current constant with sweeping the voltage at dissimilar temperature [11]. It was set up that the resistivity decreases exponentially with increasing temperature for all the Zn/Te thin films which indicate that these thin films have semiconductor behavior **(Figure 5)**.

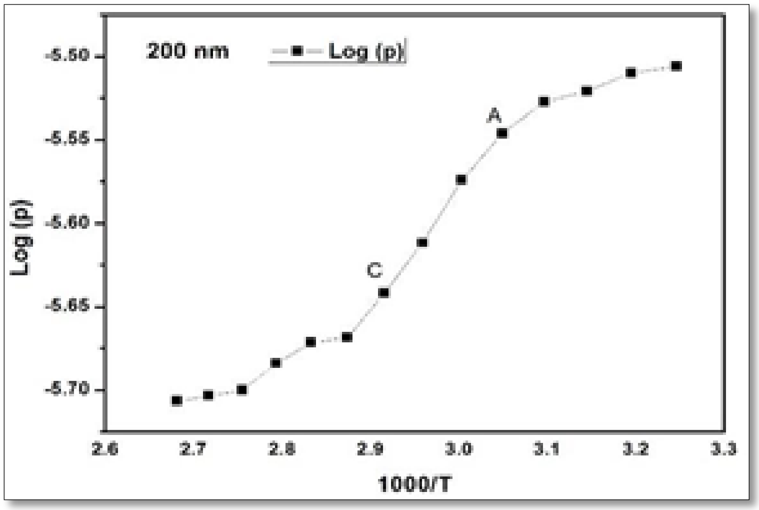

Figure 5. Graph between Log (ρ) and 1000/T for 200 nm Zn/Te thin films.

Mobility measurement

Mobility of charge carriers which is called “Hall mobility” is measured using “Hall Effect” measurement. Mobility of charge carriers exponentially decreases with increase the temperature **(Figure 6)**. It is also observed that the mobility of charge carriers at without annealed thin films is less than the mobility of charge carriers comparatively after annealed at 200°C and 300°C. It is also observed that mobility of conduction electrons is more than the valance electrons and conduction electrons are more easily affected than valence electrons. It is also observed that with increasing the temperature, relaxation time or mean free time between charge carriers collision also increases. In XRD analysis observed that after annealing the crystal grain particle size increases and there would be better contact at the interface of Zn/Te and Si substrate due to it mean free life time of charge carriers decreases and mobility decreases with increases the annealing temperature of thin films [10].

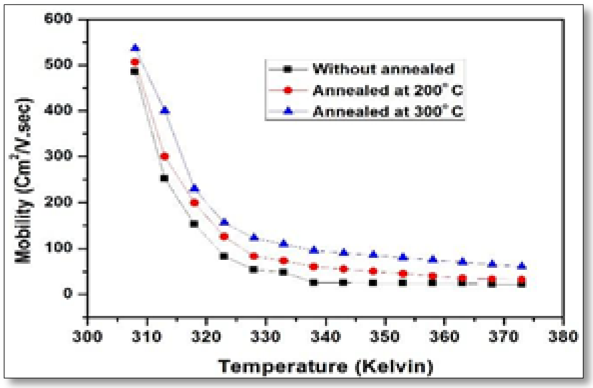

Figure 6. Graph between mobility and temperature.

Electrical switching characterization

A P-N junction at the interface of contact Zn/Te on Si substrate works as a diode can neither turn 'ON' nor turn "off" instantly. It takes finite time for turning "ON" and turning "Off" which is called switching times of diode [11]. Diode has two switching time: Forward recovery time and Reverse Recovery Time. Test unit for the measurement of switching time shown in **Figure 7**.

