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EFFECT OF PREFERRED ORIENTATION ON PHOTOVOLTAGE OF CdTe THIN FILMS

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Photovoltaic property of angularly deposited CdTe films is studied by the X-ray diffraction. The variation of photovoltage of the film deposited at different angles and different substrate temperatures are co-related with the preferential orientation of the crystallites. The magnitude of the photo-e.m.f. developed is dependent on the relative number of planes having {2 2 0} and {3 1 1} orientation and corresponding optical absorption.

INTRODUCTION

IT HAS been already observed [1–4] that thin films of CdTe develop appreciable photovoltage if there is an oblique angle of deposition of the vapour onto the substrate. Previously some workers [2, 4, 5] tried to correlate the dependence of photovoltage with microstructure with the help of electron microscopy only. In the present work we have studied the dependence of photovoltage with different parameters like crystallite size, preferred orientation, angle of inclination during deposition, substrate temperature and optical absorption coefficient α. An attempt is made to correlate the results.

EXPERIMENTAL DETAILS

The films are deposited by evaporating specpure CdTe powder from a quartz crucible placed in an inclined tungsten coil in a vacuum of the order of 10^{-4} Pa on a properly cleaned glass substrates with a Hind Hivac Vacuum Coating Unit (model 12-A4). The rate of deposition is maintained constant $3.5\,\text{nm}\,\text{s}^{-1}$. The thickness of the film is measured with a surfometer (SF101). X-ray diffraction data are recorded with a Philips X-ray diffractometer using monochromatic CuKα radiation. The photovoltage is measured by using a Keithley Electrometer (610C). A tungsten filament lamp is used as the source of light and the intensity of the light falling on the sample, determined with the help of Eppley Thermopile, is maintained constant at $300\,\text{mW}\,\text{Cm}^{-2}$ in all cases. The films deposited in vacuum and exposed to the atmosphere after deposition are found to be *p* type as determined by thermoelectric measurements. The absorption of the films are studied at the optical absorption edge of CdTe by a Carl Zeiss (VSU2P) spectrophotometer.

RESULTS AND DISCUSSION

The X-ray diffraction patterns show that the CdTe films deposited on glass substrates are of polycrystalline nature. The values of the integrated intensity were determined from the areas of the different peaks. The relative values of the intensities of the peaks as compared to the bulk values gives an idea about the preferential orientation of the planes parallel to the substrates. The size of the crystallites were determined from the Scherrer formula

$$P = (K\lambda)/\beta\cos\theta$$

where P is the crystallite size, λ is the wavelength of the X-rays, θ is the Bragg angle, β the width of the peak at half the maximum intensity and K is a constant of proportionality usually taken as equal to unity.

The values of the observed intensities, crystallite sizes and the photovoltage for thin films deposited at different angles of inclination are shown in Table 1. It is observed that the photovoltage increases gradually with the angle of inclination and attains a maximum value at about 30°. At higher inclinations there is a fall in the value of the photovoltage. The relative values of the intensities for the bulk CdTe are 100, 60 and 30 for {1 1 1}, {2 2 0} and {3 1 1} reflections respectively (Powder Diffraction File). By comparing the intensities in the present case it is observed that the films are preferentially oriented with most of crystallites having their {1 1 1} planes parallel to the plane of the substrates. At 0° inclination (i.e. at normal incidence on the substrate) the {1 1 1} preferred

Table 1. Variation of different parameters with angle of inclination during deposition for CdTe films (1 μm *thick*) *deposited at* 230°C *substrate temperature*

Angle of deposition (degree)	*hkl*	Integrated intensity (arb unit)	Crystallite size (Å)	α at absorption edge (cm^{-1})	Photovoltage (volt/cm)
0	1 1 1	1410	400	3.76×10^4	.05
	3 1 1	37	200		
15	1 1 1	1050	485	4.31×10^4	16
	2 2 0	33	425		
	3 1 1	36	320		
30	1 1 1	350	530	4.74×10^4	60
	2 2 0	52	425		
	3 1 1	39	435		
45	1 1 1	710	450	4.02×10^4	1.6
	2 2 0	50	210		
	3 1 1	48	275		

orientation is maximum with {1 1 1} peak very strong, {2 2 0} peak absent and {3 1 1} peak very weak. I_{220}/I_{111} for 0, 15, 30 and 45 degree inclination is observed to be 0, 0.031, 0.148 and 0.07 respectively. Similarly I_{311}/I_{111} is observed to be 0.026, 0.034, 0.114, 0.067 for the different inclinations. Thus it is observed that with inclination the number of crystallites having {2 2 0} and {3 1 1} orientation increases till 30° and then falls. The values of the crystallite size also increases in all the three directions with inclination, attains a maximum value at about 30 degrees and then fall. Thus a correspondence in the photovoltage, crystallite size, preferred orientation of crystallites is observed. The photovoltage for 15° inclination is more than that for 45° degree inclination possibly because of the larger crystallite size in the former case.

The variation of the different parameters with substrate temperature have also been studied for a fixed inclination of 30°. (At which inclination the photovoltage is maximum.) The results are shown in Table 2. It is observed that with increase in the substrate temperature the relative number of planes having {2 2 0} and {3 1 1} orientations, the corresponding crystallite size values and the photovoltage values increase.

The variation of optical absorption coefficient (α) with angle of inclination and substrate temperature shows that absorption is maximum for films deposited obliquely at an angle 30° and substrate temperature 230° C. The values of α at absorption edge are shown in Table 1 and Table 2.

So it can be concluded that with increase in

Table 2. Variation of different parameters with substrate temperature for CdTe films (1 μm *thick*) *deposited at* 30° *inclination*

Substrate temperature (° C)	*hkl*	Integrated intensity (arb unit)	Crystallite size (Å)	α at absorption edge (cm^{-1})	Photovoltage (volt/cm)
30	1 1 1	2500	345	3.03×10^4	0
150	1 1 1	1480	450	4.31×10^4	10
	3 1 1	33	340		
230	1 1 1	350	530	4.74×10^4	60
	2 2 0	52	425		
	3 1 1	39	435		

crystallite size, and {2 2 0} and {3 1 1} orientation there is an increase in the absorption of light and photovoltage. All the above parameters exhibit optimum values at 30° inclination and maximum substrate temperature.

The increase of optical absorption with the increase of {2 2 0} and {3 1 1} orientation may be due to smaller interplanar spacings compared to {1 1 1} orientation. As a result the number of planes in an unit cell for {2 2 0} and {3 1 1} orientations will be large. Therefore the optical absorption coefficient is greater when all these orientations are present as comparison to the presence of only {1 1 1} orientation.

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