IOSR Journal of Applied Physics (IOSR-JAP)
e-ISSN: 2278-4861.Volume 8, Issue 4 Ver. IV (Jul. - Aug. 2016), PP 18-21
www.iosrjournals.org

Effect of NIO dopant on structural, optical and electrical properties of CDO thin film by PLD

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Abstract: *Nickel oxide doped CDO thin films have been deposited at room temperature and in 723K with different concentrations 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), (200), and (220)The results it was calculated show that the UV emission is at a constant peak position in the spectra.*

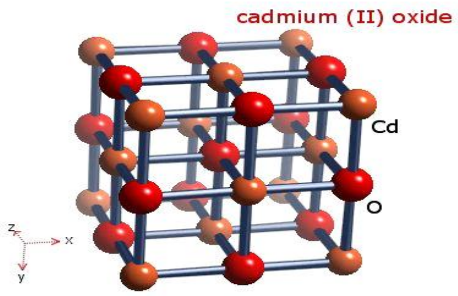
Keywords: *(CDO)1-x(NIO)x Thin Film; structural properties; pulse laser deposition technique; optical properties and electrical properties.*

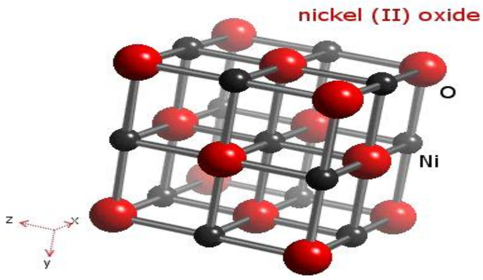
I. Introduction

Cadmium oxide is as a compound semiconductor including cadmium and oxygen(1), CdO is generally used extensively as TCOs with different physical applications (2), especially in the production of optelectronic devices such as in n-type layer of thin films used for solar cell as well as with a result of its high transparency in the visible region of the solar spectrum(3,4), the main properties of CdO summarized have a solid brown color and exhibit certain intrinsic feature such as high melting point (1500 C^o), high density (8150 kg/m3), and molecular weight (128.4 gm/mol), it is also characterized with cubic crystal structure {NaCl (fcc) type; lattice constant a= 0.4695 nm}.

CdO has a high electrical conductivity (low, resistivity) , which doing an effect of moderate electron mobility and higher carrier concentration arising from native defects of oxygen anionic vacancies and cadmium interstitials(5), in addition CdO includes an intermediate direct band gap ranging from 2.26 eV to 2.45 eV as thin films, and 2.5 eV as bulk(6), CdO can be got by heated cadmium directly in air to high temperature of 900 C^o.

Nickel oxide is the chemical compound with the formula NiO. It is notable as being the only well characterized oxide of nickel. The mineralogical form of NiO, bunsenite, is very rare. NiO can be prepared by multiple methods(7). Upon heating above 450 oC, 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 oC, the rate for this reaction can be increased by the addition of NiO(8). 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(9,10).





1.2 Experimental Details

Cadmium oxide was a purity of 99.99% (11,12), and Nickel oxide with purity of 99.99% (13,14), were mixed together at different concentration of x= (0.01, 0.03, 0.05) Wt% using rotary pump agate pump for 1 hour then the mixture was pressed into pellets of (2.5 cm) in diameter and (0.2 cm) thick, using hydraulic manually type (SPECAC), under pressure of 6.5 tonsThe 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. 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 (2.5 cm).

II. Results and Discussion

1- X-ray Characterization

The X-ray diffraction (XRD) patetern of the undoped and CdO doped NiO thin film deposited on glass substrate is illustrated in Figure 3; the figur reveals a polycrystalline cubic 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, respectively.

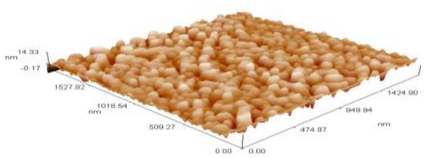
It is apparent from this figure that all films are preferentially orientated along (111) crystallographic directions and the preferential orientation peak for CdO doped film became sharper and more intense. This may be attributed to the crystallinity of the CdO film being improved with NiO doping.

