Effect of the Thickness and Annealing Temperature on the Structural Properties of Thin CdS Films Prepared by Thermal Evaporation

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Abstract

A thin CdS Films have been evaporated by thermal evaporation technique with different thicknesses (500, 1000, 1500 and 2000Å) and different duration times of annealing (60, 120 180 minutes) under 573 K annealing temperature, the vacuum was about 8×10^{-5} mbar and substrate temperature was 423 K. The structural properties of the films have been studied by X- ray diffraction technique (XRD). The crystal growth became stronger and more oriented as the film thickness (T) and duration time of annealing (T_a) increases.

Keywords
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تأثير السمك ودرجة حرارة التلدين على الخواص التركيبية لأغشية CdS الرقيقة المحضرة بطريقة التبخير الحراري

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الخلاصة:

حضرت أغشية كبريتيد الكادميوم بتقنية التبخير الحراري بسمك مختلفة (٥٠٠، ١٠٠٠، ١٥٠٠ و ٢٠٠٠ أنكستروم) ، و لدنت بدرجة حرارة ٥٧٣ درجة مطلقة لأزمنة تلدين مختلفة (٦٠، ١٢٠ و ١٨٠ ثانية) وكان مقدار الفراغ ٨×١٠^{-٥} و بدرجة حرارة أرضية ٤٢٣ مطلقة . تم دراسة الخواص التركيبية للأغشية بتقنية حيود الأشعة السينية، ووجد أن النمو البلوري أصبح أكبر و أكثر اتجاهية بزيادة السمك و زمن التلدين.

Introduction

CdS is considered at present one most promising materials for photonic devices. It has also high absorption coefficient in the visible range of the solar spectrum and its band gap is closed to the optimum value for efficient solar energy conversion. The material can be prepared in n- type and p-type forms so that solar cells can be formed in both homojunction and heterojunction configurations [1]. CdS films have been prepared by by several method, such as chemical bath deposition, electrodeposition, pulsed laser deposition and rf magnetron sputtering. Since nonvacuum techniques of films deposition are inherently susceptible to contamination[1], only vacuum-deposition technique has been studied in this paper.

Experimental

CdS thin films have been deposited by thermal evaporation technique in

vacuum higher than 8×10^{-5} mbar under controlled growth conditions of different thicknesses (500, 1000, 1500 and 2000 $\overset{0}{A}$.), the films have been annealed at 573K for different duration times of annealing (60, 120 and 180 min.) . The films thicknesses were investigated by weight method, under substrate temperature about 423 K. CdS starting material with 99.999 % purity. The glass slide substrates were cleaned with acetone, ethanol, and rinsed with deionised water in an ultrasonic cleaner and finally etched in a 10% HF solution. The crystal structure of these films was checked by x-ray diffraction technique using CuKα . the grain size (D) was calculated using XRD analysis from Scherrer relation [2]

$$D = 0.9\lambda/\beta\cos\theta$$

Where λ is X-ray wavelength, β is the angular width at half maximum intensity (full width at half maximum intensity (FWHM)) and θ is the diffraction angle (Bragg angle). The grain size (D)was calculated using FWHM of (002) plane.

Results and Discussion

Figure (1) illustrates the x-ray diffraction spectra for *CdS* powder and films which were prepared by thermal evaporation technique and annealed at 573 K. The spectra of *CdS* powder and films are compared with ASTM cards of *CdS* structure, and indicated a polycrystalline structure of pure hexagonal phase. This result is in agreement with those of El-Assali *et al* [3], and Punnoose *et al*. [4]. The spectrum of *CdS* powder exhibited sharp peaks at (100), (002), (101), (102), (110), (103) and(112), and weak peaks at (004) and (202).

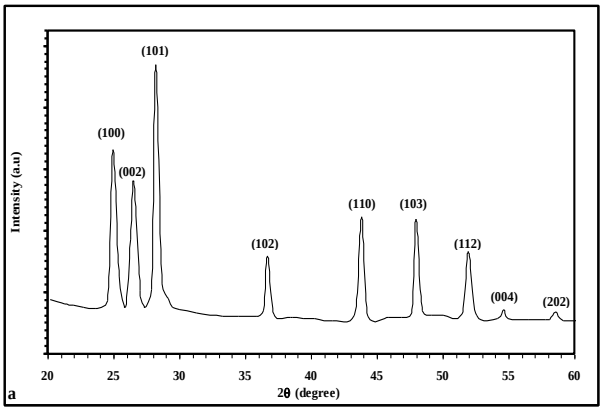

Fig. (1) The x-ray diffraction spectra for CdS Powder

1. The Effect of annealing

The x-ray diffraction spectra for 500Å thick of the as deposited film displayed strong reflection at (002) plane and very low intensity peaks of (100), (101), (102), (110), (103), (112), (004) and (202).

