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Effect the heat treatment on the properties of the $_{X}$ (NiO) $_{X-1}$ (CdO) Thin film using pulsed laser deposition technique at 732K

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Abstract: *(CdO)1-x(NiO)x thin films have been deposited at annealing temperature (732K) with different concentration of NiO of x=(0.01, 0.03 and 0.05)Wt% onto glass substrates by using pulsed laser deposition technique Nd-YAG laser with λ =1064nm , energy =500 mJ and number of shots = 500. the X-ray diffraction (XRD) results reveals that the characteriste deposited(CdO)(NiO)thin films polycrystalline was cubic structure and many peaks (111), (20 0),and (220) with disappear the peak of NiO, The results it was calculated show that the UV emission is at a constant peak position in the spectra.*

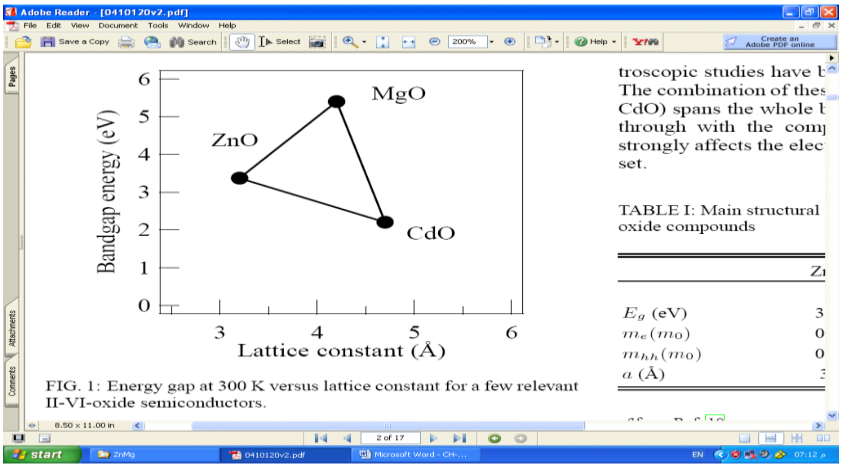
Keywords: *(CdO)1-x(NiO)x Thin Film; structural properties; pulse laser deposition technique; optical properties and electrical properties.*

I. Introduction

The word thin film is generally used to describe a larger or several layers of atoms of certain material. The properties of thin films are usually different from those of the bulks. This is because of two dimensions thin films. In solid "three dimensions" the particles are under the influence of forces of all direction. While for thin films the forces acting upon the particles at the surface only. Also the presence of the large number of defects during the preparation of thin films reduces the mobility of the carriers and therefore the semi conducting films have a higher resistivity than a bulk one which contains the same number of carriers per unit volume(1,2) .

Transparent conducting Oxide (TCOs):

Tack transparent conduction oxides (TCOs) researchers paid a great deal of attention to what is owned by the unique qualities of the material advantage for other materials, such as thin films oxides that possess high optical transmittance in the visible region and a high reflectivity in the infrared region (3,4) .



Cadmium oxide is an inorganic compound with the formula CdO. It is one of the main precursors to other cadmium compounds. It crystallizes in a cubic rocksalt lattice like sodium chloride, with octahedral cation and anion centers.(5) It occurs naturally as the rare mineral monteponite. Cadmium oxide can be found as a colorless amorphous powder or as brown or red crystals.(6) Cadmium oxide is an n-type semiconductor(7) with a band gap of 2.18 eV (2.31 eV) at room temperature (298 K).

NiO can be prepared by multiple methods. Upon heating above 400 °C, nickel powder reacts with oxygen to give NiO. In some commercial processes, green nickel oxide is made by heating a mixture of nickel powder and water at 1000 °C, the rate for this reaction can be increased by the addition of NiO.(8,9) The simplest and most successful method of preparation is through pyrolysis of a nickel(II) compounds such as the hydroxide, nitrate, and carbonate, which yield a light green powder.(10,11) Synthesis from the elements by heating the metal in oxygen can yield grey to black powders which indicates nonstoichiometry (12,13).

II. Experimental Details

Cadmium oxide from Company with a purity of 99.99% and Nickel oxide(14) with purity of 99.99% were mixed together at different concentration of x= (0.1, 0.3, 0.5) Wt. % using rotary pump agate pump for 1 hour then the mixture was pressed into pellets of (1.5 cm) in diameter and (2.5 cm) thick, using hydraulic manually type (SPECAC), under pressure of 6.5 tons. The pellets were sintered in air at temperature of (450K) for 3 hour. The CdO:NiO films were deposited on glass slides substrates of (10×10 mm). The substrate were cleaned with dilated water using ultrasonic bath for 15 minute in order to deposit the films at room temperature then annealing treatment at (450C°) by furnace under vacuum (8*10-2 mbar) were carried out to the films. PLD technique was used to deposit the films under vacuum of (8×10-2 mbar) using Nd:YAG laser with (λ= 1064 nm) SHG Q-switching laser beam at 500 mJ, repetition frequency (6Hz) for 500 laser pulse is incident on the target surface making with an angle of 45° . The distance between the target and the Nd:YAG laser was set to (10 cm), and between the target and the substrate was (1.5 cm). The thickness of CdO:NiO thin film was carried out using optical interferometer method employing He-Ne laser 632 nm with incident angle 45°. This method depends on the interference of the laser beam reflected from thin film surface and then substrate .

