Thermal Annealing Effects On Characterization Of Tin Sulfide Thin Films

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***Abstract*—This research describes the optical, structure and morphology nano clustered SnS thin films prepared by Sn evaporation followed by the Thermal Oxidation in air process. Atomic force microscopy AFM was used to investigate that the grain size an RMS increased with the increasing the annealing temperature from 100 ºC to 200 ºC . The optical properties show that the energy gap increased to 2.2 eV and 2.8 eV. XRD results estimated that the crystallite size increased with increasing the annealing temperature, but the microstrain and the dislocation density are decreasing.**

Keywords—Thin films, Grain size, SEM , Energy gap, Transmittance,

1. Introduction

Thin films of Tin Sulfide (SnS) have attracted much for solar cell due to the high absorption (>$10^4 cm^{-1}$)[1,2] and high conductivity .SnS belongs to groups (IV-VI) compounds formed with(Sn and S).SnS is an important optoelectronic material that is found in zinc blend with lattice constant (a=0.5845 nm) [3], orthorhombic with lattice constants (a= 0.385 nm, b= 1.142 nm c= 0.438 nm) [4,6] crystal structures .The optical properties of SnS vary depending on synthesizing or fabrication method, but most work agrees with direct from 1.2 eV to 1.5 eV and indirect from 1.0 eV

to 1.2 eV band gap values. These properties enable SnS thin films to be used as an absorption layer in the fabrication of heterojunction solar cell [7].SnS thin films can be prepared by different methods such as thermal evaporation ,pulse electro depositions ,SILR ,electron beam evaporation, chemical bath deposition [8,9 ,10].In this research is grown by thermal evaporation, this method has many advantages, it is low cost and widely used because it is a simple, economic and viable technique, also, an attempt has been annealed by 100 ^{o}C and 200 ^{o}C .

2. Experimental

SnS thin films with around 100 nm were deposited with rate deposition 40 nm/s at R.Tand they were annealed at 100°C and 100°C on chemically and ultrasonically cleaned glass substrates with the high Vacuum Coating unit at a vacuum about 10^{-4} torr. The distance between source and substrate was maintained at 6.5 cm for the cases. The prepared films were annealed in vacuum at elevated temperature for 2 hour. X-ray diffractometer (XRD-6000, Shimadzu)

was used to investigate the structure and crystalinity of Thin films. Scanning electron microscope SEM (T-scanVega III Czech) was employed to study the structure of SnS thin films . Atomic force microscope AFM (AA 3000 scanning probe microscope) was employed to study the morphology of thin films. The absorption of the thin films was measured by using UV–Vis double beam spectrophotometer (CECIL, C. 7200,France).

3. Results and dissection

Figure 1 depicts XRD spectra of SnS thin films deposited at different annelaing temperatures in the range (100 and 200)^{o}C. The spectra reveal the presence of traces of other phases along with predominant SnS phase. Degree of crystalline was also found to increase with substrate annealing temperature . The films deposited on glass and annealed at Ts = 100 ^{o}C and 200 ^{o}C showed peaks mainly of SnS phase .

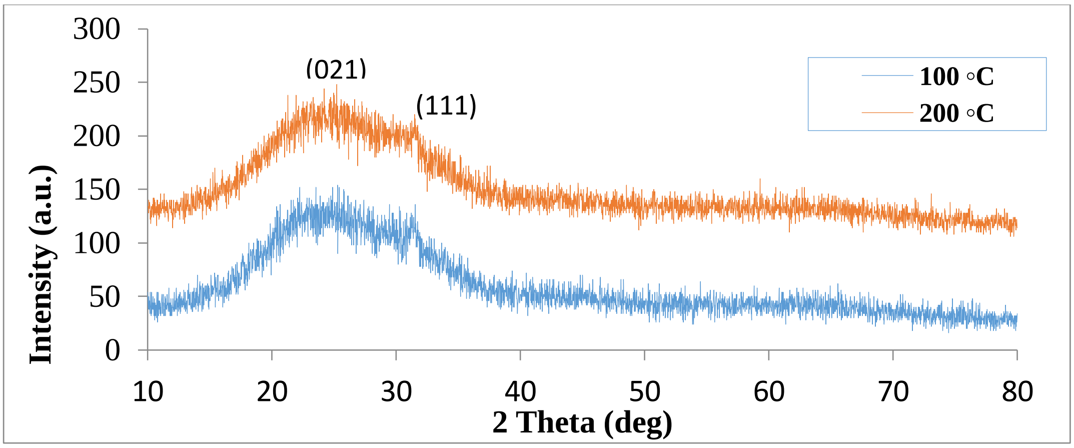

Fig. 1 XRD spectra of SnS thin films deposited glass substrate.

