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STRUCTURAL AND ELECTRICAL PROPERTIES OF (CDO)1-X (V2O5)X PREPARED BY PULSE LASER DEPOSITION TECHNIQUE FOR SOLAR CELL APPLICATIONS

Asmaa Natiq Mohammed ALI[1], Lamia K. ABBAS[2] & Ihab Abbas TAHER[3]

Abstract

In this work ,pure and doped(CdO)thin films with different concentration of V2O5x (0.0, 0.05, 0.1) wt.% have been prepared on glass substrate at room temperature using Pulse Laser Deposition technique(PLD).The focused Nd:YAG laser beam at 800 mJ with a frequency second radiation at 1064 nm (pulse width 9 ns) repetition frequency (6 Hz), for 500 laser pulses incident on the target surface At first ,The pellets of (CdO)1-x(V2O5)x at different V2O5 contents were sintered to a temperature of 773K for one hours.Then films of (CdO)1-x(V2O5)x have been prepared.The structure of the thin films was examined by using (XRD) analysis..Hall effect has been measured in orded to know the type of conductivity, Finally the solar cell and the efficiency of the CdO:V2O5 cells have been studied.

Keywords: Pulsed Laser Deposition, Structural Properties.Hall Measurements, Solar Cell.

[1] Baghdad University, Iraq, asmaa.natiq23@gmail.com, https://orcid.org/0000-0003-1331-9582
[2] Baghdad University, Iraq
[3] Al-Muthanna University, Iraq, ehab_abass@mu.edu.iq, https://orcid.org/0000-0002-1501-7652

1. Introduction

Transparent Conducting Oxides (TCOs) have long been a subject of various investigations due to its unique physical properties and applications in commercial devices successfully used for many applications, including phototransistors, gas sensor, solar cells, liquid crystal displays, IR detectors and anti-reflection coating The group of IIB-VIA oxides have presented a great deal of interest because of their applications in various technologies [1]. The semiconducting compounds of this group crystallize mostly in the zincblende (B3), wurtzite (B4), or both structures. CdO has attracted attention as a transparent conducting oxides (TCOs) because of its (i) band gap (~2.5 eV), (ii) high conductivity, (iii) ease in doping, (iv) chemical stability in hydrogen plasma, (v) abundance in nature and no toxicity[2,3]. Cadmium oxide is also a (II-VI) of table periodic elements, n-type semiconductor with donor defects, such as Cd interstitials and oxygen vacancies. CdO thin films are prepared by many physical and chemical techniques, various techniques such as thermal evaporation, sputtering, and solution growth and pulsed laser sputtering [4]. CdO films have a cubic structure such as NaCl (rock-salt), lattice constant equal 4.69 Å and unit cell of face center cubic (FCC) [5]as CdO is a promising candidate for a transparent conducting oxide material because it has a simple rock-salt crystal structure, high carrier mobility, and high conductivity, which is due to the nonstoichiometric property which resulted from oxygen vacancies in cadmium [6].In this research the essential aim of work to prepare a pure CdO thin films and doped V2O5 using PLD technique at different concentration (0.0, 0.05, 0.1) wt.% . and study the structural, electrical properties and solar cell efficiency of these prepared samples.

2.Experimental Part

CdO nanoparticles with different concentrations ofV2O5was pressed under a 5 ton to form a target of 1.5 cm and 0.2 cm diameter and thickness respectively. It should be as dense and homogeneous as much as possible to ensure a good quality of the deposit The $(CdO)_{1-x}(V_2O_5)_x$ films were deposited on glass substrates of (2.5×7.5 cm) which are cleaned with dilated water using ultrasonic process for 15 minutes and placed in front of the target with its surface parallel to that of the target. to deposit the films at room temperature by PLD technique using Nd:YAG with (λ = 1064 nm) at energy 800 mJ, repetition frequency (6Hz) for 500 laser pulse is incident on the target surface making an angle of 45° with it . The focused Nd:YAG switching laser beam coming through a window is incident on the target surface making an angle of 45° with it. The substrate Sufficient gap is kept between the target and the substrate, The distance between the target and the laser was set to (10 cm), and between the targe and the substrate was (1.5 cm), under vacuum of (1×10^{-3}mbar). Si wafer (111) was used as a starting substrate in the electro chemical etching to prepared solar cell. The samples were cut from the wafer and rinsed with acetone and methanol to remove dirt. In order to remove the native oxide layer on the samples, they were etched in diluted HF acid (10:90).In order to study the structural properties, the crystal structure is analyzed with a SHIMADZU 6000 X-ray diffract meter system which records the intensity as a function with wavelength of Bragg's angle. The source of radiation is Cuk(λ =1.5406Å.).The solar cell efficiency was measured for the samples.