III. Results and Discussion

1- X-ray Characterization

The X-ray diffraction (XRD) pattern of the CdO pure and doped NiO thin film deposited on glass substrate is illustrated in Figure1 ; the figur reveals a polycrystalline structure of the film. In this diffraction pattern, the peaks at 2θ correspond to diffraction from (111) and (200) and (220) planes of the CdO cubic phase with disappear the peak of NiO, respectively.

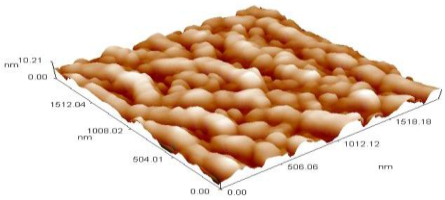
It is apparent from this figure that all films are preferentially orientated along (111) crystallographic directions and the preferential orientation peak for CdO doped film is sharp. This may be attributed to the crystallinity of the CdO film being improved with NiO doping.

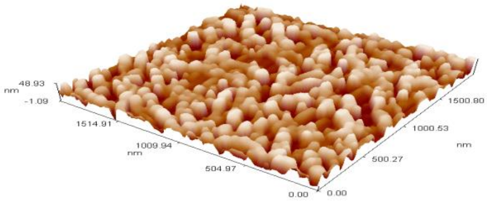
Fig1: XRD diffraction for CdO pure and CdO:NiO with different concentration at 723K

NiO %	2θ (Deg.)	FWH(Deg.)	Intensity (a. u.)	d_{hkl} Exp.(Å)	G.S (nm)	d_{hkl} Std.(Å)	hkl	Phase
pure	32.9620	0.2370	2601	2.7152	35.0	2.7110	(111)	CdO
	38.2280	0.2720	1599	2.3524	30.9	2.3478	(200)	CdO
	55.3430	0.3070	666	1.6587	29.2	1.6601	(220)	CdO
1	32.9711	0.2432	2000	2.7145	34.1	2.7110	(111)	CdO
	38.2262	0.2795	1117	2.3525	30.1	2.3478	(200)	CdO
	55.3480	0.3422	463	1.6586	26.2	1.6601	(220)	CdO
3	32.9711	0.2561	1658	2.7145	32.4	2.7110	(111)	CdO
	38.2811	0.2900	1146	2.3493	29.0	2.3478	(200)	CdO
	55.3487	0.3486	458	1.6585	25.7	1.6601	(220)	CdO
5	32.9896	0.2584	1719	2.7130	32.1	2.7110	(111)	CdO
	38.3640	0.3295	653	2.3444	25.5	2.3478	(200)	CdO
	55.3481	0.3504	400	1.6586	25.6	1.6601	(220)	CdO

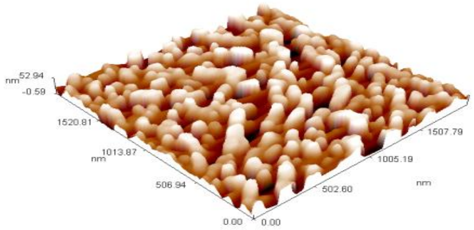
2- Atomic force microscopy:

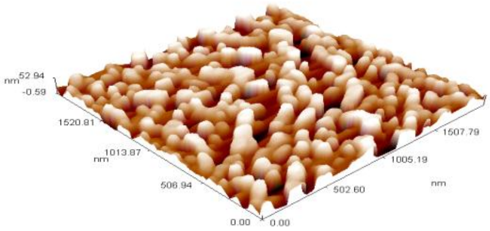
AFM scans of the surface were carried out to study the change in the surface morphology of the films. AFM images of pure and CdO doped NiO films are shown in Fig2. The roughness of the films. The 2.5_m×2.5_mimages are utilized for measuring the surface roughness of the films. The roughness of the pure CdO film is measured to be 12.49 nm. Further, the roughness of the samples decreases with increase in doping concentration. The roughness of 1, 3, and 5 wt.% CdO doped NiO measured is 12.49nm,9.48nm,13.2nm and 18.6nm respectively.