NiO%	2θ (Deg.)	FWHM (Deg.)	Intensity (a. u.)	d_{hkl} Exp.(Å)	G.S (nm)	d_{hkl} Std.(Å)	hkl	Phase
pure	32.9374	0.2969	373	2.7172	27.9	2.7110	(111)	CdO
	38.2821	0.3013	346	2.3492	27.9	2.3478	(200)	CdO
	55.2068	0.2900	128	1.6625	30.9	1.6601	(220)	CdO
1	33.0258	0.3200	459	2.7101	25.9	2.7110	(111)	CdO
	38.1887	0.4446	432	2.3548	18.9	2.3478	(200)	CdO
	43.4100	0.3450	14	2.0829	24.8	2.0842	(200)	NiO
	55.2525	0.3067	127	1.6612	29.2	1.6601	(220)	CdO
3	33.0455	0.3450	299	2.7085	24.0	2.7110	(111)	CdO
	38.2053	0.4097	390	2.3538	20.5	2.3478	(200)	CdO
	43.4100	0.4530	28	2.0829	18.9	2.0842	(200)	NiO
	55.3380	0.3410	90	1.6588	26.3	1.6601	(220)	CdO
5	32.9262	0.5467	246	2.7181	15.2	2.7110	(111)	CdO
	38.0030	0.8297	50	2.3658	10.1	2.3478	(200)	CdO
	43.2100	0.4623	30	2.0920	18.5	2.0842	(200)	NiO
	55.2443	0.4099	60	1.6614	21.9	1.6601	(220)	CdO

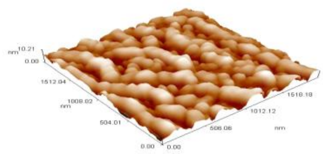
Fig1: XRD for CdO pure and CdO:NiO with different concentration at R.T.

2- Atomic force microscopy:

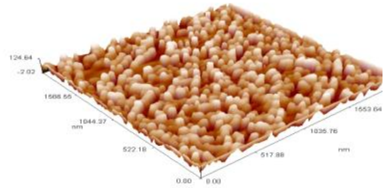
AFM scans of the surface were carried out to study the change in the surface morphology of the films. AFM images of pure and CdO doped NiO films are shown in Fig2. The NiO doped films show smooth surface compared to the cadmium oxide films. The roughness of the films was calculated by the Nanoscope IIIa. 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 10.21 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 14.35nm, 25.1nm and 18.5nm respectively.



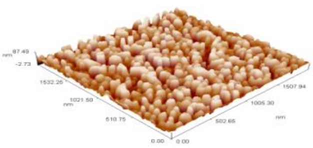
Pure (CDO)



CdO:0.01NiO



CdO:0.03NiO



CdO:0.05NiO

Fig2: atomic force microscopy for Cdo pure and for CdO:NiO at R.T with different concentration.

3- Optical properties:

The absorption spectrum of the CdO and NiO doped CdO 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.

Figure shows the optical transmittance 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 low transmission in the UV region. 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 and the graph is illustrated in Figure .

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 2.16 and 2.26 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 room temperature

Fig4: Transmission spectra of CdO doped NiO at room temperature

Fig5: The energy gap of CdO:NiO at room temperature.

4- Electrical properties:

The Hall measurements show that the CdO:NiO films deposited on glass substrate 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 decreases.

The type of charge carrier concentration (nH) and Hall mobility (μH), have been estimated from Hall measurements. Table below illustrates the main parameters estimated from Hall Effect measurements for (CdO)1-x(NiO)x films with different concentration of NiO at room temperature 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 . It is clear that the carrier concentration nH increases while the Hall mobility μH increases with the increasing of NiO content . Increases the density of charge carriers is essentially because of the lowering the potential barrier. While the increasing of mobility is come from the inverse relation between μH and nH.

Material	R_H (cm^3/C)	□ (□ .cm)^1	type	□$_H$ ($cm^2/V.s$)	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 R.T	**6.12E-05**	**1.98E+03**	**N**	**$1.2*10^{-1}$**	**$1.02*10^{23}$**
CdO :3%NiO at R.T	**7.50E-06**	**3.26E+03**	**N**	**$1.5*10^{-2}$**	**$3.3*10^{23}$**
CdO :5%NiO at R.T	**4.42E-05**	**4.14E+02**	**N**	**$1.8*10^{-2}$**	**$1.3*10^{23}$**

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

Fig7: Hall mobility (μH) as a function of NiO content at room temperature for (CdO)1-x (NiO)x films

5-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 room temperature, with average thickness of (500) nm. From this figure, it is found that there are two stages of d.c conductivity mechanism throughout 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 RT.

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	0.036	283-363	1.73E-03	5.78E+02
0.03	0.033	283-363	8.05E-05	1.24E+04
0.05	0.011	283-363	5.44E-05	1.84E+04

The values of the Ea1 at R.T

III. Conclusion

CDO doped NIO thin films were successfully deposited on glass substrates using pulsed laser deposition techniqe. The films at R.T 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 R.T.

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