Electrical, Structural Properties of Tellurium Thin Films on Silicon Substrate

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Abstract: **Tellurium (Te) thin films of various thickness (200nm, 275nm, 350nm & 500nm) were prepared on Silicon (Si) substrate by thermal evaporation method under the vacuum of about 10^{-5} torr using vacuum coating unit. It is observed that the resistivity decreases exponentially with the Increasing Temperature. A direct band gap between 0.368 eV to 0.395 eV is obtained at different temperatures with Four Probe Method which shows that when we increase the thickness of material the band gap will decreases. It is also observed that voltage decreases with the increasing the temperature using four probe method. Samples were studied by X-ray diffraction (XRD), and atomic force microscopy (AFM) to obtain comprehensive and consistent micro structural information.**

Key Words: **Thermal evaporation, Vacuum coating unit, Four Probe Method.**

1. INTRODUCTION

Tellurium is an important semiconductor material for the development of various modern technologies of solid state devices like (Gas sensors, Air products, polarizer's, temperature controller in satellites, solar cells, microwave devices, etc.).It is a direct band gap semiconductor in which energy band gap can varies between 0.35 eV to 0.5 eVwith temperature.

The various methods have been developed for the preparation of silicon-tellurium (Si-Te) thin films such as thermal vapour deposition, molecular beam epitaxial, organ-metallic chemical vapour deposition, solution growth etc. The choice of the deposition method may be based on quality of the films required for specific applications. A well-defined composition of Si–Te can be obtained in thin film form by thermal evaporation method under the vacuum of 10^{-5} torr. In the current work thin films of Te of various thickness (200nm, 275nm, 350nm & 500nm) has deposited on clean silicon substrate and structural and electrical properties have been studied to examine the role of thickness.It is observed that the resistivity increases exponentially with the Increases in 1/T. A direct band gap between0.368 eV to 0.395 eV is obtained at different temperatures with Four Probe Method which shows that when we increase the thickness of material the band gap will decreases for all investigated samples.

2 EXPERIMENTAL DETAILS

Materials& Methods

Tellurium (Te) was purchased from Koch-Light laboratories LTD, colnbrook Berks England. Single crystal N type silicon wafer substrate was Grade prime CZ have diameter 3 inch, thickness was 380+/-25 micron, orientation <100>, Resistivity was 1-10 ohm cm, and surface was single side polished.

Synthesis

Thin film of Si-Te has deposited using thermal evaporation method on a properly cleaned silicon substrate (n type) of 1x1 cm^2dimension. Initially clean the tungsten boat and chamber by acetone.The tellurium (Te) powder having (99.99%) purity was placed in a tungsten boat and start the pumping unit to create the high vacuum in thechamber.After reaching the high vacuum(10^{-5}mbar) in the chamber the Te is heated indirectly by passing the current slowly to the electrodes and then Teof different thickness (200nm,275nm,350 nm&500nm) have deposited on silicon substrate.Thickness of the Te layer on Si substrate were controlled using quartz crystal monitor (“Hind Hivac” Digital Thickness Monitor Model–DTM–101).

Characterization

The surface morphology of thin films were analysed by Barker private ltd make atomic force microscopy (AFM). Structural characterization was done using panalytical (Xpert-Pro) manufactured X-ray diffraction (XRD) unit & electrical properties was studied by Four probe ES-246 setup manufactured by OMEGA type.

All the thin films were prepared at different thickness and then calculated the Energy band Gap using four probe methods. Each sample was studied by X-ray diffraction (XRD), and atomic force microscopy (AFM) to obtain comprehensive and consistent micro structural information.

3. RESULTS AND DISCUSSION

Electrical properties

The Energy band gap observed by using four probe method for Si-Te thin film of thickness of Te (200nm, 275nm,350 nm&500nm) varied between 0.368 eV to 0.395 eV at Different temperatures. The effect of thickness on energy band gap of thin films is shown in fig. 1.

Fig.1 shows the important findingof thicknessdependence on the band gap. The band gap increases as the thickness decreases.

