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Investigation of Thickness and Temperature variation on Band Gap of Tellurium thin film on silicon substrate

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Abstract

Tellurium (Te) thin films of various thickness were prepared on Silicon (Si) substrate by thermal evaporation method under the vacuum of about 10^{-5} torr. It is observed that the resistivity decreases exponentially with the increases temperature. A direct band gap between 0.368eV to 0.395eV is obtained at different temperatures which shows that when we increase the thickness of material the band gap will exponentially decreases.

Keywords: Thermal evaporation, Vacuum coating unit, direct band gap.

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)[1]. It is a direct band gap semiconductor in which Energy band gap varies between 0.368eV to 0.395eV at Different temperatures [2].

A variety of methods have been developed for the preparation of Si/Te thin films such as thermal vapour deposition under vacuum, 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 [3]. Composition of Si–Te can be obtained in thin film form by thermal evaporation method under the vacuum [4].

In this paper we have deposited thin film of Si-Te by taking silicon as a substrate and then deposited Te of different various thicknesses. (200nm, 350nm & 500nm). It is observed that the resistivity increases exponentially with the Increases in 1/T. A direct band gap between 0.368eV to 0.395eV is obtained at different temperatures with Four Probe Method which shows that when we increase the thickness of material the band gap will exponentially decreases for all investigated samples.

2 Experimental

Thin film of Si/Te has deposited using thermal evaporation method on a properly cleaned silicon substrate (n type) of dimension. Tellurium is placed in a tungsten boat 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 Tellurium (99.99%) of different thickness (200nm, 275nm,350nm & 500nm)have deposited on it thickness of the Te deposited films were measured using quartz crystal monitor ("Hind Hivac" Digital Thickness Monitor Model–DTM–101).All the films were prepared at different temperatures 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

3.1 Energy Band Gap study

The Energy band gap observed by using four probe method for Si/Te thin film of different thickness of Te varied between 0.368eV to 0.395eV at Different temperatures. Energy band gap of the Te layers can be seen in Table 3.1 the band gap of the 200 nm Te layer is 0.395eV, showing a large band gap expansion compared to the band gap bulk crystalline Te, however, the 350 nm Te layer have a band gap of 0.370eV, which is significantly smaller than the value of the bulk crystalline Te. The band gap values obtained from the absorption measurements of the corresponding Te layers deposited on fused silica substrate Fig. 3.1 shows the plots of $\alpha \sim E^{1/2}$ versus E where α is the absorption coefficient obtained from the absorption measurement and E is the photon energy for the 200nm and 350nm Te layers. The values of the band gap obtained by extrapolating the linear portion of the plots for all the samples.

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Another important finding from Fig.1 is the thickness dependence of the band gap the band gap increases as the thickness Decreases, and it is even larger than the band gap of bulk crystalline Te when the thickness is less than 200nm, showing a band gap expansion. However, when the thickness is larger than 500nm, the band gap is smaller than the value of bulk crystalline Te. As discussed below, the thickness dependence of the band gap can be explained with the One-dimensional quantum confinement effect and the amorphous effect in the Te thin films. For one-Dimensional confinement, the quantization energies

$$\Delta Eg \sim h^2/2ma^2$$

Table 3.1

Thickness of films	Energy Band Gap
200 nm	.3948 eV
275nm	.3817 eV
350nm	.3688 eV
500 nm	.369eV

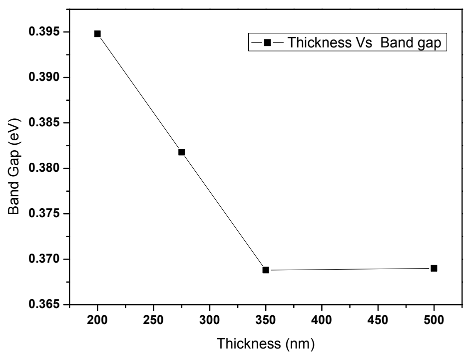

Fig1. Graph between Thickness Vs Band Gap

3.2 Resistivity and Temperature study

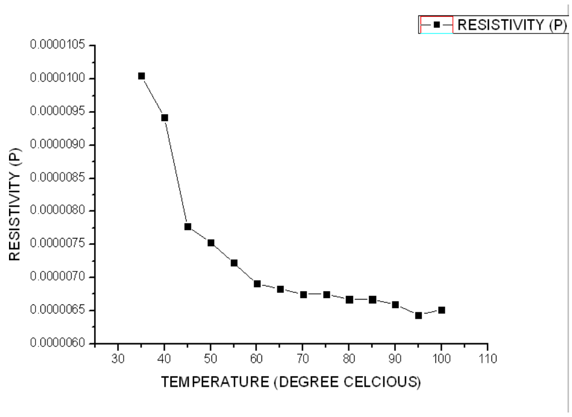

Fig2. Graph between Resistivity Vs Temperature

The effect of Te on the Resistivity of the prepared Si-Te thin films of thickness(200nm, 275nm, 350nm & 500nm) deposited on silicon(Si) substrate held at room temperature were studied. Measurements were taken during heating from room temperature (35^0C), 40^0C, 45^0, 50^0, 55^0, 60^0C till 100^0 C by the difference of temperature of 5^0Cand keep the current (mA) constant at 4mA, 6mA&8mA. The variation of the resistivity ρ with temperature is shown in Fig2. It was found that the resistance of the Si-Te thin film composition is very high and decrease quickly with increasing temperature. It was found that the resistivity decreases with increasing temperature for all the compositions 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.