3.Result and Discussion

Fig. (1)and Fig.(2) show the X-ray diffraction patterns for pure and doped CdO with different doping ratio of V2O5(0.0, 0.05, 0.1) wt.%..prepared at RT and annealed to 373K respectively . The presence of different peaks in the figure shows that the films are polycrystalline in nature with referential orientation along the (111) crystal plane with data of thin films coincides with that of known cubic structure. We can noticed from x-ray pattern that the peaks (2θ=32.93, 38.18, 55.282 ,65.84, 69.114) referred to {(111),(200),(220), (311), (222)} direction , respectively for films prepared atRT. These peaks shifted to {2θ=33.0747, 38.3570, 55.2377, 66.0445 , 69.2608} corresponding to {(111),(200),(220), (311), (222)} direction respectively when films annealed to 373 K. Tabl2 (1) and table (2) show the experiment of standard peaks from International Centre for Diffraction. There are no additional peaks without V2O5 upon doping indicates the solubility of the doping in the crystal structure.these result agreed with [7,8,9]

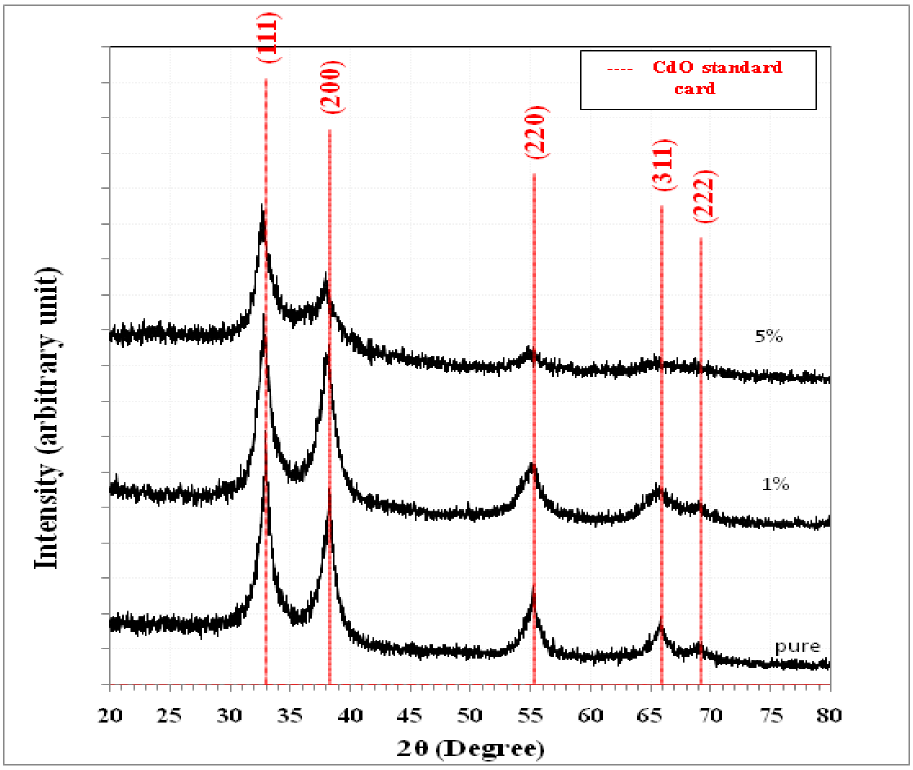


Figure (1) X-ray diffraction patterns of deposited CdO films doped with different concentration of V2O5 prepared at RT

