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Effect of the cobalt additive on the urbach energy and dispersion parameters of cadmium oxide thin films

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ABSTRACT

Cobalt doped CdO thin films were deposited on glass substrate using spray pyrolysis technique, at a substrate temperature of 400 °C. The effect of cobalt additive in CdO thin film on Urbach energy and dispersion parameters was studied. It is observed that the increases of Co contain in CdO thin film increasing the reflectance, optical conductivity, and skin depth, in addition increasing Urbach energy that inversely dependence with energy gap that changed from 2.53 to 2.47 eV. While the transmittance and dispersion parameters such as E_d, E_o, M_{-1}, M_{-3}, S_o, and λ_o are decreased with increasing Co contain in CdO thin film.

KEYWORDS

Co doped CdO;
Eubach Energy;
Dispersion parameters;
Spray pyrolysis.

INTRODUCTION

Transparent conducting oxides are used extensively for many applications such as flat panel display, smart windows, light emitting diodes, solar cells and heat reflectors[1–4], optical storage devices[5], gas sensors[6-7]. The electro optical properties of CdO make this material very convenient as a solar cell material[8].

CdO is n-type semiconductor with rock-salt crystal structure(FCC) having a direct optical band gap of 2.2 eV[9].

In recent years CdO-based transparent conducting oxides (TCOs) received much attention due to their exceptional carrier mobility, nearly metallic conductivities and simple crystal structure[10].

CdO is n-type semiconductor, with a well-established direct band gap at approximately 2.5 eV[11]. When compared to ZnO, the transmittance of CdO in the visible region of the spectrum has been reported as rather low[12], however, cadmium oxide is characterized by a much lower resistivity.

Undoped and doped CdO thin films have been deposited by techniques such as reactive sputtering[13–15], ion beam sputtering[16], activated reactive evaporation[11], chemical bath deposition[17-18], spray pyrolysis[19-20], metalorganic chemical vapor deposition[21-22], and sol–gel[23-24].

The aim of this study is to determine the Urbach energy and dispersion parameters of CdO thin film that doped by various concentration of Co, prepared by chemical pyrolys is method.

EXPERIMENTAL PROCEDURE

A spray pyrolysis method was employed to prepare Cdo and Co-doped Cdo thin films on glass substrate, at a substrate temperature of 400 °C. Cadmium chloride (BDH Chemicals Laboratory, England) dissolves in redistilled water. The various concentrations (1% and 5%) of cobalt are used as doping element. The deposition parameters such as spray nozzle-substrate distance (28 cm), spray time (8 s) and the spray interval (2 min) were kept constant. Solution flow rate was maintained at5ml/min at a pressure of 10^5 Pascal. Thickness was about 350 nm that determines by using gravimetric method. Optical transmittance spectra in the wavelength ranging 300–900 nm were recorded using UV-Visible spectrometer (Shimadzu UV-VIS).

RESULTS AND DISCUSSIONS

By using UV-Visible spectrophotometer in the range of 300-900 nm,the optical transmittance (T) was measured from the equation[25]:

$$A = Log\ 1/T \quad (1)$$

Where (A) is the absorbance. Figure 1 shows the optical transmittance versus the wavelength. It is evident that the optical transmittance increases in the visible region and decreases in the UV region for pure and Co-doped CdO films. In addition, it can notice that the transmittance decreased with increasing Co contain in CdO films.

In addition, the reflectance (R) is calculated from the following equation[25]:

$$R + T + A = 1 \quad (2)$$

Figure 2 represent the reflectance versus the wavelength. From this figure, it can notice that the reflectance is increasing with increasing Co contain in CdO films.

The optical conductivity ($\sigma_{optical}$) depends directly on the wavelength and absorption coefficient (α) as a relation[26]:

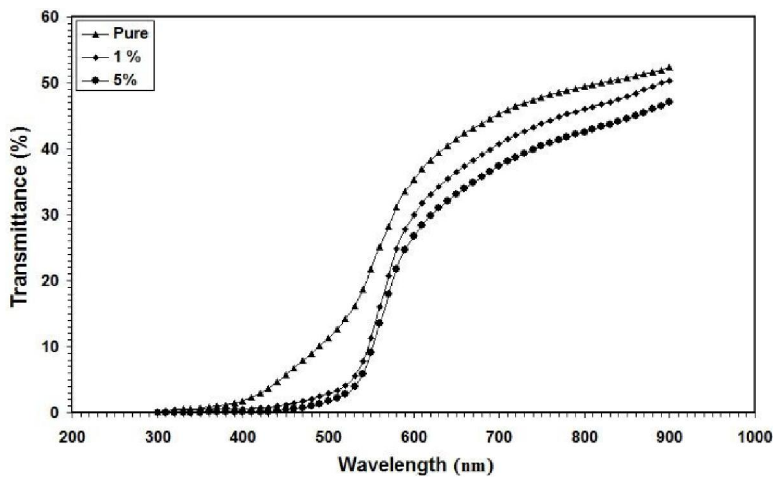

Figure 1 : Transmittance versus wavelength for pure and Co-doped CdO films

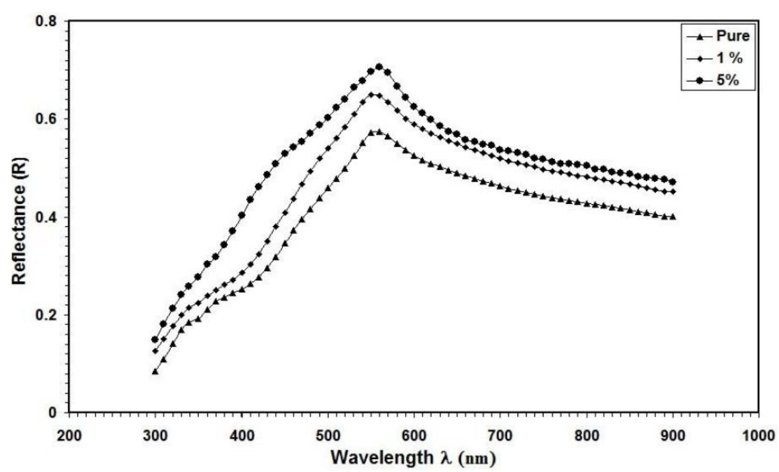

Figure 2 : Reflectance versus wavelength for pure and Co-doped CdO films

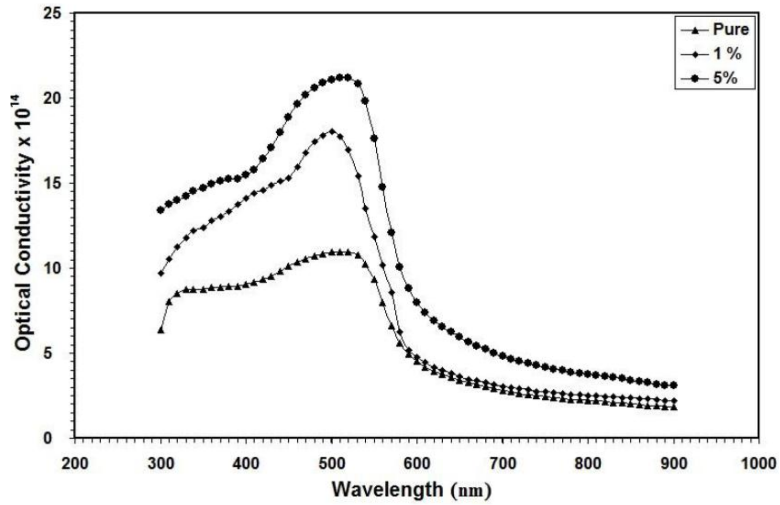

Figure 3 : Optical conductivity versus wavelength for pure and Co-doped CdO films

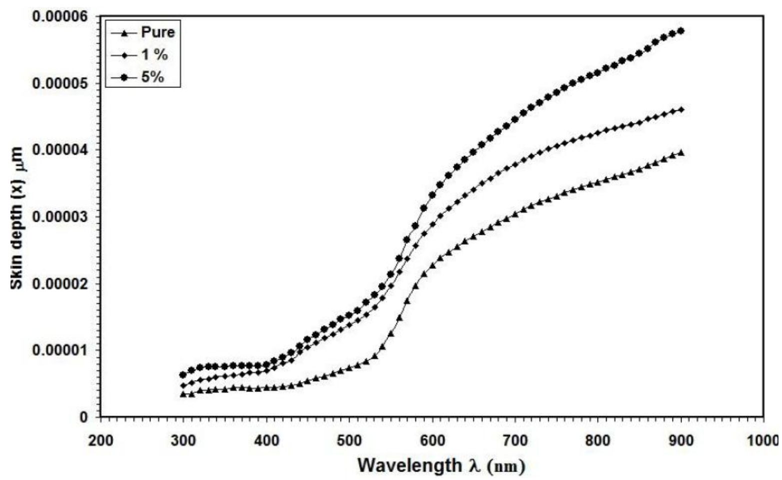

Figure 4 : Skin depth versus wavelength for pure and Co-doped CdO films

$$\sigma_{optical} = \frac{\alpha n c}{4\pi} \quad (3)$$

Where (n) is the refractive index and (c) is the velocity of light. The optical conductivity versus photon energy curve is shown in Figure 3. From this figure, it can notice that the optical conductivity is increased by increasing Co contain in CdO films. The gradual increase of optical conductivity in the low energy range, then its value increases rapidly beyond absorption edge region because of the high increase of the absorbance in this region.