3.3 Electrical properties of the thin film

The effect V-I characteristics is Shown in Fig3.As prepared Si-Te thin films of different thickness were Measurements taken during heating from room temperature 35^0C to 50^0,75^0, 100^0 C. In it voltage increased by the difference of 2mv and measurements of current (mA) have taken at different temperatures. It was found that the current increases with respect to the voltage with increase the temperature.

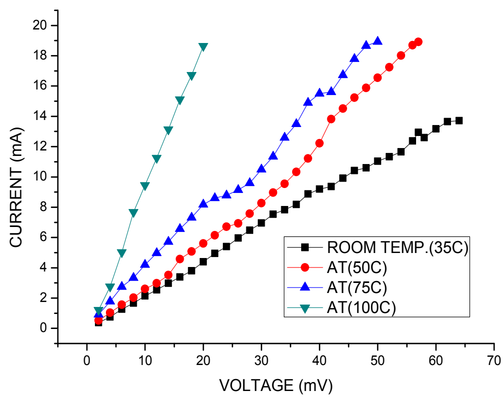

Fig.3 V-I Characteristics of thin films

3.4 Structural properties of the thin film

3.4.1 XRD Analysis

Bragg's law (nλ=2dsinθ) is a simplistic model to understand what conditions are required for diffraction. The space between diffracting planes of atoms determines the peak positions. The peak intensity determined by what atoms are in the diffracting plane .XRD Analysis is based on the peaks observed for Te content, as we observed when we deposited 200 nm Te on Si then a very few peaks are observed. Growth rate were increased For 350 nm Te and further for 500 nm these peaks become more. This results as we increased the thickness of material no. of peaks are increased comparatively.

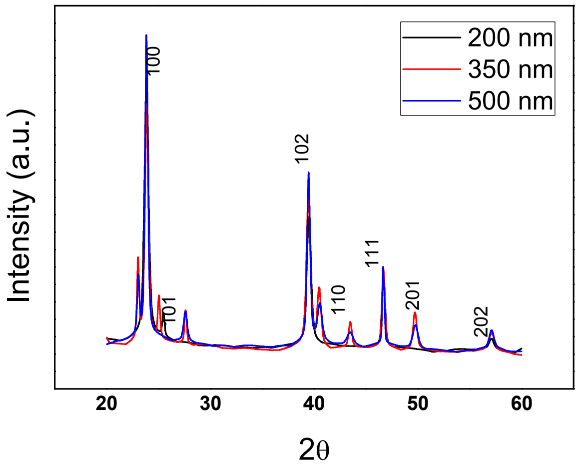

Fig.4 Comparative analysis between intensity and 2θ

3.4.2 Atomic Force Microscopy analysis

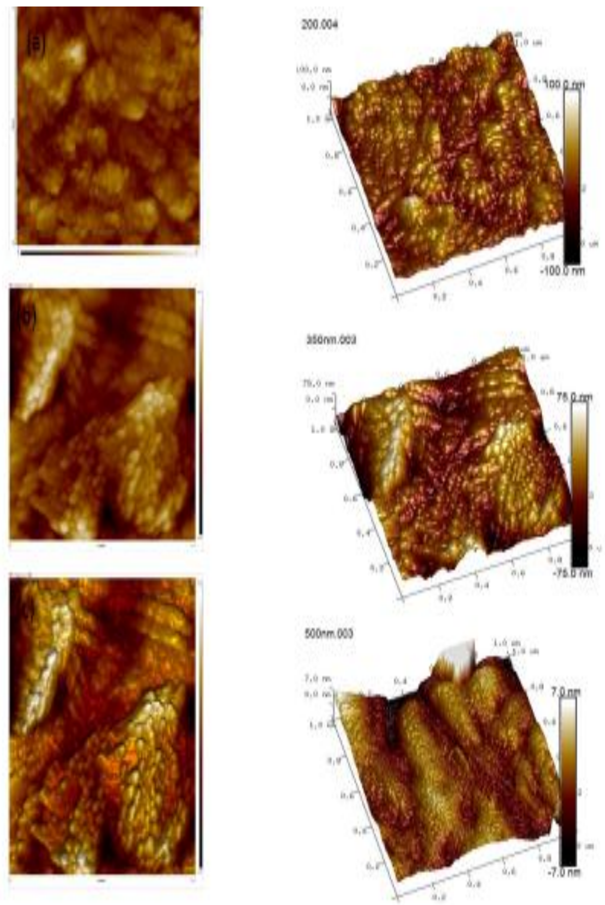

Fig.5 AFM Images of growth of Tellurium of Different thickness on Si substrate with their 3 D-views

AFM provides a 3D profile of the surface on a nanoscale, by measuring forces between a sharp probe and surface at very short distance. The probe is supported on a flexible cantilever. The AFM tip "gently" touches the surface and records the small force between the probe and the surface. In AFM analysis we have observed that by the increasing the thickness of Te thin film on Si substrate island size of Te increased simultaneously.

4 Conclusions

Thin films of Te of various thicknesses (200nm, 275nm, 350nm & 500nm) were prepared on Silicon (Si) substrate under the vacuum of about 10-5 torr. using vacuum coating unit. A direct Energy band gap between 0.368eV to 0.395eV is obtained at different temperatures with Four Probe Method which shows that when we increase the thickness of material the Energy band gap will exponentially 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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