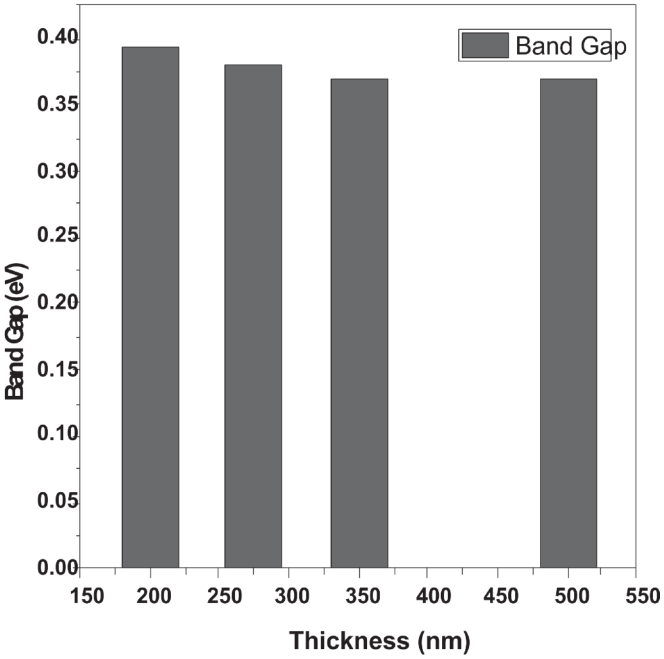

Figure 1. Graph between Thickness Vs Band Gap

3.2 Resistivity and Temperature study

It is observed that the resistivity decreases exponentially with the Increases Temperature for all Te-Si thin films shown in fig.2, fig.3 and fig.4.

It was found that the resistance of the Si-Te thin film is very high and decrease quickly with increasing temperature. It was also found that the resistivity decreases with increasing temperature for all the thin films indicating that these films have a semiconducting behaviour.

It is observed that the resistivity at low temperature is high. As the temperature rises, the degree of ionization of the impurities increases, and the raise of the carrier concentration results in a rapidly decrease of the resistivity higher temperature by a tendency to decrease. The reason for the tendency lies in the temperature dependence of the mobility. In this temperature range, the films exhibit a metallic behaviour. Hence, the mobility of the carriers decreases with raising the temperature because of the lattice scattering. At low temperatures resistivity is more at high temperatures the Resistivity is less. It is also observed that voltage decreases with the increasing the temperature using four probe method for all the Tellurium thin films shown in fig.5,fig6&fig.7.

The effect of thickness and temperature on resistivity of the prepared thin films were also studied. The measurements were taken by sweeping the voltage at different temperature (room temperature, 50^0C, 75^0C, 100^0C) for 200nm, 350nm and 500nm thin films respectively. It was found that the resistance of the Si-Te thin film is very high and decrease quickly with increasing temperature. It was found that the resistivity decreases with increasing temperature for all the thin films indicating that these films have a semiconducting behaviour.