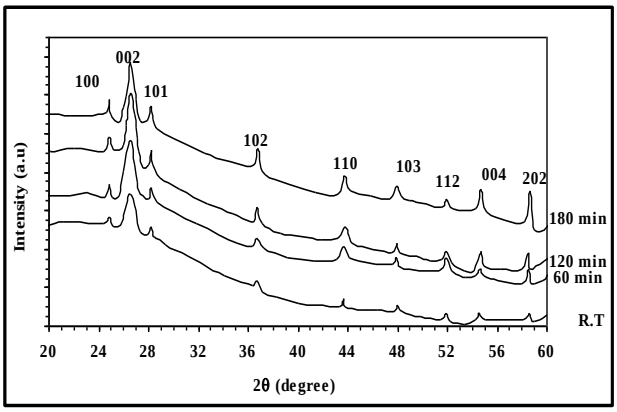

Fig. (2) x-ray diffraction of 500 Å thin CdS films for different duration times of annealing

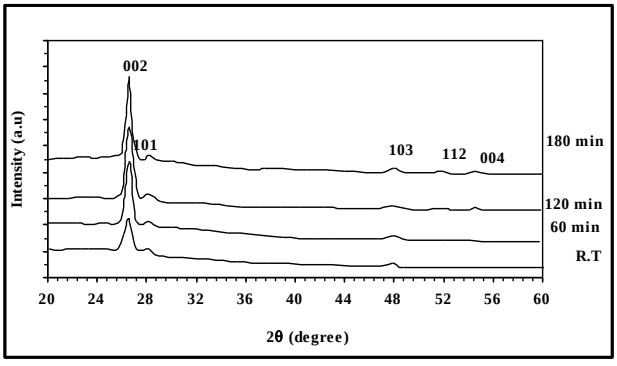

Fig.(3) ***x-ray diffraction spectra of 1000*** **Å** ***thin CdS films for different duration times of annealing***

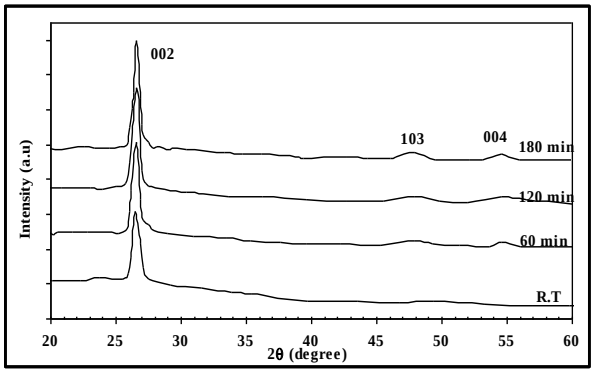

Fig.(4) ***x-ray diffraction spectra of 1500 Å thin CdS films for different duration times of annealing***

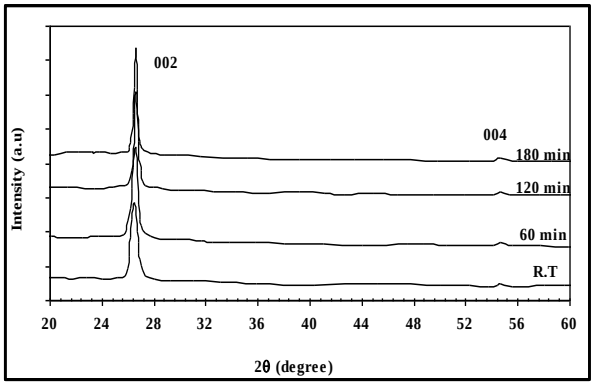

Fig.(5) x-ray diffraction spectra of 2000 Å thin CdS films for different duration times of annealing

However after annealing the samples for 60 min. the XRD patterns showed one significant peak, but one expected an improvement in crystallinity, spatially after annealing for 120 and 180 min. one can observe an increasing in the intensity of peaks and decreasing in FWHM, which means increasing the crystal growth and the grain size, these results indicate that the process of grains formation is thermally activated[4].

