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Study the Effect of Indium on the Urbach Energy and Dispersion Parameters of CdO Thin Films

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Abstract

CdO thin films have been deposited onto glass substrate by chemical spray pyrolysis. Transmittance and reflectance spectra in the range300-900 nm were recorded via UV-Visible spectrophotometer for various In-content in the CdO:In thin films. Transmittance decreased with increasingIn-content in the CdO:In thin films, while the reflectance slightly increased in the wavelength more than 480 nm. Urbach energy decreased with increasing In-content in the CdO:In thin films. Dispersion parameters are calculated, and find that E_d, E_o, ε_∞, n(0), S_o,M_{-1} and $M_{-3}$are increased with increasing In-content in the CdO:In thin films.

Keywords**:** Thin films**,** Cdo:In, Spray pyrolysis, reflectance, Dispersion,

Introduction

Transparent conducting oxide (TCO) thin films have great importance in electronic device applications and among these TCOs, cadmium oxide (CdO), an n-type semiconductor with band gap of 2.5 eV [1].

Inthethinfilmform,itfindsapplicationsingassensordevices,photodiodes,transparentelectrodes, phototransistors and solar cells[2].

Various techniques have been employed to prepare CdO thin films such as spray pyrolysis [3], sputtering [4,5], solution growth [6], activated reactive evaporation [7], pulsed laser deposition [8] and sol-gel method [9].
Urbach energy and dispersion parameters of CuO thin films were calculated and study the effect of In contenton these films.

Experimental Part

0.1M of $Cd(CooCH_3)_2$(supplied from Sigma-Aldrich Chemicals) dissolve in re-distilled water and an aqueous solution of 0.1M of $InCl_3$(2% and 4% volume) (supplied from Sigma-Aldrich Chemicals) were used as precursormaterials to obtain the deposited films by chemical spray pyrolysis on to glass substrate. The optimum conditions were arrived at the following parameters:Substrate temperature was kept at 350 ^oC during deposition process, the distance between nozzle and substrate was 28 cm, compressed air was used as a carrier gas ,and rate of depositon was 2 ml/min. Thickness wasobtained bygravimetricmethod was about 350 nm. Double beam UV-Visible spectrophotometer was used in order to record the absorbance spectra and calculate the optical parameters..

Results and Discussion:

The obtained results measured that recorded from UV-Visible spectrophotometer is plotted in Fig.1 for In-doped CdO thin films prepared by chemical spray pyrolysis. From this figure, it can notice the decreases of transmittance with increasing In-doping in the CdO thin films, and also decreased with decreasing wavelength (at high photon energy, the absorbance of films increases leads to decreasing transmittance).

