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Study on the Aging effect of thermally evaporated ZnTe thin films

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Abstract: Zinc telluride (ZnTe) thin films deposited on suitably cleaned glass substrates by thermal evaporation technique at a vacuum of 10^{-6} Torr., Microstructural properties are studied using X-ray line broadening analysis for the aged thin films. The prepared ZnTe thin films are found to be polycrystalline sphalerite in structure with preferred orientations along [111], [220] and [311] directions. The variation of different structural parameters such as grain size and microstrain with thickness along with different substrate temperatures in fresh and annealed conditions have been reported. The structural parameters of aged thin films were also evaluated and were found to be almost same.

Key words. Aging effect, ZnTe thin films, grain size, microstrain.

1. Introduction

Zinc telluride is an important semiconductor of II-VI family of compound semiconductors and with zincblende structure(a = 6.1026 Å) having a direct band gap 2.21eV at room temperature. ZnTe thin films have found potential applications in large number of optoelectronic devices. Different methods have been successfully applied for deposition of ZnTe thin films on non crystalline and single crystal substrates; physical vapour deposition (PVD) or vacuum evaporation is also important because it gives good quality polycrystalline ZnTe thin films at relatively low cost. In zinc telluride thin films it has been observed that various structural parameters such as grain size and lattice strain, highly influence different photoconducting processes. For better understanding of the device performance of the ZnTe thin films the influence of various structural parameters should be known (Bellakhder et al 2001; Kalita et al 1999; Kalita et al 2000; Nishio et al 1999; Patel and Patel 1984; Winnewisser et al 1997; Sarma et al 2004, Schafler and Zehetbauer 2005).

X-ray diffraction (XRD) method is the oldest but still most powerful technique of structural characterization of thin films. The experimental quantities that can be measured from the XRD data are the angular position, total intensity, line width and the line profile of the Bragg reflections. It is well known that broadening of XRD profile is caused by crystallite size and existence of microstrains and faults in crystalline materials.

In this paper an attempt has been made to evaluate the grain size and micro strain using different techniques. Using the same techniques structural parameters of aged thin films were studied which were found to be almost same

2. Experimental details

Zinc telluride thin films were deposited by thermal evaporation technique on suitably cleaned glass substrates at a vacuum 10^{-6} Torr. using a Hind High Vacuum Coating Unit (HINDHIVAC 12A4). Pure (99.999%) ZnTe bulk sample procured from Koch Light Lab. U.K, was used for deposition. A good quality tantalum boat was used to evaporate the bulk sample. During the time of deposition substrates were kept at elevated temperatures (T_s = 423K) with the help of a radiation heater. The sizes of the thin films used for the X-ray diffraction were about 2cm × 2cm. Thickness of the deposited films was measured using a suitably designed and assembled multiple beam interferometer. Annealing of the thin films were done at temperature 475K for two hours keeping the sample inside a continuously evacuated glass jacket at a vacuum 10^{-2} Torr., using an arrangement consisting of highly sensitive heater, copper-constantan thermocouple and a microvoltmeter.

The x-ray line profile from all the films including the bulk sample were recorded with the help of a Philips X'pert Pro X- ray diffractometer using CuK_{α} radiation. The tube was operated at 40kV and 30mA. Care had been taken to minimize instrumental broadening by using highly stabilized power supply, soller slits and appropriate slits to reduce the divergence of the X-ray beams. The scanning speed of the goniometer was maintained at $0.02^{0}(2\theta)$ /second.

3. Results and discussions

3.1 *Background correction*

Background correction of the x-ray diffraction profiles is very important since the x-ray diffraction parameters e.g. integrated intensity, peak height, integral width, Fourier coefficient and variance of line profiles are affected differently by an improper choice of background level. In ZnTe thin film samples and bulk samples, the background has been taken to be the mean of the two minima adjacent to the peaks.

3.2 *Determination of lattice strain*

The indexing of the lattice planes (hkl) was done with the help of reciprocal lattice method using the angular position of the Bragg reflection profile. A deviation of the measured lattice parameter of the thin film samples from the strain free bulk sample strongly indicates the presence of strain. The origin of the strain, which may be present in the bulk sample also, is related to the lattice misfit that in turn depend upon different growing conditions of the polycrystalline samples. The strain developed in ZnTe bulk sample as well as in thin film samples along different orientations were evaluated using the relation, $\varepsilon = \beta_{2\theta} \cot \theta / 4$, where $\beta_{2\theta}$ is the full width at half maximum of the diffraction peaks along [111],[220] and[311] directions. The evaluated values of strain are shown in table 1,2&3.

Table 1. Evaluated values of lattice parameters of bulk sample and of fresh ZnTe sample.

Lattice plane	For bulk sample		t = 1878Å		t =778Å	
	D in Å	ε in 10^{-3}	D in Å	ε in 10^{-3}	D in Å	ε in 10^{-3}
111	456	3.62	164	10.01	176	9.46
220	416	2.43	168	6.05	169	6.03
311	426	2.02	165	5.26	176	4.94

Table 2. Evaluated values of lattice parameters of bulk sample and of annealed ZnTe sample.

Lattice plane	For bulk sample		t = 1878Å		t =778Å	
	D in Å	ε in 10^{-3}	D in Å	ε in 10^{-3}	D in Å	ε in 10^{-3}
111	456	3.62	200	8.31	185	9.01
220	416	2.43	160	6.35	201	5.06
311	426	2.02	166	5.22	178	4.86

Table 3. Evaluated values of lattice parameter aged thin film of ZnTe sample

Lattice plane	For bulk sample		t = 1878Å		t =778Å	
	D in Å	ε in 10^{-3}	D in Å	ε in 10^{-3}	D in Å	ε in 10^{-3}
111	455	3.52	198	8.29	184	9.00
220	418	2.45	162	6.36	203	5.07
311	424	2.00	164	5.00	175	4.84

3.3 *Determination of particle size*

It has been observed that the XRD patterns of all ZnTe thin films show most preferred orientations along [111],[220] and[311] planes. The grain size of the deposited thin films in fresh and annealed conditions were estimated using the Scherrer formula, $D = K\lambda / \beta_{2\theta} \cos\theta$, where K is taken as 0.94, λ is the wave length of x-ray used and $\beta_{2\theta}$ is the pure integral width which is assumed to be equal to the full width at half maximum of the diffraction peaks along [111],[220] and[311] directions. The evaluated values of the particle size are shown in table 1,2&3.

4. Conclusions

The different evaluated values of grain size and strain along different orientations indicate that the strain in the grown polycrystalline thin films are anisotropic in nature (Bhoumik et al 2000). It has been confirmed from x –ray diffraction of the aged thin films are also polycrystalline in nature. So it can be used for different appliances.

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