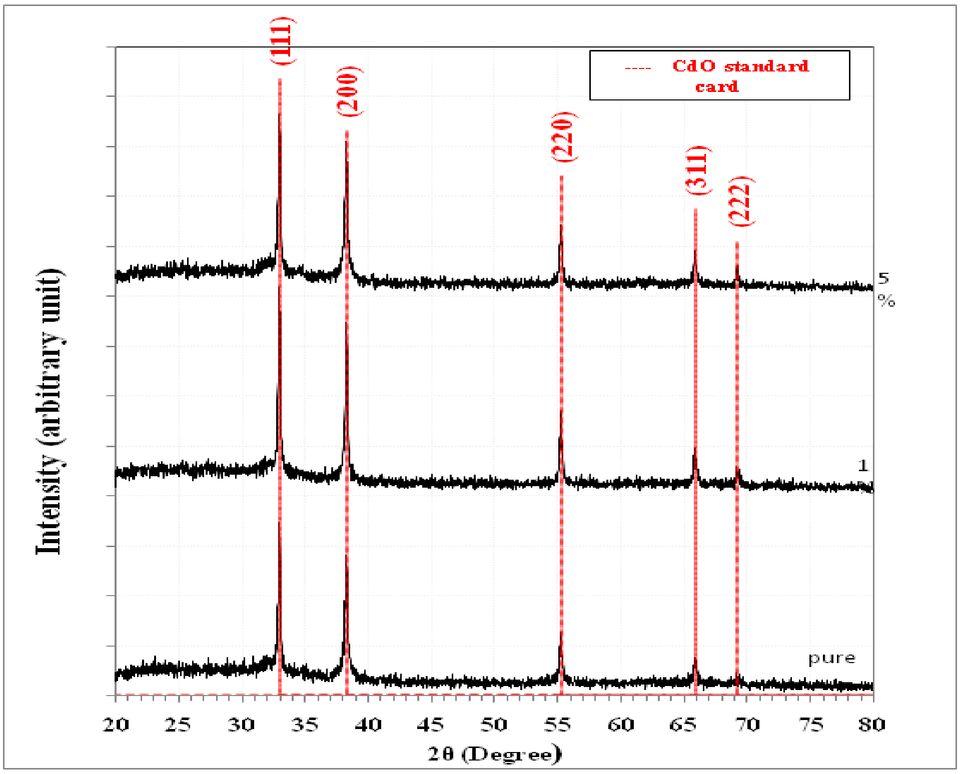


Figure (2) X-ray diffraction patterns of deposited CdO films doped with different concentration of V2O5 prepared at Ta=373K

Table (1) Structural parameters: 2θ, dhkl, (hkl), FWHM ad G.S of deposited CdO films doped with different concentration of V2O5 prepared at RT

Sample	2θ (Deg.)	FWHM (Deg.)	d_{hkl} Exp.(Å)	G.S (nm)	d_{hkl} Std.(Å)	Phase	hkl	card No.
pure	32.9349	1.1526	2.7174	7.2	2.7108	Cub. CdO	(111)	96-900-8610
	38.1857	1.0886	2.3549	7.7	2.3477	Cub. CdO	(200)	96-900-8610
	55.2828	1.6649	1.6604	5.4	1.6600	Cub. CdO	(202)	96-900-8610
	65.8485	1.1527	1.4172	8.2	1.4157	Cub. CdO	(311)	96-900-8610
	69.1142	1.6648	1.3580	5.8	1.3554	Cub. CdO	(222)	96-900-8610
1%	32.8068	1.2806	2.7277	6.5	2.7108	Cub. CdO	(111)	96-900-8610
	38.1217	1.4087	2.3587	6.0	2.3477	Cub. CdO	(200)	96-900-8610
	55.0267	1.7929	1.6675	5.0	1.6600	Cub. CdO	(202)	96-900-8610
	65.8485	1.9851	1.4172	4.8	1.4157	Cub. CdO	(311)	96-900-8610
	69.1782	1.0885	1.3569	8.9	1.3554	Cub. CdO	(222)	96-900-8610
5%	32.6147	1.7930	2.7433	4.6	2.7108	Cub. CdO	(111)	96-900-8610
	37.8655	1.6648	2.3741	5.0	2.3477	Cub. CdO	(200)	96-900-8610
	54.8986	2.3052	1.6711	3.9	1.6600	Cub. CdO	(202)	96-900-8610
	65.3362	2.2412	1.4271	4.2	1.4157	Cub. CdO	(311)	96-900-8610