The composition analysis of the SnS films showed that the tin and sulfur content in the films gradually varied with the increase of Ts. The films grown at lower annealing temperature are sulfur rich, where as films deposited at 200 ^{o}C was nearly stochiometric. Figure 2 shows SEM micrograph of SnS thin film deposited at two annealing temperatures, 100^{o} C and 200 ^{o}C. SEM images revealed the growth of randomly oriented, multi-twin grains, which are uniformly distributed over the surface. From the micrograph it is clearly seen that grain size is increased with increase of Ts, which is clearly observed in AFM studies. The formation of bigger grains is due to coalescence of smaller grains. AFM pictures (3D view) of SnS thin films grown at two typical Ts are shown in figure 3. The average grain size and rms value of surface roughness were found to increase with increase in the substrate temperature. Availability of thermal energy at higher Ts is responsible for increased grain size . The variation of grain size and surface roughness, with Ts is indicated in Table 1.

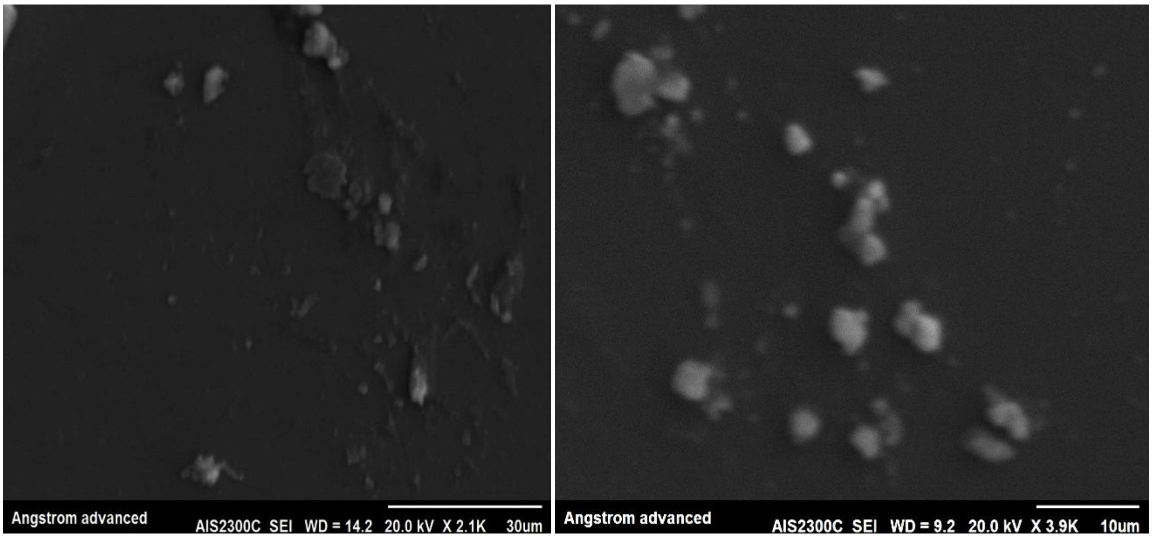

Fig. 2 SEM micrographs of SnS thin film annealed at Ts = 100 ^{o}C and 200 ^{o}C.

