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EFFECT OF SUBSTRATE TEMPERATURE ON STRUCTURAL AND MORPHOLOGICAL PARAMETERS OF ZnTe THIN FILMS

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Vacuum evaporated thin films of Zinc Telluride (ZnTe) of 5000 Å *thickness have been deposited on glass substrates at different substrate temperatures (*303 *K,* 373 *K,* 448 *K). Structural parameters were obtained using XRD analysis. Atomic Force Microscope (AFM) in non-contact mode has been used to study the surface morphological properties of the deposited thin films. The results obtained from structural and surface morphological studies have been correlated and it is found that the films deposited at higher substrate temperatures possess increasingly good crystallinity and smoother surfaces.*

Keywords: *ZNTE THIN FILM, THERMAL EVAPORATION, XRD, AFM, SUBSTRATE TEMPERATURE.*

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1. INTRODUCTION

Thin films of II-VI compound semiconductors have drawn researcher's attention for more than four decades. ZnTe is expected to be a promising material for a variety of optoelectronic devices, such as pure green light emitting devices, detectors for various optoelectronic instrumentation, etc. because of its direct wide band gap of 2.26 eV [1-3]. It is also used as terahertz detectors [4, 5] and window material for CdTe based solar cells [6]. Many researchers have used various techniques for the fabrication of ZnTe thin films including Metal organic chemical vapor deposition [7], MBE [8], vacuum evaporation [9-11] R.F. Sputtering [12] and Electrodeposition [13-17]. Among these, thermal evaporation technique offers several advantages including simplicity and cost effectiveness for larger area processing. In this paper we report our results of our investigations on structural and morphological properties dependence on substrate temperature in case of ZnTe thin films deposited using thermal evaporation technique.

2. EXPERIMENTAL

Thin films of ZnTe were deposited on an ultrasonically cleaned glass substrates using thermal evaporation technique, under a vacuum of 10^{-6} Torr at different substrate temperatures (303 K, 373 K and 448 K). A polycrystalline ZnTe (99.999 %, Aldrich make) powder was used to deposit 5000 Å thick films at the deposition rate of 5 Å per second. Structural analysis was made using X-ray diffraction technique (XRD) with the help of

CuKα radiation and the surface morphological study was carried out using atomic force microscope in non-contact mode with tungsten carbide tip.

3. RESULTS AND DISCUSSION

3.1 Structural Analysis

The X-ray diffractograms of the thin films deposited at various substrate temperatures are shown in Fig. 1. It is observed that XRD patterns of all three films show a most preferred orientation along (111) plane. Also the most prominent peak is observed nearly at 25.6° for 2θ, which shows that the deposited films possess cubic structure [18]. Structural parameters of the deposited films are given in Table 1. The sharper and intense peaks, in Fig. 1, for films deposited at increased substrate temperatures exhibit an improved crystalline structure of the films. Particle size values also increases with increase in the substrate temperature.

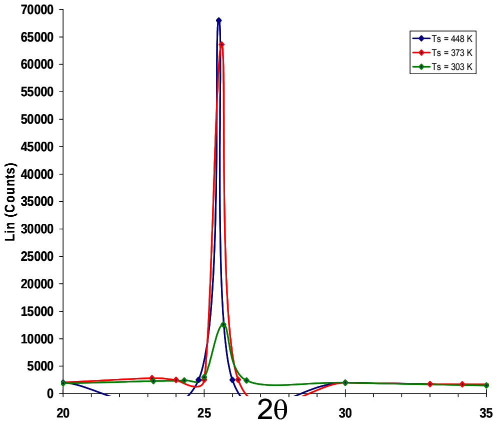


***Fig. 1** – XRD peaks of ZnTe thin films of thickness* 5000 Å, *deposited at various substrate temperatures*

***Table 1** – Structural parameters of ZnTe thin films of thickness* 5000 Å *deposited at various substrate temperatures*

Parameter	T_s = 303 K	T_s = 373 K	T_s = 448 K	JCPDS Values
$a = b = c$ (Å)	6.0038	6.0183	6.0414	6.0700
Unit Cell Volume V (Å)^3	216.4106	217.9844	220.5021	223.6485
X-ray Density ρ (gm × cm^3)	5.9221	5.8794	5.8123	5.7306

3.2 Morphological Analysis

The surface morphology of ZnTe films have been studied using Atomic Force Microscopy. Two dimensional and three dimensional AFM images (5 μm × 5 μm) of the deposited films along with height profile and the power spectrum are shown in Fig. 2.