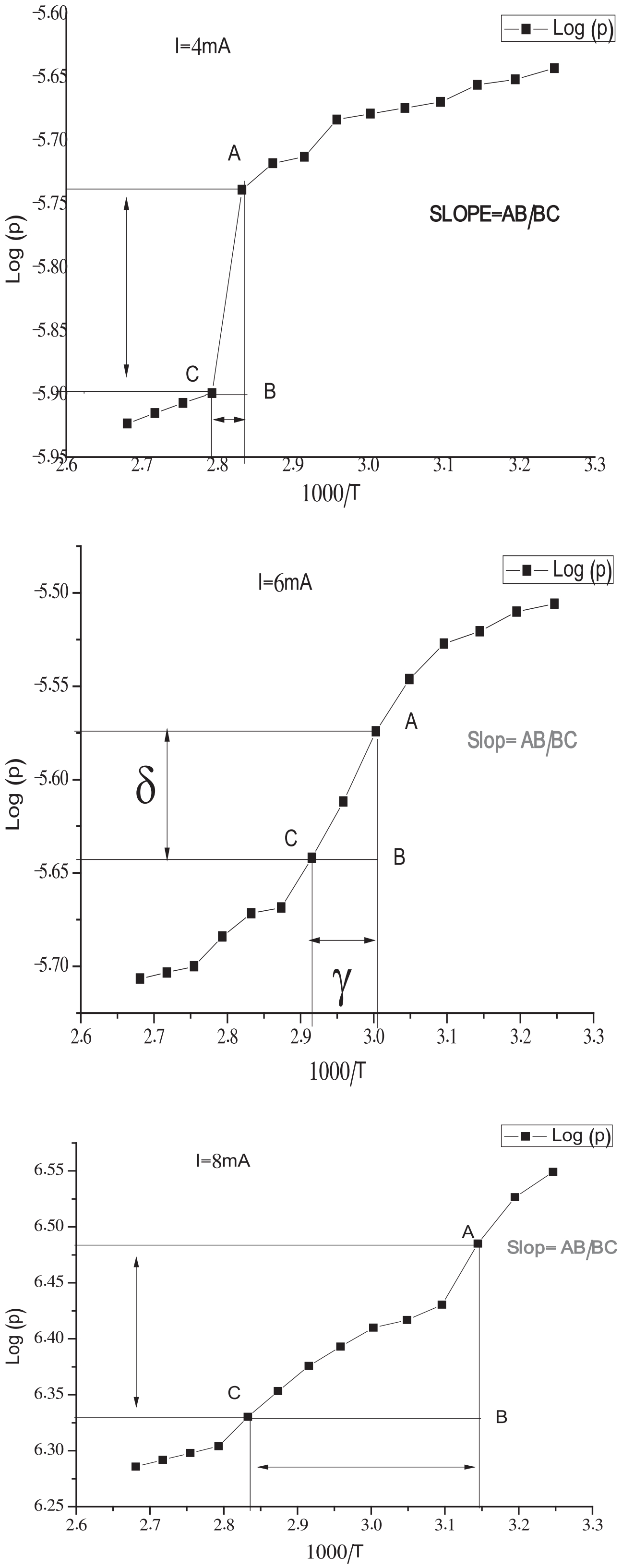

Figure 2. Graph between Log(ρ) and 1000/T for 200nm thickness of Te-Si Thin Film for I=4mA, I=6mA & I=8mA constant current using four probe method