Table (2) Structural parameters: 2θ, dhkl, (hkl), FWHM ad G.S of deposited CdO films doped with different concentration of V2O5 prepared at Ta=373K

x	2θ (Deg.)	FWHM (Deg.)	d_{hkl} Exp.(Å)	G.S (nm)	d_{hkl} Std.(Å)	Phase	hkl	card No.
pure	33.0747	0.3401	2.7062	24.4	2.7108	Cub. CdO	(111)	96-900-8610
	38.3570	0.4225	2.3448	19.9	2.3477	Cub. CdO	(200)	96-900-8610
	55.2377	0.3114	1.6616	28.8	1.6600	Cub. CdO	(202)	96-900-8610
	66.0445	0.4197	1.4135	22.6	1.4157	Cub. CdO	(311)	96-900-8610
	69.2608	0.2557	1.3555	37.8	1.3554	Cub. CdO	(222)	96-900-8610
1%	33.1410	0.2280	2.7010	36.4	2.7108	Cub. CdO	(111)	96-900-8610
	38.3152	0.2974	2.3473	28.3	2.3477	Cub. CdO	(200)	96-900-8610
	55.2949	0.2071	1.6600	43.3	1.6600	Cub. CdO	(202)	96-900-8610
	66.0048	0.3339	1.4142	28.4	1.4157	Cub. CdO	(311)	96-900-8610
	69.3774	0.3122	1.3535	30.9	1.3554	Cub. CdO	(222)	96-900-8610
5%	33.0181	0.3326	2.7107	24.9	2.7108	Cub. CdO	(111)	96-900-8610
	38.2592	0.3493	2.3506	24.1	2.3477	Cub. CdO	(200)	96-900-8610
	55.2554	0.2430	1.6611	36.9	1.6600	Cub. CdO	(202)	96-900-8610
	66.0338	0.3787	1.4137	25.0	1.4157	Cub. CdO	(311)	96-900-8610
	69.2768	0.3316	1.3552	29.1	1.3554	Cub. CdO	(222)	96-900-8610

The full width at half maximum (FWHM) of the peak (in radians), is a measure of the size of the grains in a polycrystalline film, by Scherrer's equation [10]:

$$D=\frac{0.94\lambda}{\beta\cos\theta} \quad \text{...} 1$$

where: 0.94 is the shape factor, denoting the ratio of a particle's major dimension to its minor, θ is the Bragg angle and λ the X-ray wavelength,β is full width at half maximum

The crystallite size of CdO:V2O5 decreases by impressing of X content while increases with annealing this is may be attributed to the agglomeration of v2o5 particles[11]. Table (1and2) show a comparison between experimental and theoretical diffraction peaks.To calculate constructively the spacing (d) between diffracting planes in a few specific directions, determined by Bragg's law [12]:

$$2d\sin\theta = n\lambda \quad \text{..} (2)$$

.Where θ is the Bragg angle, n is any integer, and λ is the wavelength of the beam of X-Ray, λ=0.15406 nm. These specific directions shows as spots on the diffraction pattern called reflections. The lattice constants (a and c) can be found from the equations

$d^2 = \frac{a^2}{(h^2+k^2+l^2)^{1/2}}$ …………………………………….(3)

The lattice strain (ε) can be calculated by using the relation [13]:

$\varepsilon = \beta / 4 \tan\theta$ ……………………………………………….(4)

From the Tables (3) and Figs.(3) show that the lattice constant and lattice strainfor cdodoped with different concentrations of V_2O_5prepared at RTand annealed to373 Ko increase with increasing of x content, while decreas with annealing temperature.This is mainly because of the nucleation and subsequent growth rate with increasing V_2O_5 concentration which attributed to the difference between ionic radius of Cd and V ions.