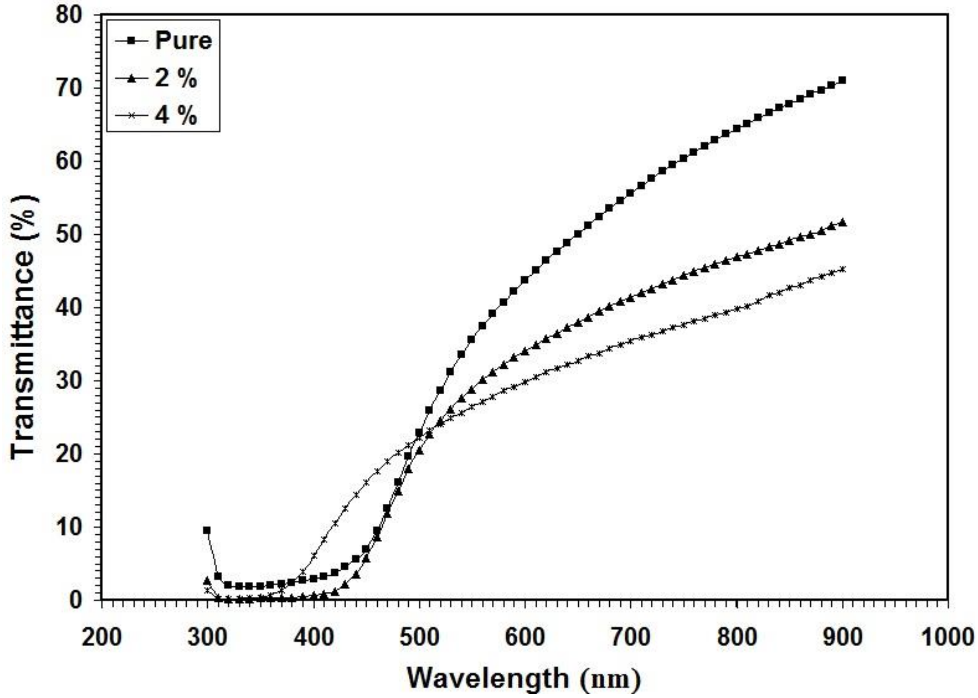

Fig.1: Transmittance spectra of CdO:In thin films with various In-doping.

The reflectance (R) has been found by using the relationship:

$$R + T + A = 1 \quad \dots \ (1)$$

where T and A is the transmittance and absorbance respectively. The reflectance spectra versus wavelength was plotted in Fig. 2. The reflectance increased slightly with increasing In-doping at wavelength more than 480 nm.

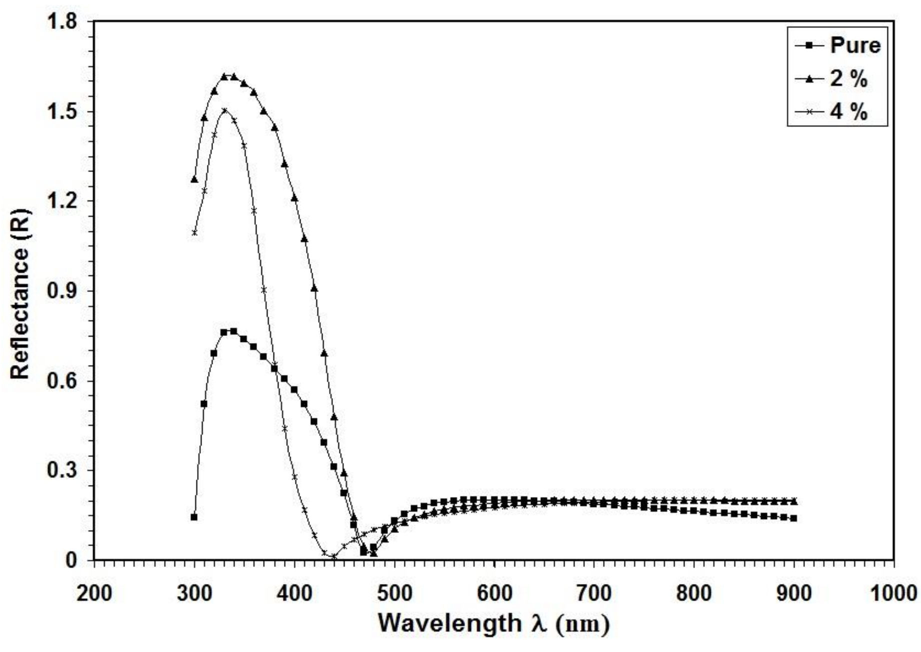

Fig.2: Reflectance spectra of CdO:In thin films with various In-doping.

The optical conductivity was calculated using the relation [10]:

$$Q = \frac{\alpha\, n\, c}{4\pi} \quad \dots \ (2)$$

where α is absorption coefficient, n is refractive index, and c is speed of light. The optical conductivity as a function of wavelength was plotted in Fig.3. From this figure, it can notice the slight decreases with increasing In-doping at wavelength more than 480 nm for pure and In-doped CdO thin films.