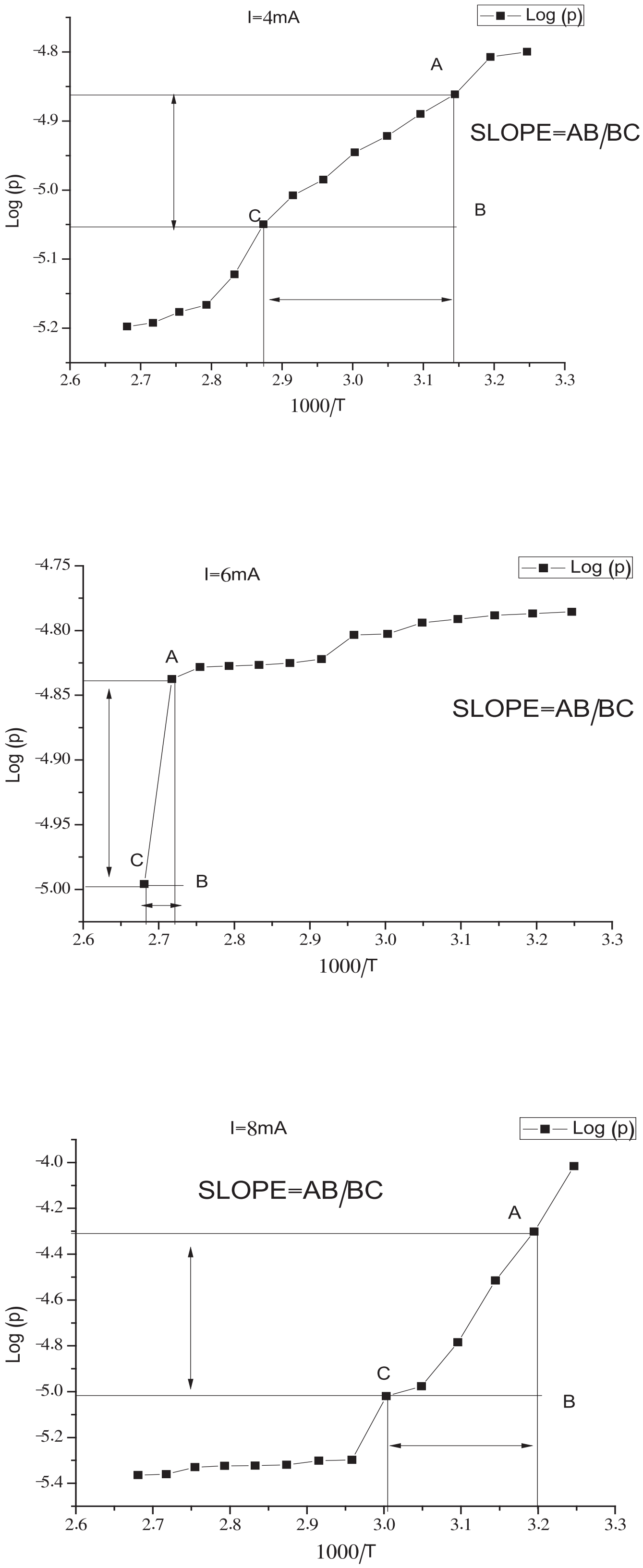

Figure 3. Graph between Log(ρ) and 1000/T for 300nm thickness of Te-Si Thin Film for I=4mA, I=6mA & I=8mA constant current using four probe method.

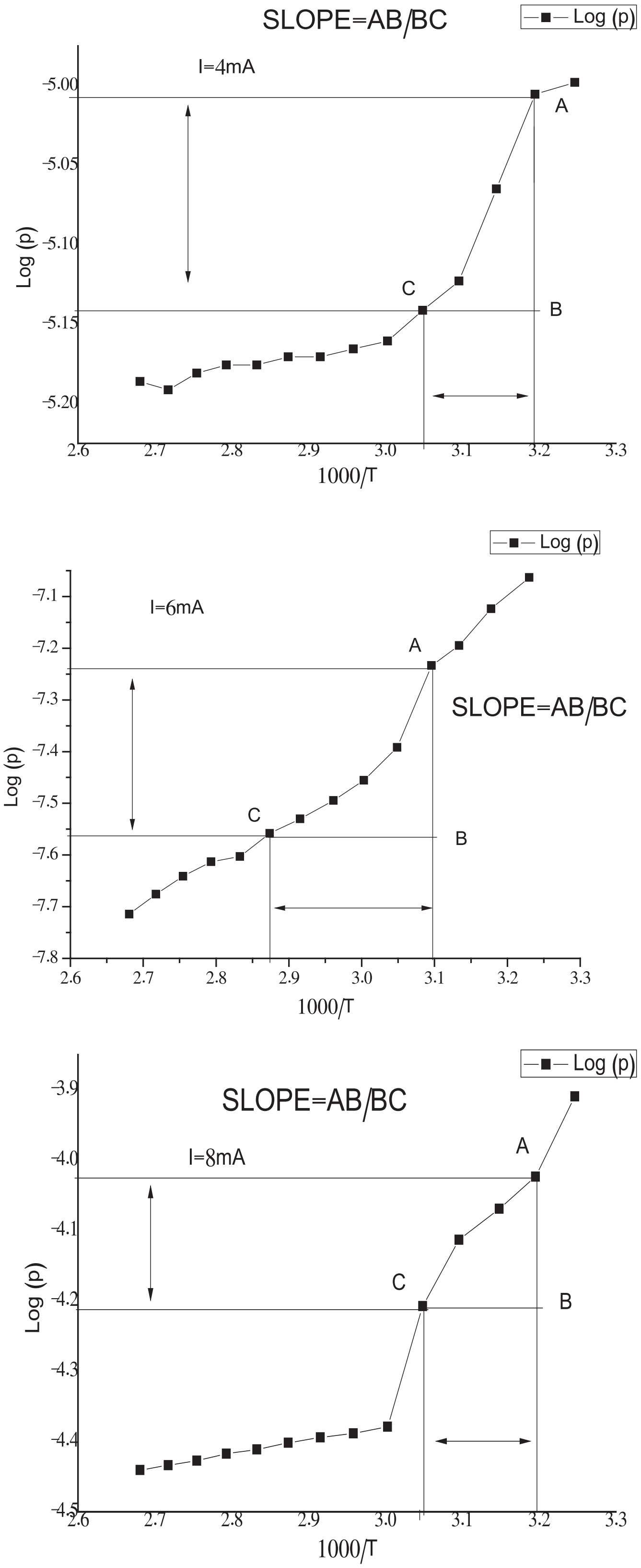

Figure 4. Graph between Log(ρ) and 1000/T for 500 nm thickness of Te-Si Thin Film for I= 4mA, I= 6mA,I= 8 mA constant current using four probe method.