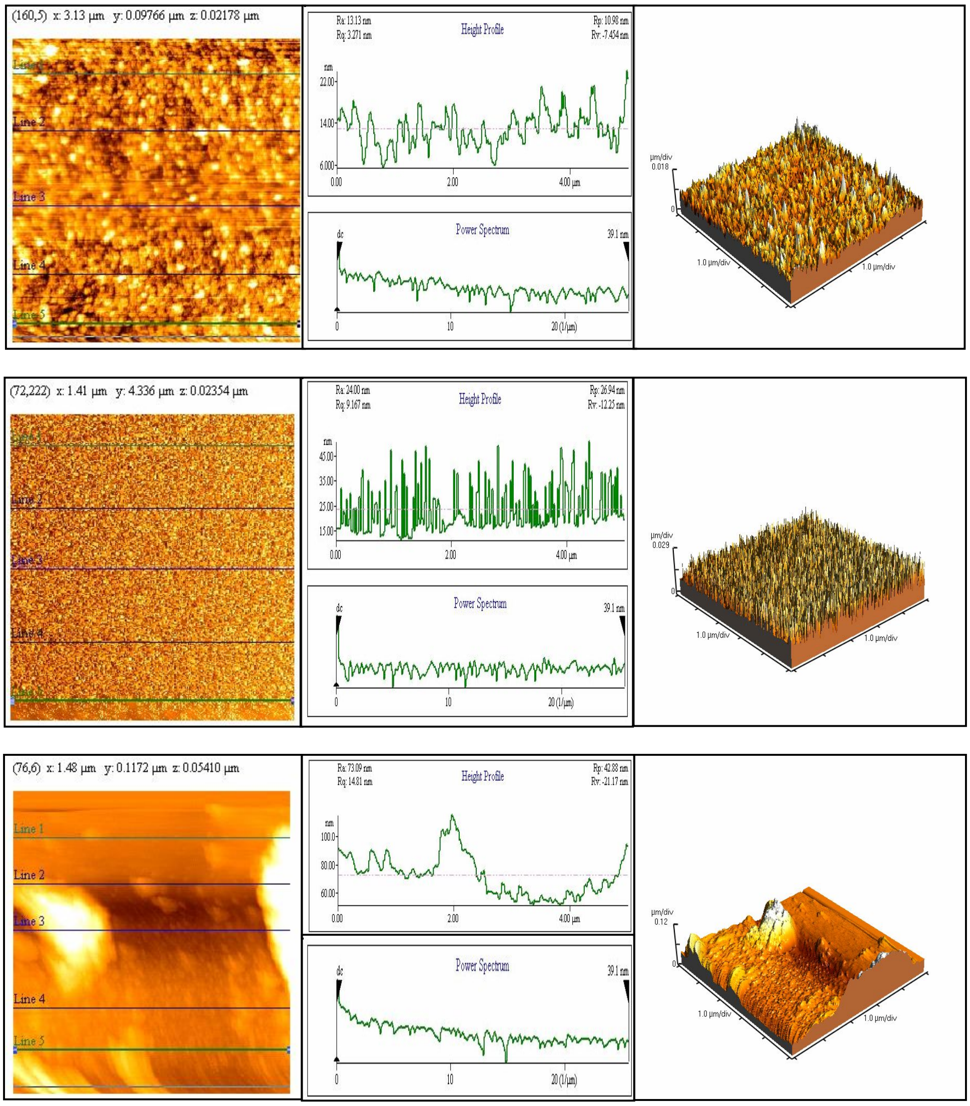
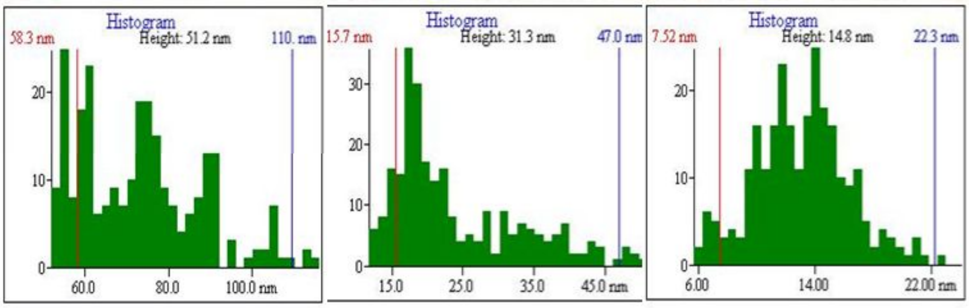


Fig. 2 *– Two and three dimensional images of ZnTe Thin films of Thickness* 5000 Å*, deposited at various substrate temperatures:* T_s = 303 *K (a),* T_s = 373 *K (b),* T_s = 448 *K (c)*

The data obtained from the analysis are given in Table 2. The difference between the rms and average roughness values of line-1 and line-2 (12.87 nm & 24.72 nm) of the film at substrate temperature 303 K is larger than that of the other three lines. This indicates poor smoothness of the film in that area which can be clearly seen in the Fig. 2. In case of the films at substrate temperatures 373 K and 448 K this difference is comparably smaller and is decreases with an increase in substrate temperature, which is the indication of better surface smoothness for the deposited films.



a b c

Fig. 3 – *Histograms of ZnTe thin films of thickness* 5000 Å, *deposited at various substrate temperatures:* $T_s = 303$ *K (a)*, $T_s = 373$ *K (b)*, $T_s = 448$ *K (c)*