CdO pure ***CdO:0.01NiO***





CdO:0.03NiO ***CdO:0.05NiO***

Fig2: Atomic force microscopy for CdO pure and CdO:NiO with different concentration at 723K

3- Optical properties:

The absorption spectrum of the CdO pure and CdO:NiO thin films deposited on glass substrates is shown in Figur3 below. The Figure shows low absorption coefficient in the UV region, whereas it is transparent in the visible region for CdO film, and it is decreasing and shifted toward the visible region for CdO doped NiO film with increasing of wavelength.

Figure shows the optical transmission spectra with wavelength from 400 nm to 1100 nm of the CdO doped NiO thin films. It is observed from this figure that the films show high transmission in the visible region and it well be constant. The optical transmittance increases for CdO doped NiO film .

Assuming direct transition, the dependance of (αhν) 2 on the photon energy hν is plotted following Tauce relation . The extrapolation of the linear part of the above plot to (αhν)2 =0 gives the energy gap values of the CdO and NiO doped films, which were found to be about 2.4 and 2.53 eV respectively. It can be noticed from this figure that the value of energy gap is increasing for CdO doped NiO film. These values are in a good agreement with the values presented by other workers.

Fig3: Absorption spectra of CdO doped NiO at 723K.

Fig4:Transmission spectra of CdO doped NiO at 723K.

Fig5: The energy gap of CdO:NiO after annealing at 723K.

4- Electrical properties:

The Hall measurements show that the CdO:NiO films are n-type semiconductor, The observed characteristics were supported from the measurement of resistivity, mobility and Hall coefficient as illustrated in table. The result shows that the mobility and conductivity increase when Cdo doped NiO, where the resistivity increases.

Table below illustrates the main parameters estimated from Hall Effect measurements for (CdO)1-x(NiO)x films with different concentration of NiO at (723) K, respectively. It is clear from this table that the all samples have a negative Hall coefficient (n-type), i.e. Hall voltage decreases with increasing of the current. Figure show carriers concentration (nH) and Hall mobility (μH) as a function of concentration and different annealing temperature. It is clear that the carrier concentration nH increases while the Hall mobility μH decreases with the increasing of NiO content .When the films were annealed lead to showed an opposite manner a increasing in the nH while increasing in the value μH, as shown in Table . Increases the density of charge carriers is essentially because of the lowering the potential barrier. While the decreasing of mobility is come from the inverse relation between μH and nH.

Material	*R_H (cm^3/C)*	*σ ($(\Omega.cm)^{-1}$)*	*type*	*μ_H ($cm^2/V.s$)*	*N_H (cm^{-3})*
CdO pure	***10.18E-02***	***2.54E+02***	***N***	***25.9***	***$6.19*10^{19}$***
NiO pure	***1.56E+05***	***4.17E-06***	***P***	***65.057***	***$1.2*10^{12}$***
CdO :1%NiO at 723K	***4.05E+07***	***3.03E+03***	***N***	***$1.02*10^{-3}$***	***$1.54*10^{11}$***
CdO :3%NiO at 723K	***5.17E-05***	***2.53E+03***	***N***	***$1.3*10^{-1}$***	***$1.12*10^{23}$***
CdO :5%NiO at 723K	***2.86E-03***	***2.95E+02***	***N***	***$2.1*10^{-1}$***	***$2.19*10^{21}$***

Fig6: Carrier concentration (nH) as a function of NiO content at room temperature and 723K for (CdO)1-x (NiO)x films.

Fig7: Hall mobility (μH) as a function of NiO at 723K for (CdO)1-x (NiO)x films

DC Conductivity

Figures below shows the variation of lnσd.c versus 1000/T for (CdO)1-x(NiO)x film deposited by pluses laser on glass substrates with different concentration of NiO x= (0.01,0.03,0.05) Wt. % at annealing temperatures (723K), with average thickness of (500) nm. From this figure, it is found that there are two stages of d.c conductivity mechanism through out the temperatures range (283-363K).

Fig8: The relation between Ln (σ) versus reciprocal of temperature (1000/T) (CdO)1-x(NiO)x films with different concentration of NiO at 723K.

concentration	*E_{a1} (eV)*	*Range (K)*	*σ_{RT} ($\Omega^{-1}.cm^{-1}$)*	*ρ(Ω.cm)*
pure	***0.045***	***283-363***	***7.60E-02***	***1.32E+01***
0.01	***0.033***	***283-363***	***5.23E-04***	***1.91E+03***
0.03	***0.028***	***283-363***	***5.79E-05***	***1.73E+04***
0.05	***0.014***	***283-363***	***3.91E-05***	***2.56E+04***

The values of the Ea1 at 723K annealing temperature.

IV. Conclusion

CdO doped NiO thin films were successfully deposited on glass substrates using pulsed laser deposition techniqe. The films annealed at 723K exhibited structure of CdO. From the optical transmittance it was revealed that the transparency and band gap increase with doping concentration. In electrical properties we note that decrease of electrical conductivity cause decrease of resistivity in this film at 723K.

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