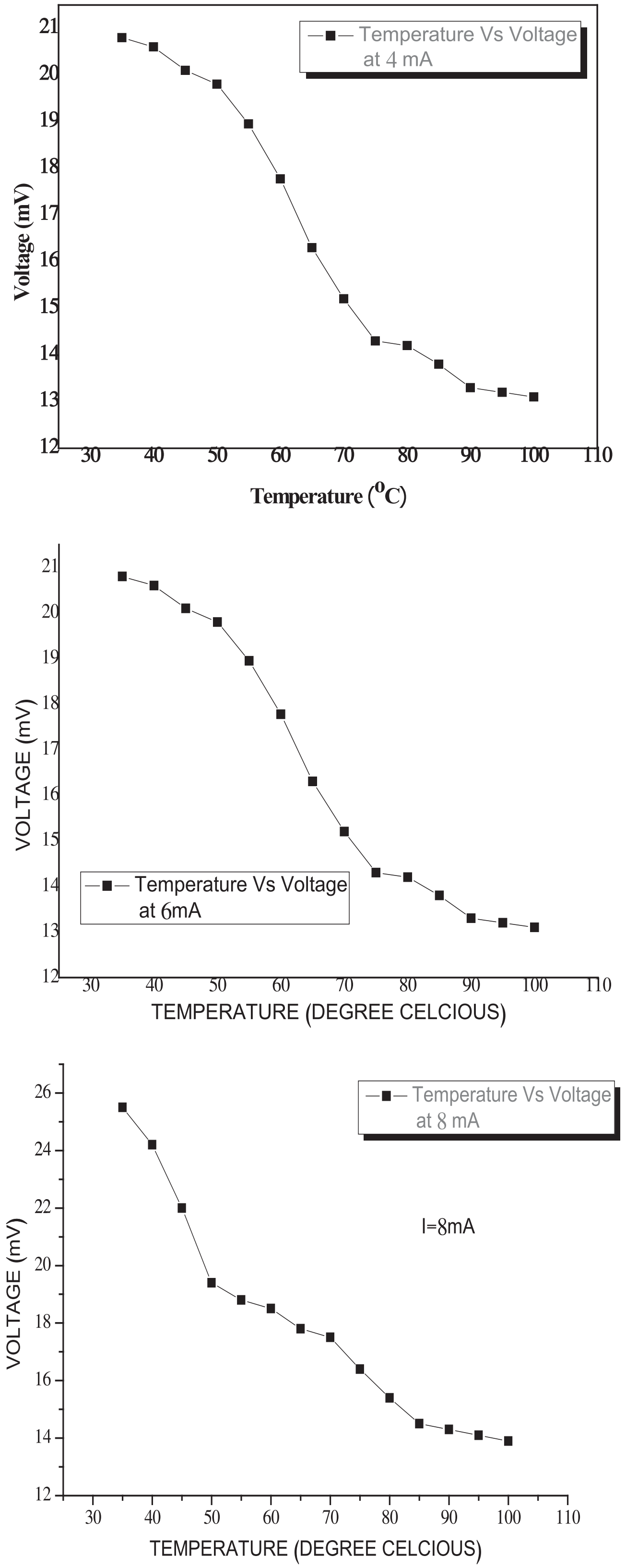

Figure 5. Graph between Voltage and Temperature (˚ C) for 200 nm thickness of Te-Si Thin Film using four probe method.