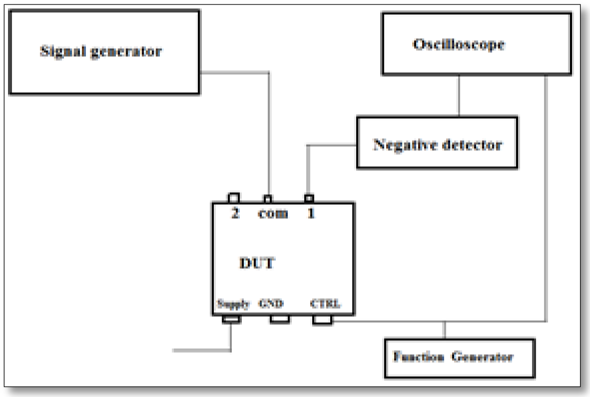

Figure 7. Test unit for switching time measurement.

(a) Turn on time (forward recovery time) in **Figure 8** shows that when diode is forward biased (turned on), voltage across it reduces. Turn on time is defined as time interval in which voltage across diode changes from 90% maximum voltage to 10% of minimum voltage.

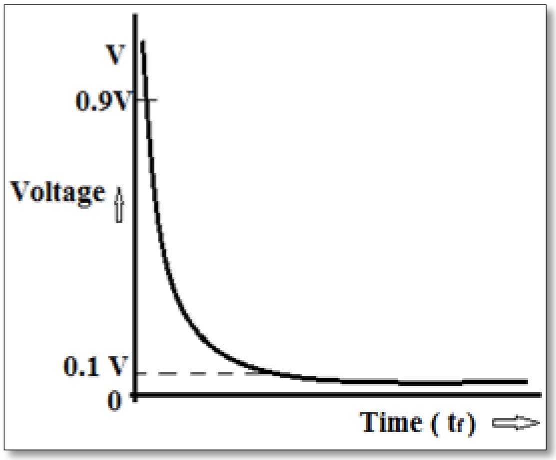

Figure 8. Forward recovery time for Zn//Te thin films.

(b) Turn off Time (Reverse Recovery Time) shown in **Figure 9** which indicate that when a forward biased diode is suddenly reverse biased, current does not drop to zero instantly. It takes finite time to drop to zero. This time is known as Turn off time. Reverse recovery time plays a major role in high speed switching application. For fast switching from "ON" state to "OFF" state, the reverse recovery time should be as small as possible. In **Figure 9** (ts) is the storage time, when the diode is in reversed biased the positive terminal of battery repels injected minority holes and negative terminal of battery repels injected minority electrons. Therefore, current flows whose direction is from N-region to P-region (reverse current). This current is constant till all injected holes return back to their parent region P and excess electrons to N-region. This time interval (t1-to) is known as storage time (ts).

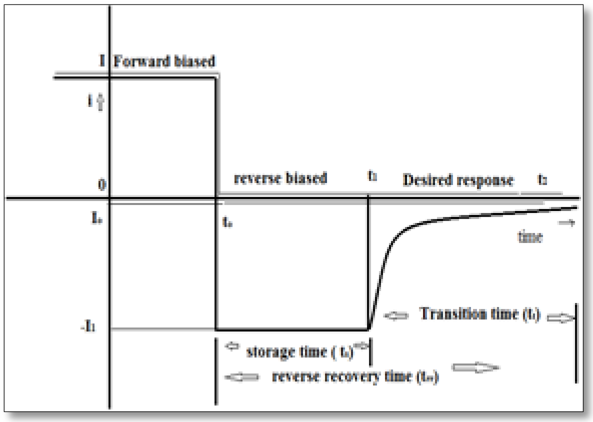

Figure 9. Reverse recovery time for Zn/Te thin films.

After this instant current falls to reverse saturation current (I0) (I0 is due to thermally generated minority charge carriers).The time interval (t2-t1) is called as transition time (tt).

Sum of these two time intervals (ts and tt) equals the turn off time or reverse recover time (trr) of P-N junction diode [1,8].