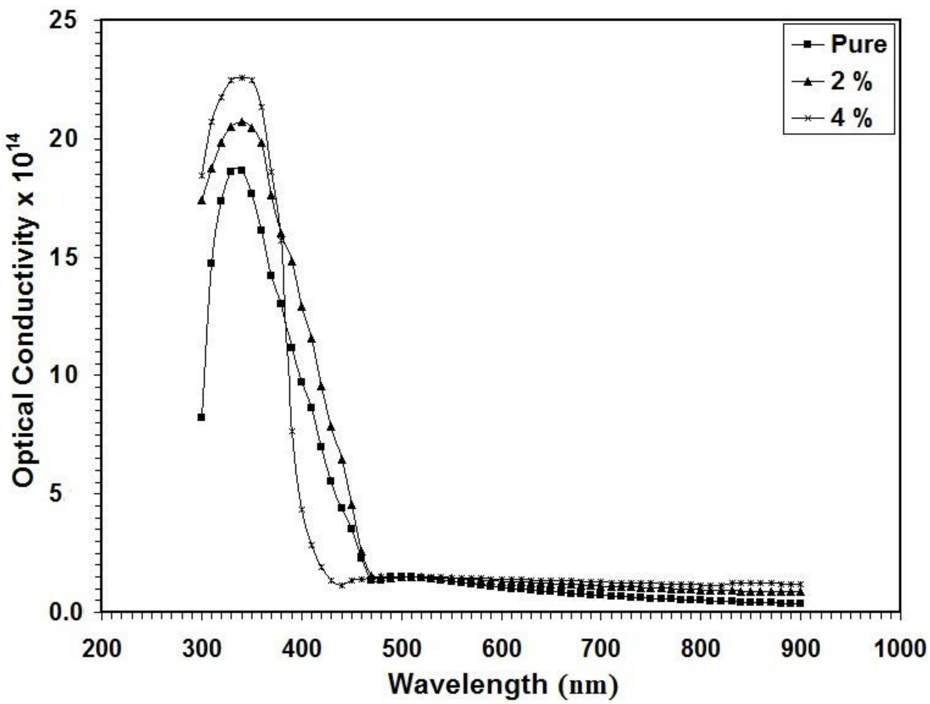

Fig.3: Optical conductivity of CdO:In thin films with various In-doping.

The absorption edge gives a measure of the energy band gap and the exponentialdependence of the absorption coefficient, in the exponential edge region Urbach rule is expressed as[11]:

$$\alpha = \alpha_o \exp\left(\frac{h\nu}{E_U}\right) \quad \dots \ (3)$$

where $\alpha_\circ$ is aconstant, E_U is the Urbach energy, which characterizes the slope of the exponential edge. The values of E_U are obtained from plotting relation between lnα versus photon energy (hυ) as in Fig. 4, the slope value represent the Urbachenergy.

These values are listed in Table 1.The absorption in this region is due to the transitions between the extended states in one band and the localized statesin the exponential tail of the other band. From the Table, the Urbach energy decreased with increasing In-content in CdO thin films.