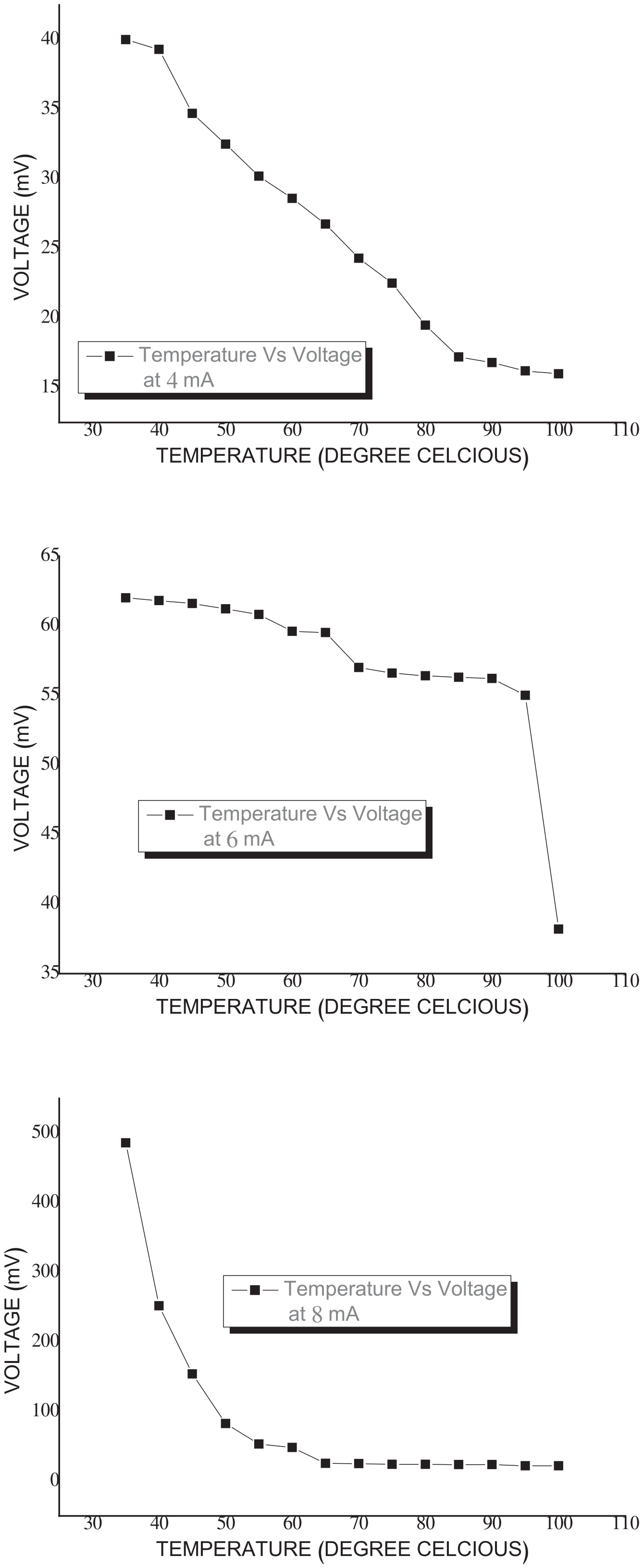

Figure 6. Graph between Voltage and Temperature(˚ C) for 350 nm thickness of Te-Si Thin Film using four probe method.