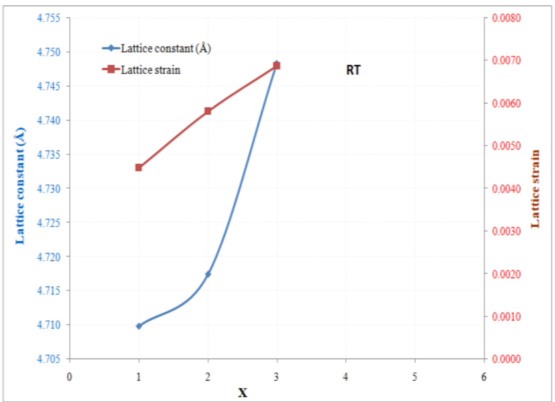
Table (3) Lattice strain and lattice parameters of deposited CdO films doped withdifferent concentration of V_2O_5 prepared at RT and Ta=373K

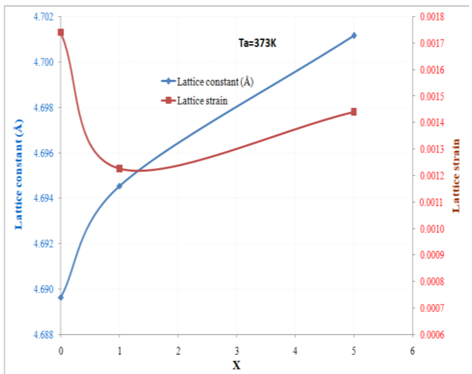
RT		
x	Lattice constant (Å)	Lattice strain
o	4.70988	0.0045
1%	4.71749	0.0058
5%	4.74822	0.0069
Ta=373K		
0	4.68963	0.0017
1%	4.69455	0.0012
5%	4.70116	0.0014

Figure (3) The variation of lattice constant and lattice strain of deposited CdO films doped with different concentration of V_2O_5 prepared at RT and annealed at Ta=373K

Hall Measurements of CdO: V_2O_5 thin films

In this measurement, the Hall Effect used to study some of the physics of charge transport in thin films samples. Hall mobility, carrier type and concentration were measured from Hall coefficient (RH) data and d.c conductivity. The Hall constants RH were determined from the average measured values of the Hall voltage VH. The complete data RH,µH, n, σ and ρ with doping concentration of V_2O_5 for CdO thin films are tabulated in Table (3). The results indicate that the materials under study are n-type semiconductor possibly due to the donor formation .The variation of carriers concentration and Hall mobility with V_2O_5 content of Cdo:V_2O_5 films prepared at RT substrate are shown table (4).





Table(4) Hall parameters Hall CoefficientnH ,μH for CdO films at V2O5content

Concentration of V2O5	ρ (Ω.cm)	σR.T×10-3 (Ω.cm)-1	Hall Coefficient RH(Cm3/C)	nH (cm-3)	μH × 102 (cm2/V.s)	Type of Conductivity
Pure	$3.57*10^{4}$	$2.8*10^{-6}$	$1.99*10^{1}$	$3.13*10^{17}$	3.32	n
%1	$7.1*10^{4}$	$1.39*10^{-5}$	$48.6*10^{1}$	$7.23*10^{16}$	3.04	n
5%	$24.54*10^{4}$	$2.2*10^{-5}$	$11.97*10^{1}$	$3.16*10^{17}$	1.06	n
Ta=373K						
pure	$1.7*10^{-2}$	$15.8*10^{1}$	$3.79*10^{5}$	$1.64*10^{13}$	82	n
1%	$1.05*10^{-2}$	$9.5*10^{1}$	$2.37*10^{5}$	$^{6}2.6*10^{13}$	63.8	n
5%	$3.08*10^{-2}$	$3.24*10^{1}$	$1.38*10^{7}$	$4.5*10^{12}$	11	n