The x-ray diffraction for 1000, 1500 and 2000 Å thick showed in figs.(3), (4), and (5). We can observe that the (002) plane stilled the preferred orientation, and the structural improvement is obviously, where the increasing of the duration times of annealing causes an increasing in the intensity of peaks and decreasing in FWHM. Other peaks disappeared consequently except (004), this result is due to the re-arrangement happened throw the annealing. This result is in agreement with those of El-Assali *et al.* [3] and Punnoose *et al.* [4].

The grain size for CdS films at different duration times of annealing showed in fig.(6) and table (2). The grain size increasing clearly throw the annealing because of the improvement in the structure. This improvement may be attributed to recrystallization of the films structure [2]. the re-crystallization, spatially after 120 min. this result coincides with Rasha [5].

Other structural parameters of thin CdS films were tabulated in table (1)

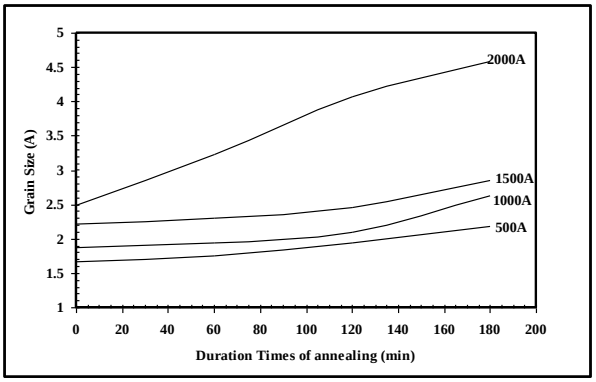

Fig.(6) duration times of annealing Vs grain size

2. The effect of thicknesses

The as-deposited CdS films grown on slide glass substrates is hexagonal wurtzite structure with a preferential orientation of the (002) diffraction plane. The dependence of X-ray diffraction intensity on film thickness was shown in Figs. (7, 8, 9 and 10).

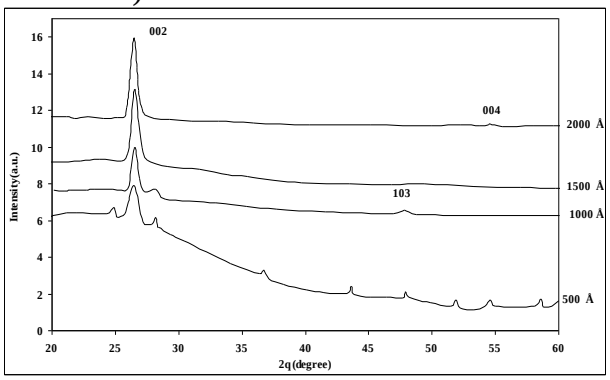

Fig.(7) x-ray diffraction spectra of thin CdS films as deposited for different thicknesses

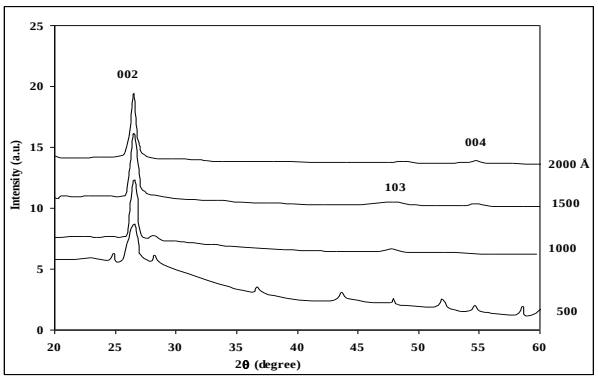

Fig.(8) x-ray diffraction spectra of thin CdS films annealing at 573K for 60 min. for different thicknesses

The thickness had a pronounced effect on the x-ray diffraction spectra of the CdS thin films as shown in Figs. (7, 8, 9 and 10) and table (1). A comparison between the spectra of the films shows that there is more crystallization and more orientation of the crystal growth in the case of the thicker film. The plane (002) became more stronger than the other planes. This structural improvement due to increasing the crystallite. These results coincide with Shadia et al[6], and Ngamnit et al **[1]**.