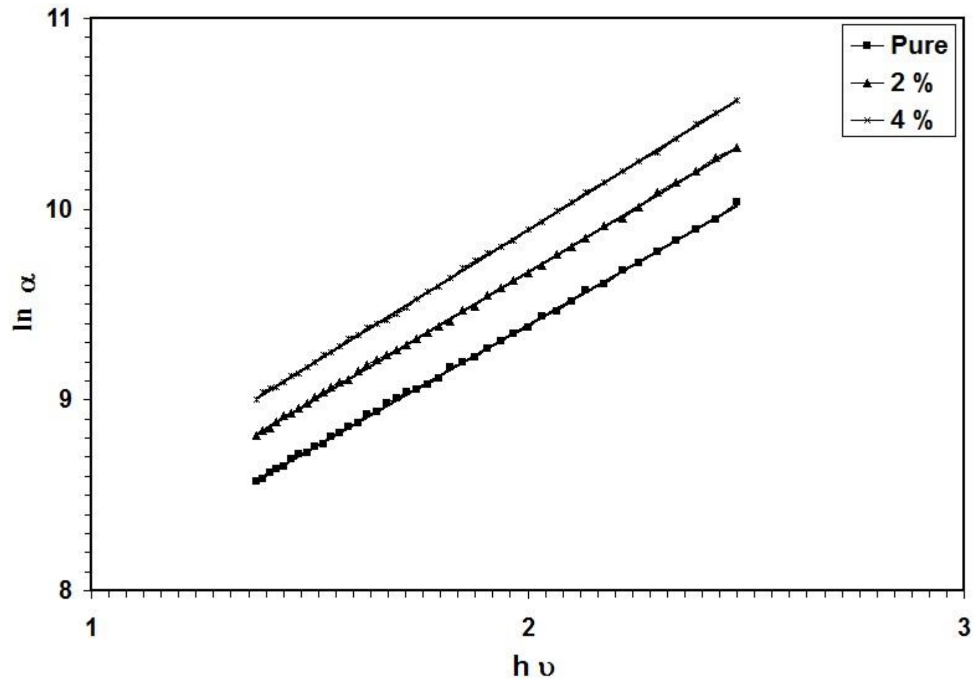

Fig.4: Lnα versus hυ of CdO:In thin films with various In-doping.

The refractive index dispersion for crystallized and amorphousmaterials can be expressed as [12]:

$$n^2 - 1 = \frac{E_o E_d}{E_o^2 - E^2} \quad .....(4)$$

Where n is the real part of refractive index, hυ is the photon energy, E_o is the average excitation energy for electronictransitions and E_d is the dispersion energy, which is ameasure of the strength of interband optical transitions.This model describes the dielectric response for transitionsbelow the optical gap.

By plotting $(n^2-1)^{-1}$vs. $(h\upsilon)^2$and fittinga straight line, the values of the parameters E_o and E_d were calculated from (E_o/ E_d) represents the intercept onthe vertical axis and $(E_oE_d)^{-1}$is the slope of the plot, this shown in Fig. 5.

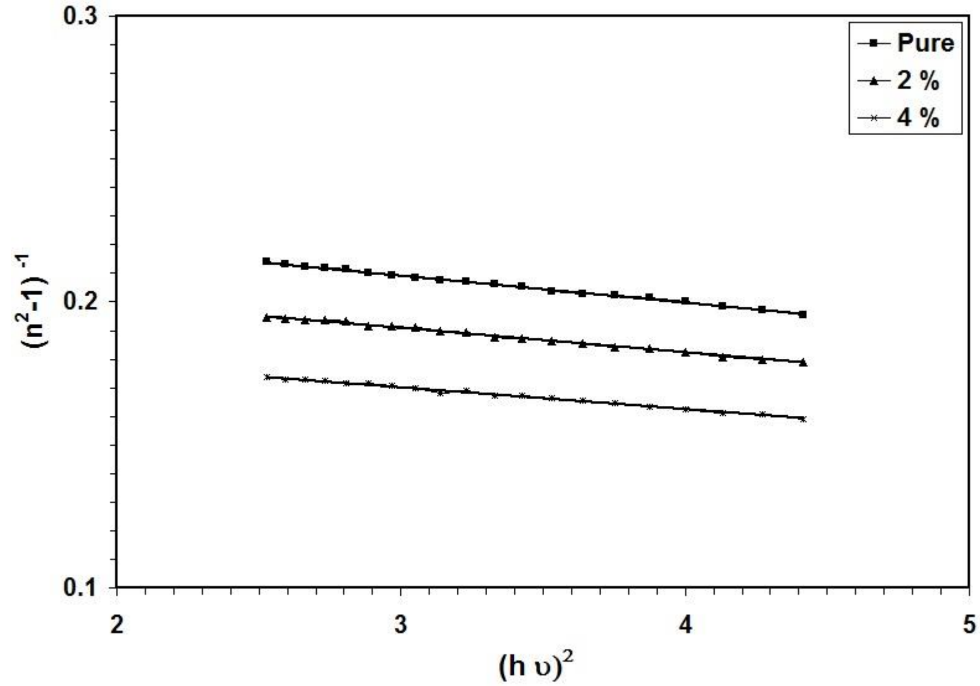

Fig.5: $(n^2-1)^{-1}$ versus $(h\upsilon)^2$ of CdO:In thin films with various In-doping.