Structural properties

The Zn/Te thin films characterized with XRD with and without annealing. XRD pattern for 200 nm shown in **Figure 10** and 500 nm shown in **Figure 11**. Results point out XRD peaks analogous to Tellurium Zinc at specific 2θ angle for orthorhombic face of thin films. This work confirmed that corresponding materials have been successfully deposited on substrate, Silicon and Zinc peaks are exposed whereas no peak related to "Te" appeared because of non-crystalline performance of Tellurium. Subsequent to annealing Tellurium has been merged in Zinc and relative peaks of composites of Zinc telluride starts appear. Observed peaks analysed using standard XRD pro software [12]. By XRD analysis it is also observed that with higher annealing temperature peak height increases and the peak width decreases. It has been observed that grain and crystals size increases due to growth of the peak height is the function of annealing temperature which could grow up the crystalline phase of thin films.

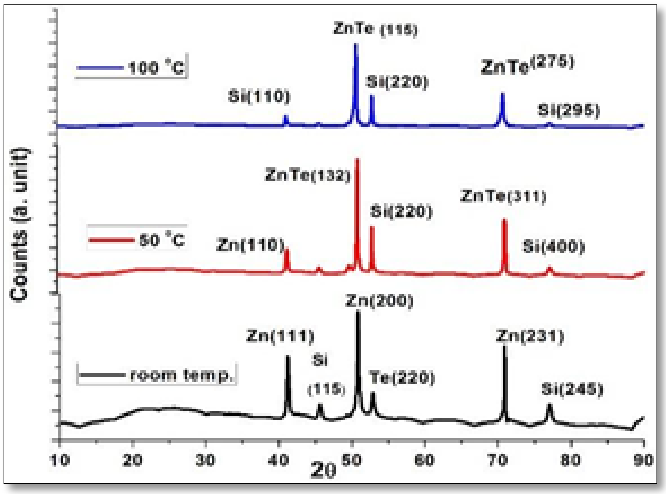

Figure 10. Combined XRD spectra of Zn/Te thin films for 200 nm.

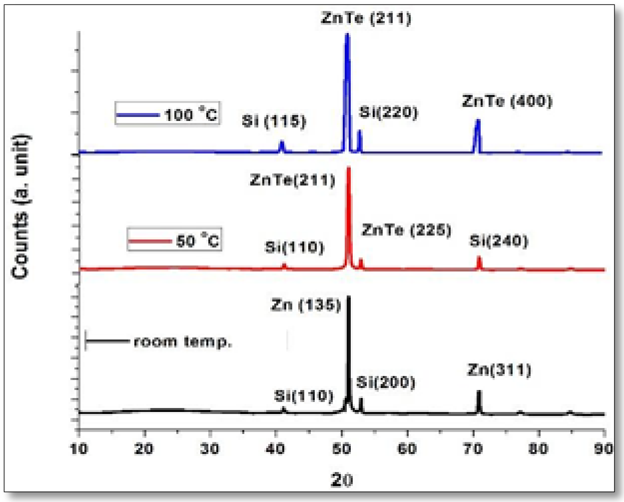

Figure 11. Combined XRD spectra of Zn/Te thin films for 500 nm.

AFM analysis

By AFM Analysis observed that crystallinity and granularity of thin films increased with increase the thickness of the Zn/Te thin films. By **Figure 12** it is also noticed that by means of enhance the thickness size of the crystal and grain particles also increases. This shows that thin film grows in granular phase manner and become smoother as the thickness increased [13]. An AFM image confirms the polycrystalline nature of Zn/Te on Si thin films **(Figure 12)**.

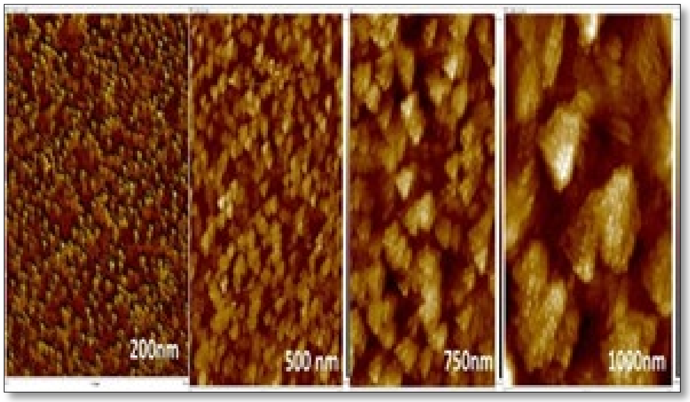

Figure 12. AFM images of Zn/Te-Si thin films of different thickness (200, 350, 500, 1000 nm).