Solar cell Efficiency measured

The I-V characteristics of n-CdO:V2O5/p-PSi solar cell in both dark and under illumination using power densities equal to 100mW/cm2with the applied forward and reverse bias at different laser fluencies were shown in Figs. (4 to 5).In general the forward current higher than reveres current.We can see clearly from our figures that by increasing the bias voltage the trend of the photocurrent density curve will increased, but we will see the reverse behavior of the depletion region, by increasing the forward voltagethedepletion region will decreased. This increasing in the depletion layer will lead to increase the photocurrent density.Our results showed that by increasing the annealing temperature the photocurrent density will increase, we think the reason behind that is the grain size and the grain boundaries. The annealing temperature lead to increase in the grain size,as well as it lead to reduce the grain boundaries and as a result it will improve the structure of the thin films which is going to lead to increase of the mobility and increase the photocurrent density.The solar cells parameters such as (Vo, Isc, Im, Vm, FF and the solar cell efficiency were calculated from these figures as shown in Table (5). This table shows that the optimum laser fluencies with highest efficiency for all pure samples, and the samples deposited on porous Si best than that deposited on Si wafers. From figures (6, 7) shows the efficiency of (CdO)1-x:V2O5x/porous silicon solar cells by different annealing temperature and composition (x). The best results come out from this research was at Ta = 373k and compositional x= 1%.

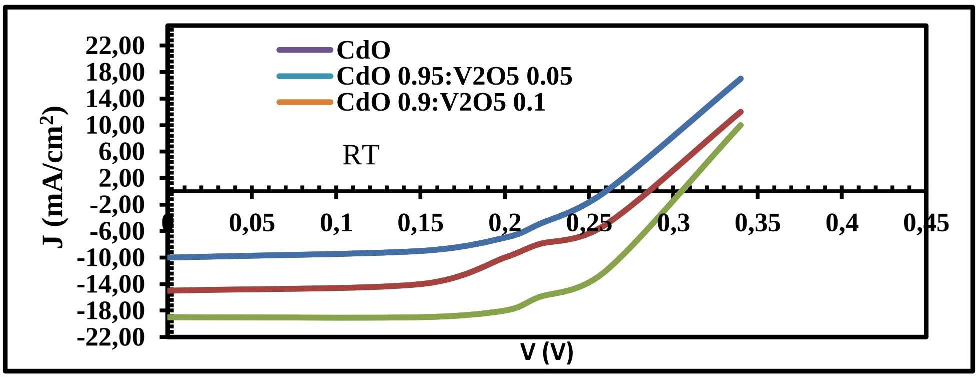


Figure. (4), shows the variation of Efficiency of pure and doped CdO with different V2O5contents

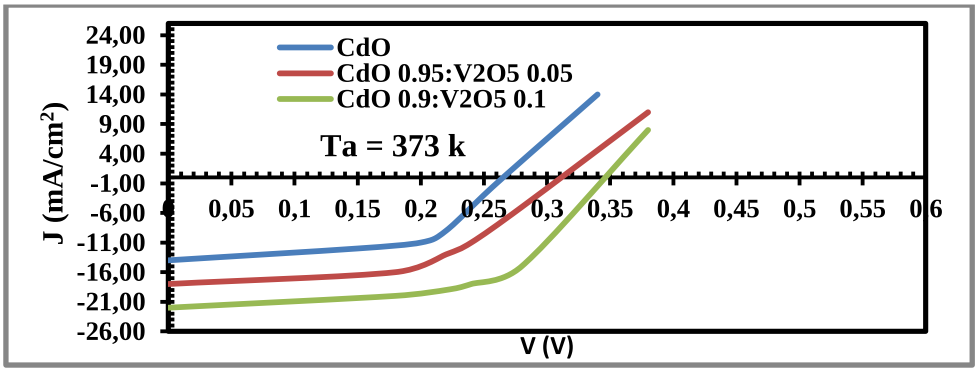


Figure. (5), shows the variation of(J)of pure and doped CdO with different V2O5contents