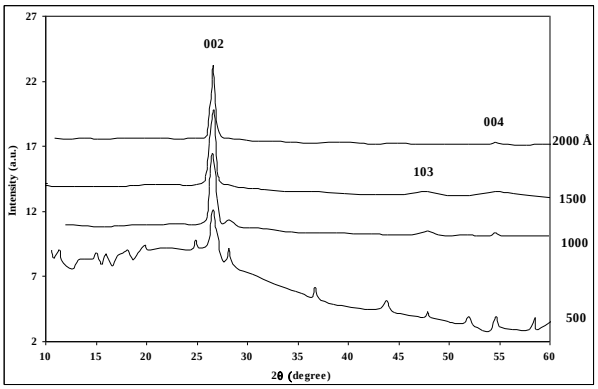

Fig.(9) x-ray diffraction spectra of thin CdS films annealing at 573K for 120 min. for different thicknesses

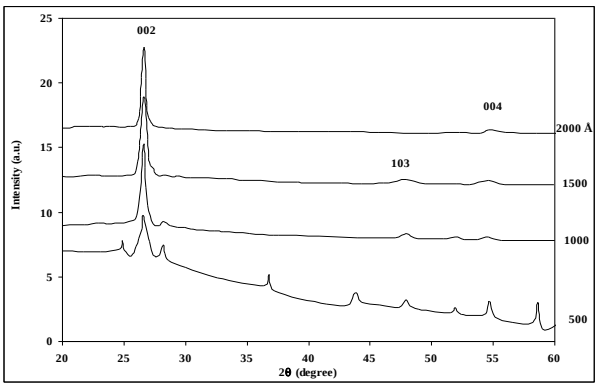

Fig.(10) x-ray diffraction spectra of thin CdS films annealing at 573K for 180 min. for different thicknesses

Fig. (11) showed the relation between the grain size and the thickness, a slight increasing in the grain size values before 1000 Å, but after 1500 a clearly increasing in the grain size values. Table (2) showed the grain size for CdS films after annealing for different thicknesses.

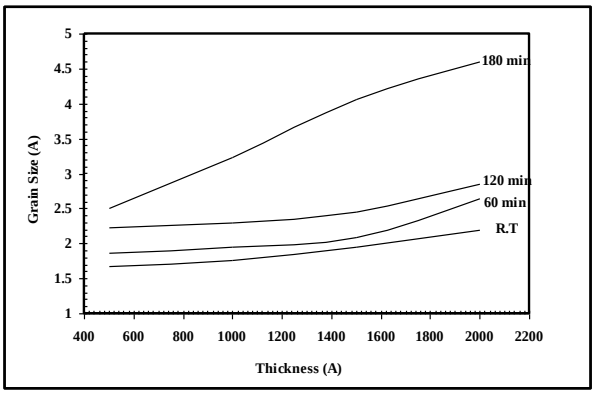

Fig.(11) Thicknesses Vs grain size

Table (1) Shows the structural parameters of thin CdS films for different thickness

	hkl	2θ	$(I/I_0)_{stnd.}$	$d_{stan.}$(Å)	$(I/I_0)_{exp.}$	$d_{exp.}$(Å)
CdS alloy	100	24.9	62	3.694	70.6	3.573
	002	26.6	91	3.341	59.3	3.348
	101	28.2	100	3.15	100	3.162
	102	36.7	29	2.44	34.1	2.447
	110	43.8	48	2.064	47.62	2.066
	103	47.9	50	1.895	46.72	1.898
	112	51.9	31	1.758	35.51	1.761
	004	54.6	5	1.667	15.39	1.680
	202	58.6	3	1.572	14.55	1.574
500 Å	hkl	2θ	$(I/I_0)_{stnd.}$	$d_{stan.}$(Å)	$(I/I_0)_{exp.}$	$d_{exp.}$(Å)
at RT	100	24.87	62	3.737	5.89	3.577
	002	26.5	91	2.992	28.15	3.361
	101	28.17	100	1.953	6.71	3.165
	102	36.7	29	1.62	3.60	2.447
	110	43.61	48	3.747	6.06	2.074
	103	48	50	2.768	5.24	1.898
	112	51.91	31	2.287	5.73	1.760
	004	54.6	5	1.928	5.56	1.680
	202	58.55	3	3.726	5.89	1.575
at 60 min	100	24.87	62	3.737	5.89	3.577
	002	26.5	91	2.992	50.25	3.361
	101	28.2	100	1.953	8.84	3.162
	102	36.71	29	1.62	7.53	2.446
	110	43.67	48	3.747	9.00	2.071
	103	48	50	2.768	5.56	1.898
	112	51.91	31	2.287	7.04	1.760
	004	54.6	5	1.928	9.98	1.679
	202	58.6	3	3.726	11.62	1.574
at 120 min	100	24.87	62	3.737	10.80	3.577
	002	26.5	91	2.992	51.06	3.348
	101	28.2	100	1.953	12.93	3.162
	102	36.71	29	1.62	12.77	2.446
	110	43.8	48	3.747	10.64	2.065
	103	48	50	2.768	7.20	1.898
	112	51.91	31	2.287	7.04	1.760
	004	54.6	5	1.928	12.60	1.678
	202	58.55	3	3.726	14.73	1.575
at 180 min	100	24.87	62	3.737	12.44	3.577
	002	26.5	91	2.992	51.88	3.348
	101	28.2	100	1.953	13.58	3.162
	102	36.78	29	1.62	14.89	2.441
	110	43.82	48	3.747	12.27	2.064
	103	48	50	2.768	8.18	1.898
	112	51.91	31	2.287	7.20	1.760
	004	54.6	5	1.928	16.86	2.143
	202	58.62	3	3.726	25.70	1.573