The refractive index at infinite wavelength (n_∞) can be determined from the following relation [13]:

$$\frac{n_\infty^2-1}{n^2-1} = 1-(\frac{\lambda_o}{\lambda})^2 \quad ...(5)$$

The plot of $(n^2-1)^{-1}$versus$\lambda^{-2}$was plotted to find the values of (n_∞) of CdO:In thin films. These values are shown in Table 1.

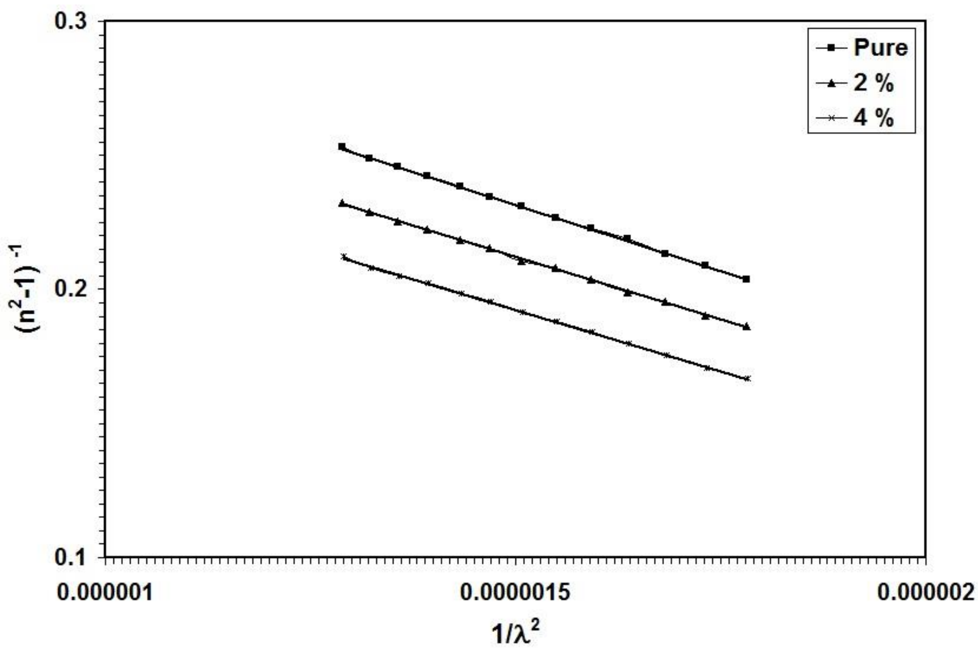

Fig.6: $(n^2\text{-}1)^{-1}$ versus $1/\lambda^2$ of CdO:In thin films with various In-doping.

The M_{-1} and M_{-3} moments of the optical spectra have obtained from the following relations [14]:

$$E_d^2 = \frac{M_{-1}^3}{M_{-3}} \quad \text{and} \quad E_o^2 = \frac{M_{-1}}{M_{-3}} \quad \ldots (6)$$

The values of M_{-1} and M_{-3} moments of the optical spectra are increased with increasing In-content in the CdO:In thin films as shown in Table 1.

Table 1: Some optical parameters of CdO:In thin films.

Sample	E_d (eV)	E_o (eV)	E_g (eV)	ε_∞	n(o)	M_{-1}	M_{-3} eV^{-2}	S_o x10^{13} m^{-2}	λ_o nm	U_Em eV
Pure	21.87	4.81	2.406	5.545	2.35	4.54	0.196	1.01	592	769
2 %	24.25	4.85	2.425	6.000	2.45	5.00	0.212	1.07	599	740
4 %	27.47	5.03	2.517	6.560	2.56	5.50	0.219	1.10	615	704

Conclusions

CdO thin films with various amounts of In-content have been deposited onto glass substrate by chemical spray pyrolysis. Transmittance spectra in the range of 300-900 nm decreased with increasingIn-content in the CdO:In thin films. Urbach energy decreased with increasing In-content in the CdO:In thin films, while the energy gap increased from 2.406 eV to 2.517 eV after additive of 4% In in the CdO:In thin films. Dispersion parameters such as: E_d, E_o, ε_∞, n(0), S_o,λ_o, M_{-1} and $M_{-3}$are decreased with increasing In-contain in the CdO:In thin films.

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