SEM analysis

The without annealing and annealing result measured by SEM images for dissimilar magnification which has decreases as of 10 µm to 1 µm which is exposed in **Figure 13**. These thin films visibly point out that Tellurium and Zinc full-grown on Silicon which results that large granular clusters starts to be appear with the decrease in magnification from 10 µm to 1 µm later than annealing surface morphology of thin films recrystallize. After annealing rough lumps and large bunch starts to appear in spherical shape and distributed on the whole surface. These clusters formed due to the agglomeration of particles during to heat treatment. In accordance to the SEM images it may bring to a close that thin films which are as-deposited have partially amorphous structure even as after annealing it becomes polycrystalline in nature. Without annealed thin film becomes smoother in outside morphology on the other hand after annealing minute gapes starts appear in between the granules due to diffusion of Tellurium in Zinc particles which supports our electrical studies. After annealing the amplitude of atomic vibration increases due to it crystal grain size shows large interatomic spacing between the grain particles. By SEM analysis it also concluded that grain size is increases when the annealing temperature is increasing [6,7].

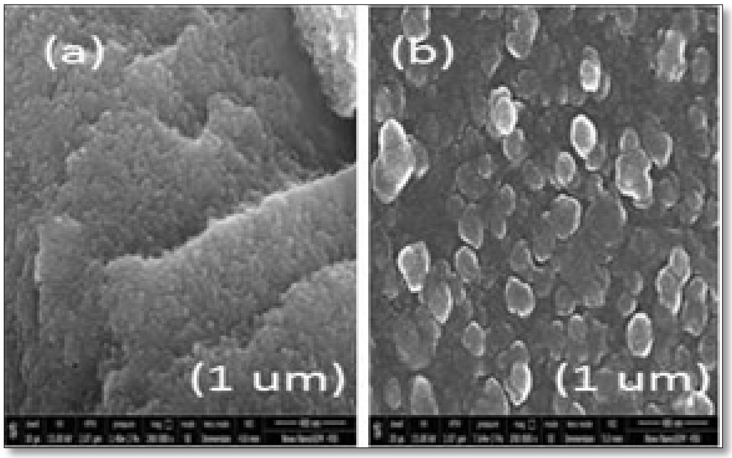

Figure 13. SEM image for 500 nm (a) Without annealing (b) Annealing.

CONCLUSION

Zn/Te Thin films hetero structure of variety of thickness has been fabricated on silicon under the vacuum of about 10^{-5} torr, by vacuum coating unit. Energy band gap (direct) has been obtained 2.22 eV to 2.30 eV at without annealing through Four point Probe scheme which results that as we increase the material thickness, Energy band gap decreases exponentially. To find out the effect of recrystallization thin films of Zn/Te were annealed at 200°C and 300°C. After annealing it has been observed that energy band gap increases till 750 nm and suddenly decreases due to "Quantum Confinement Effect" and higher size of the grain particles and energy band gap obtained in range of 2.85 eV to 2.97 eV. Atomic force microscopy, X-ray diffraction, and scanning electron microscopy analysis are done to get complete and reliable micro structural in sequence. I-V Electrical measurements done for find out the nature of thin films. Electrical switching times study also done in forward and reverse bias after set up the devices to find out the effect of forward recovery time and reverse recovery time on P-N junction Zn/Te heterostructure which shows that reverse recovery time is product of transition time and storage time that is desirable measurement in high speed switching applications.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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