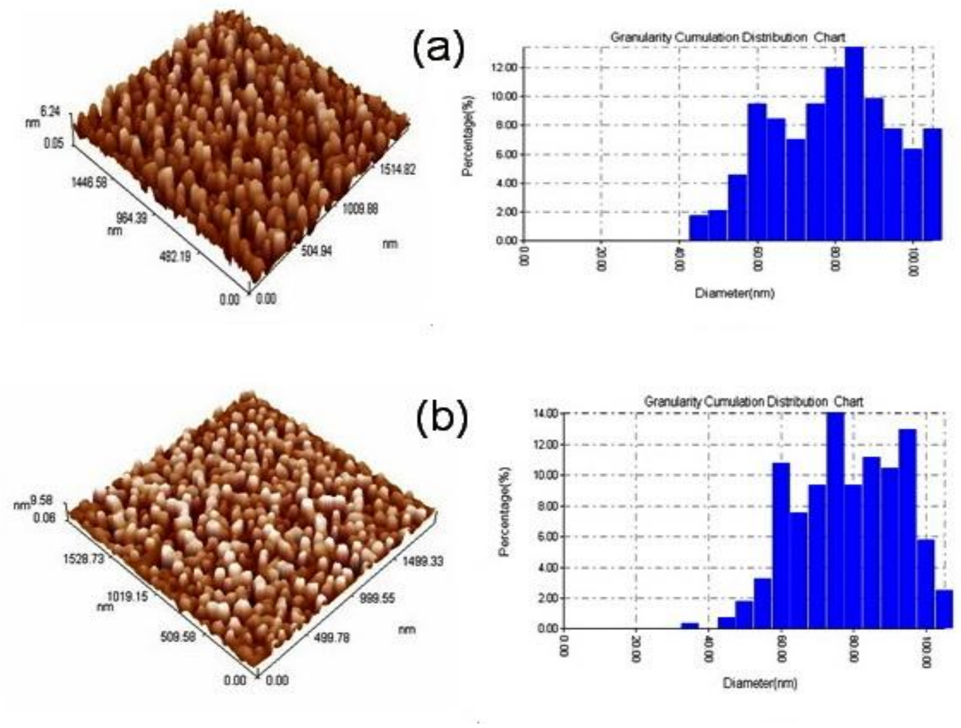

Fig. 3: AFM images of SnS thin film annealed at (a) 100 ^{o}C and (b) 200 ^{o}C.

Thermal annealing	Average grain size (nm)	rephgness average (nm)	RMS (nm)
100 ^{o}C	76	2.14	2.5
200 ^{o}C	78	1.24	1.45

The optical band gap of the AgO film was calculated from the transmission and absorption spectra. Figure (4a) displays the absorbtion as a function of wavelength. It is obvious that the film gives good absorpance characteristics at the spectral range (400- 900) nm . Figure (4b,) shows the band gap of SnS thin films measured from the plot of the square of $(\alpha h\upsilon)^2$ versus photon energy $h\upsilon$(where α is the absorption coefficient) by extrapolating the linear part of the curve toward the photon energy axis is found to be 2.4eV and 2.8 eV. The existence of two energy gap could be attributed to the fluctuation of absorption edge which is due to the energy band structure and the variation of density of state with the energy level, also this variation can be attributed to low thickness of the film.

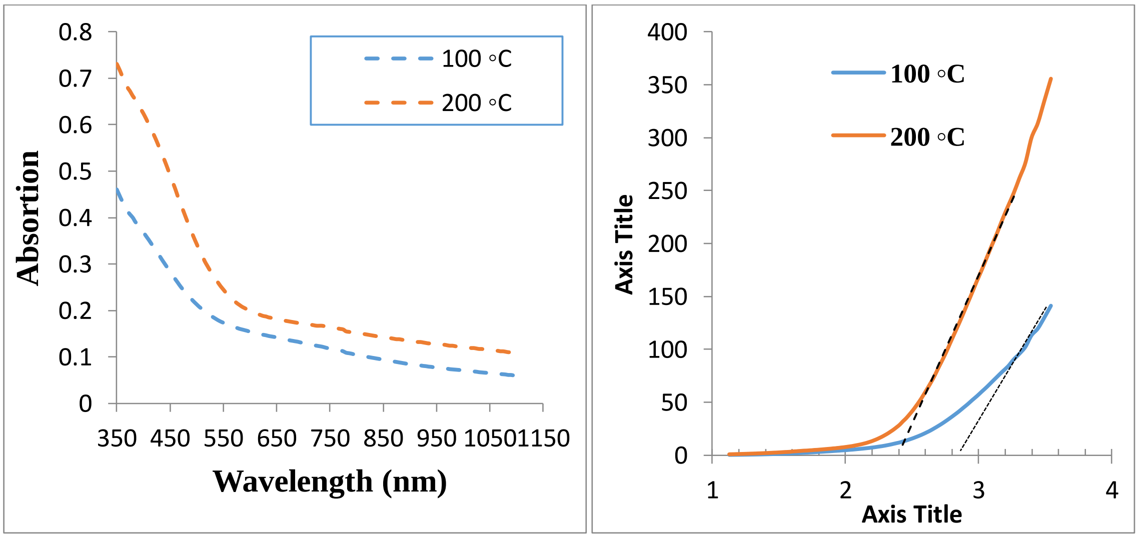

Fig. 4: absorption spectrum of SnS thin film and $(\alpha hv)^2$ versus photon energy plot .

4.Conclusion

Sns thin films were deposited onto glass substrates at different temperatures (100 ºC and 200 ºC) . XRD results indicated that the thin films had a preferred (021) orientation and that the peak intensity of the (111) orientation increased with increasing growth temperature up to200 ºC. The grain size and the roughness of the thin films depended on the growth

temperature. The higher the growth temperature, the rougher the surface and the bigger the grain size. The annealing effects of the thin films grown at room temperature were observed and characterized. We found that the XRD patterns and the surface morphologies of the annealed thin films was greatly improved when the thin film was annealed at 100 and 200 ºC .

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