Table 2 – *Data obtained from AFM analysis of ZnTe thin films*

Line	Sub. Tem. (k)	$R_{P\text{-}V}$ (nm)	R_{RMS} (nm)	R_{AVG} (nm)	Mean Ht. (nm)	Med. Ht (nm)	Arc Lth (µm)	Bearing Ratio @30% (nm)	Bearing Ratio @80% (nm)	Peak R_P (nm)	Valley R_V (nm)
01	303	124.7	24.72	12.87	73.15	66.61	5.049	71.21	61.27	109.9	-14.79
	373	49.98	11.52	9.558	23.99	21.48	6.069	28.51	13.59	32.66	-17.31
	448	16.86	3.482	2.865	13.14	12.92	5.032	15.04	10.13	9.970	-6.891
02	303	206.8	53.39	39.21	73.12	47.43	5.076	73.21	37.48	164.4	-42.43
	373	44.03	10.31	8.474	23.99	23.29	6.101	29.23	14.19	26.34	-17.69
	448	20.99	4.201	3.126	13.10	12.07	5.032	14.01	9.77	14.62	-6.366
03	303	210.7	68.35	61.26	73.14	30.45	5.150	113.9	19.04	150.8	-59.92
	373	45.73	10.61	8.846	23.98	22.93	5.997	29.36	13.59	26.73	-19.00
	448	11.16	2.387	1.909	13.12	12.82	5.020	14.27	11.12	6.495	-4.665
04	303	44.15	10.74	9.193	73.11	73.15	5.156	80.12	61.87	223.21	-20.94
	373	48.89	10.27	8.404	24.01	22.44	5.935	28.69	15.04	30.09	-18.79
	448	17.59	3.151	2.540	13.06	13.15	5.039	14.85	10.36	9.676	-7.913
05	303	64.05	14.81	11.97	73.09	72.91	5.150	78.49	59.20	42.88	-21.17
	373	39.18	9.161	7.600	24.00	20.25	5.930	27.71	17.10	26.94	-12.25
	448	18.44	3.271	2.585	13.13	13.20	5.025	14.65	10.41	10.98	-7.454

A difference between peak and valley values ($R_{P\text{-}V}$), obtained from the height profile is listed in Table 2. A large difference in the value of $R_{P\text{-}V}$ for all five lines of the image of film at lower substrate temperature (ranging from 44.15 nm to 210.7 nm) shows a poor surface smoothness of that film. The films deposited at higher substrate temperature show relatively low value of $R_{P\text{-}V}$. Thus it is again confirmed by the difference of peak and valley observations made along five arbitrarily scanned horizontal lines of AFM scan that as substrate temperature increases, the surface smoothness improves.

Bearing ratio is the two dimensional projection of three dimensional surface. It gives a percentage of covered area in a film at the particular height. Thus it shows a length of the particle above a horizontal line throughout the distribution. Bearing ratio allows a comparison of roughness data for all three films and it is listed in Table 2. There is a large difference in these values (ranging from 71.21 nm to 113.9 nm @ 30%) and 19.04 nm to 61.87 nm @ 80 %) for the film deposited at $T_s = 303$ K. For other two films with $T_s = 373$ K and 448 K these differences are comparably smaller.

Power spectrum curve is the important parameter in analysis of any rough surface. It determines the contact area between two solids and can provide both, lateral and longitudinal information. A convenient way to describe surface roughness is to represent it in the term of profile heights $z(x, y)$. For a typical digitized AFM scans, the value of x and y are quantized. Thus the power spectra exhibit the overall surface features of the deposited films as shown in Fig. 2. Looking to all three curves it is clear that the curve for the film at $T_s = 303$ K possess an irregular and spread peaks in comparison to that of the other two films. Peaks in the power spectrum indicate the periodicity of the surface and frequency of each peak gives a length that defines this periodic surface. Spread peak exhibits the deviations from average value. The spectrum for the film at $T_s = 373$ K exhibits a sharp peak showing better surface properties.

Mean height, which is the central value of the roughness profile over the evaluation length, decreases as the substrate temperature of the deposited film is increased, showing a better smoothness of the film surface. The median height which is a mid point on the roughness profile over the evaluation length such that half of the data fall above it and half below it, is also inversely proportional to the substrate temperature of the film. In the obtained data, there is a large variations in median value for the film at $T_s = 303$ K, particularly at line number 2 and 3, which can also be seen from the Fig. 3. The large difference in mean and median values of the film deposited at $T_s = 303$ K shows an asymmetric distribution.

The histogram is a continuous bar diagram in which, each column represents the number of image pixels having the height value in a particular range. The histograms for the deposited films are shown in Fig. 2. It indicates a decrease in height from 51.2 nm to 14.8 nm for the films deposited at $T_s = 303$ K to 448 K.

4. CONCLUSION

ZnTe thin films were successfully deposited on the glass substrates using thermal evaporation method at various substrate temperatures. It is clear from structural data that films show better crystalline structure at the higher substrate temperature. It is also clear from the detailed analysis of various AFM parameters like rms and average roughness, mean and median heights, bearing ratio, peak and valley values, power spectrum density and histograms, that at the higher substrate temperatures the deposited films possesses a better smoothness and crystalline structure on its surface, which supports the XRD analysis.

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