1000 Å	hkl	2θ	$(I/I_0)_{stnd.}$	$d_{stan.}$(Å)	$(I/I_0)_{exp.}$	$d_{exp.}$(Å)
at RT	002	26.5	91	2.992	37.48	3.361
	101	28.19	100	1.953	2.62	3.163
	103	47.8	50	2.768	2.45	1.901
at 60 min	002	26.5	91	2.992	78.07	3.348
	101	28.2	100	1.953	3.11	3.162
	103	47.87	50	2.768	3.27	1.899
at 120 min	004	26.6	91	2.992	88.38	3.348
	101	28.2	100	1.953	3.76	3.162
	103	47.87	50	2.768	4.26	1.899
	112	51.91	31	2.287	2.13	1.761
	004	54.6	5	1.928	3.76	1.680
at 180 min	002	26.65	91	2.992	96.07	3.348
	101	28.2	100	1.953	5.24	3.162
	103	47.92	50	2.768	5.24	1.897
	112	51.88	31	2.287	3.11	1.761
	004	54.6	5	1.928	4.09	1.680
1500 Å	hkl	2θ	$(I/I_0)_{stnd.}$	$d_{stan.}$(Å)	$(I/I_0)_{exp.}$	$d_{exp.}$(Å)
at RT	002	26.5	91	2.992	63.67	3.361
at 60 min	002	26.5	91	2.992	81.34	3.348
	103	47.9	50	2.768	3.76	1.898
	004	54.6	5	1.928	3.44	1.680
at 120 min	002	26.6	91	2.992	90.51	3.348
	103	47.9	50	2.768	4.09	1.898
	004	54.6	5	1.928	4.75	1.680
at 180 min	002	26.65	91	2.992	98.04	3.348
	103	47.9	50	2.768	4.75	1.898
	004	54.6	5	1.928	6.22	1.680
`2000 Å	hkl	2θ	$(I/I_0)_{stnd.}$	$d_{stan.}$(Å)	$(I/I_0)_{exp.}$	$d_{exp.}$(Å)
at RT	002	26.5	91	2.992	70.87	3.361
	004	54.6	5	1.928	2.29	1.680
at 60 min	002	26.5	91	2.992	81.67	3.348
	004	54.6	5	1.928	2.95	1.680
at 120 min	002	26.6	91	2.992	93.29	3.348
	004	54.6	5	1.928	3.44	1.680
at 180 min	002	26.65	91	2.992	100.00	3.348
	004	54.6	5	1.928	3.76	1.680

Table (2) the grain size of thin CdS films prepared by thermal evaporation

Duration times of annealing	thicknesses	500 Å	1000Å	1500 Å	2000 Å
RT		1.6758	1.8743	2.2257	2.4990
60 min		1.7586	1.9517	2.2973	3.2377
120 min		1.9517	2.0950	2.4562	4.0706
180 min		2.1919	2.6384	2.8495	4.5960

Conclusions

Good quality, adherent, uniform and pine-hole free CdS films with different thicknesses are obtained by thermal evaporation method. The films have hexagonal wurtzite structure with a preferential orientation of (002) plane. The larger grain size was at 180 min. and 2000Å.

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