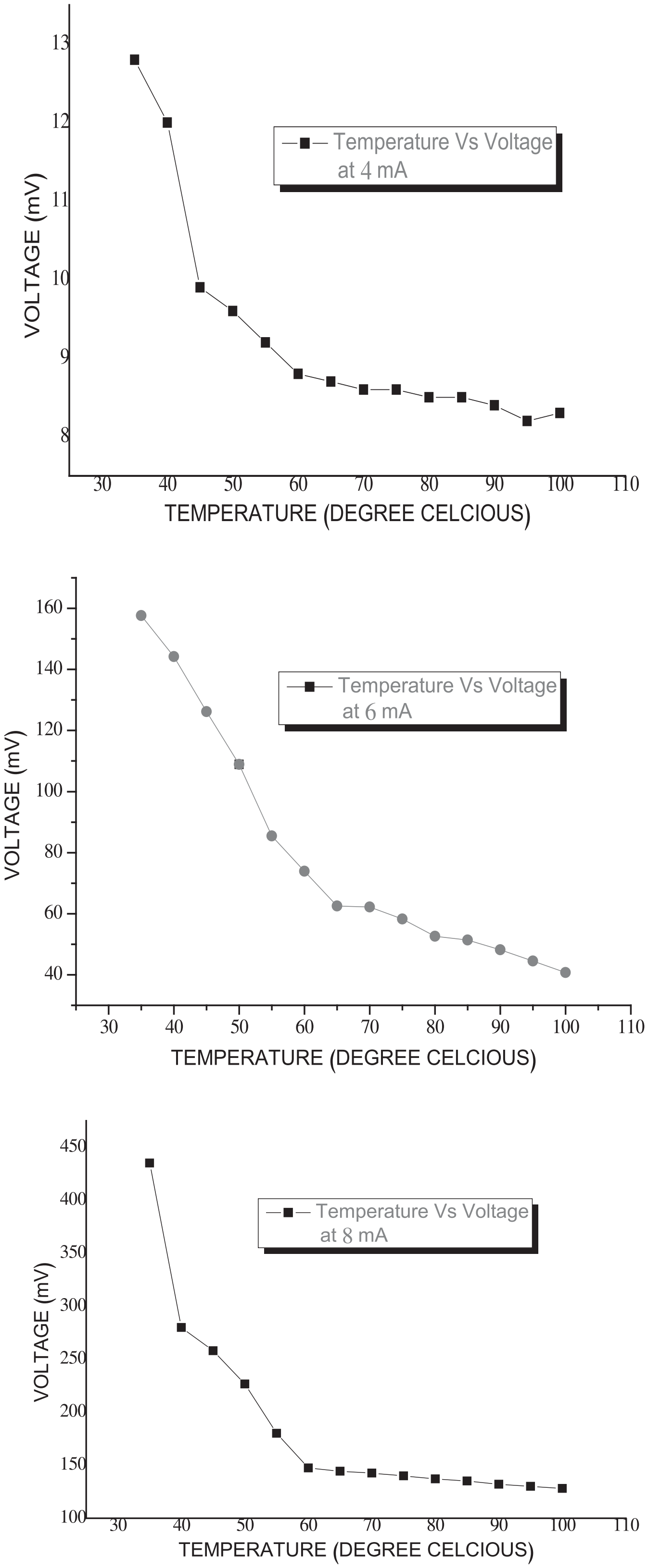

Figure 7. Graph between Voltage and Temperature (˚ C) for 500 nm thickness of Te-Si Thin Film using four probe method

The figure 8shows that number of peaks increases with the increases the thickness of Te-Si thin films .It also shows the XRD spectra of thin films for all thickness between 2θ and Intensity.It has been observed the crystanility of thin films increased as the thickness of the Te on Si substrate increased which show that film grow in ordered granular phase and become more smooth as the thickness increased which has also beenanalogy with AFM images.AFM images shows confirms the polycrystalline nature of Te-Si thin films. (Fig 9).

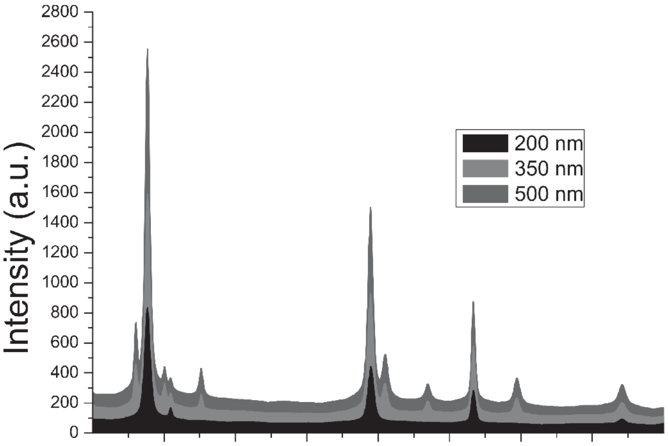

Figure 8. Combined XRD spectra of thin films.

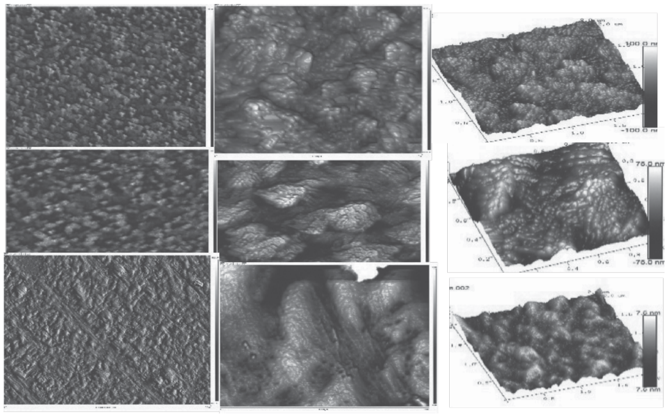

Figure 9.2D and 3D view AFM Images ofTellurium thin film of different thickness (200 nm, 350, 500 nm) on Si substrate

4. CONCLUSION

Thin films of Te of various thickness (200nm, 275nm, 350 nm&500nm) were prepared on Silicon (Si) substrate by thermal evaporation method under the vacuum of about 10-5 torr., using vacuum coating unit. A direct Energy band gap between 0.368 eV to 0.395 eV is obtained at different temperatures with Four Probe Method which shows that when we increase the thickness of material the Energy band gap will decreases and the resistivity decreases exponentially with the Increases Temperature and X-ray diffraction (XRD), and atomic force microscopy (AFM) to obtain comprehensive and consistent micro structural information.

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