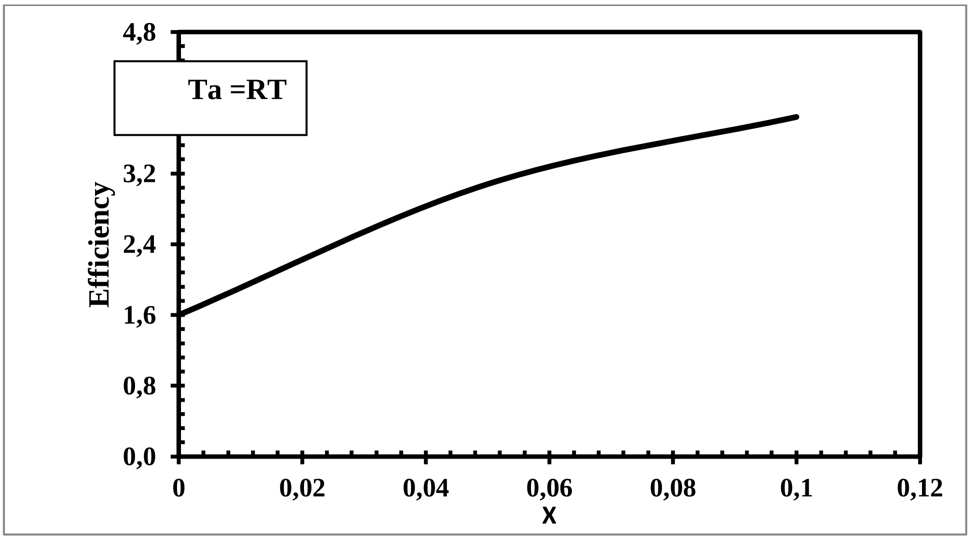


Figure. (6), shows the variation o efficiency pure and doped CdO with different V2O5contents prepared at RT

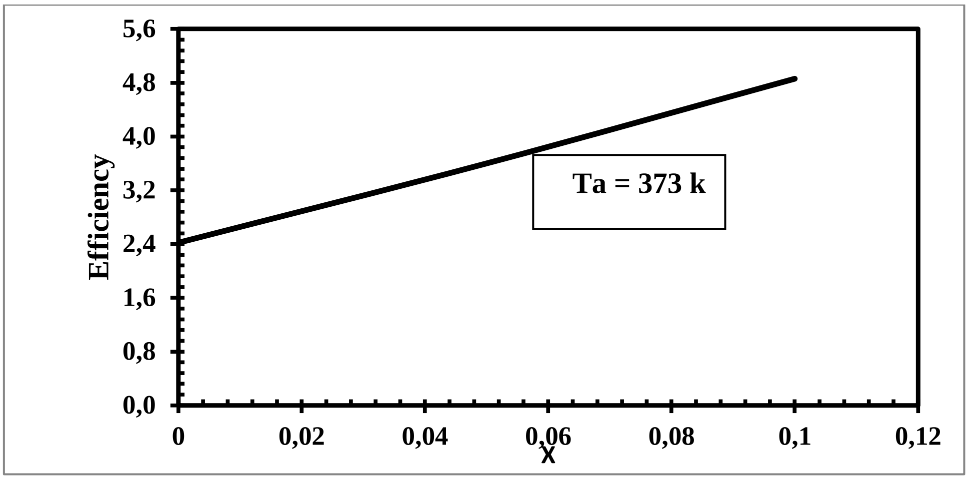


Figure. (7), shows the variation of efficiency of pure and doped CdO with different V2O5contents annealed at Ta=373K

Table 5. Shows I-V Parametersfor(CdO)1-x:V2O5x/ p-Si solar cell

Target	Composite (x)	Laser fluencies (J/cm2)	Vmax (V)	Jmax (mA/cm2)	□□□□□□□
(CdO)	0	0.23	0.2	8	1.6
(CdO)0.95:V2O50.05	0.05	0.23	0.22	14	3.08
(CdO)0.9:V2O50.1	0.1	0.23	0.24	16	3.84
Ta = 373 K					
(CdO)	0	0.23	0.22	11	2.42
(CdO)0.95:V2O50.05	0.05	0.23	0.24	15	3.6
(CdO)0.9:V2O50.1	0.1	0.23	0.27	18	4.86

Conclusion

In this study a polycrystalline structure for synthesis of pure CdO thin films and doped with different concentration of V2O5 by PLD technique on glass and p-si substrates will reported. XRD pattern of films show that the pure and doped CdO thin films were polycrystalline in cubic phase structure. The XRD calculations also shown there is increasing in bond length, lattice strain while decreases lattice constants for CdO doping with V2O5 compare with pure CdO thin films. Hall measurement show that Pure and doped CdO thin films have n-type conductivity. The efficiency of solar cell is increased by increasing V2O5 content

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