The skin depth (χ) was calculated from the following relation[27]:

$$\chi = \frac{\lambda}{2\pi K} \quad (4)$$

Where λ is the wavelength of the incident photon and K is the extinction coefficient. The skin depth versus photon energy curve is shown in Figure 4. From this figure, it can show that the skin depth is increased with increasing Co contain in CdO thin films.

The absorption coefficient near the fundamental absorption edge is exponentially dependent on the incident photon energy and obeys the empirical Urbach relation, where ln(α) varies as a function of hí. The absorption edge in the spectral range of direct optical transitions has an exponential shape following the relationship[28]:

$$\alpha = \alpha_o exp\left(\frac{E}{E_U}\right) \quad (5)$$

Where E_U is the Urbach energy, which corresponds to the width of the band tail, α_o is a constant. Thus, a plot of ln(α) versushíshould be linear whose slope

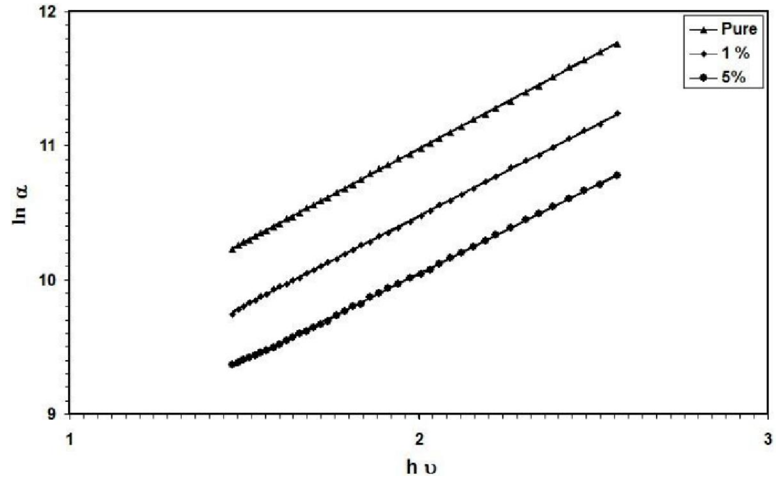

Figure 5: The lná versus hõ for pure and Co-doped CdO films

TABLE 1 : The optical parameters

Sample	E_d (eV)	E_o (eV)	E_g (eV)	ε_∞	n(o)	M_{-1} eV^{-2}	M_{-3} eV^{-2}	S_o x10^{13} m^{-2}	λ_o nm	E_U meV
Pure	93.90	5.07	2.53	19.51	4.41	18.51	0.72	6.41	624	714
1%	83.30	5.00	2.50	17.66	4.20	16.67	0.66	5.26	520	751
5%	69.69	4.94	2.47	15.08	3.88	14.08	0.57	4.29	508	781

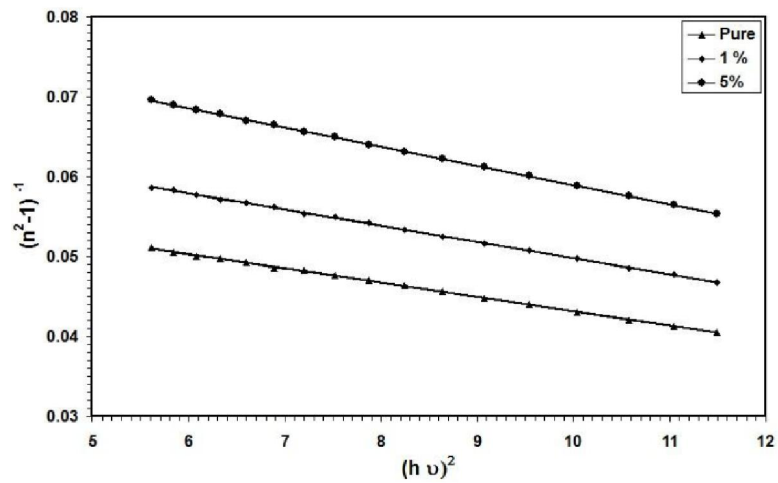

Figure 6 : The $(n^2-1)^{-1}$ versus $(h\upsilon)^2$ for pure and Co-doped CdO films

gives Urbach energy as shown in Figure 5. The Urbachenergies that calculated from Figure 5 are listed in TABLE 1. It can notice from the Table that the Urbach energy was increased with increases Co contain in CdO thin films, that related inversely with energy gap.

The dispersion in refractive index can be filled the single oscillator model proposed by Wimple and Didomenico, the spectral dependence of refractive index (n) according to this model is then defined by the equation[29]:

$$n^2 - 1 = \frac{E_o E_d}{E_o^2 - (h\upsilon)^2} \qquad \textbf{(6)}$$

Where E_o is the single oscillator energy parameter and E_d is the dispersion energy which is a measure of the strength of the interband transitions. The oscillator energy (E_o) is an average energy gap that listed in TABLE 1. By plotting of $1/(n^2-1)$versus $(h\upsilon)^2$ as shown in Figure 6 can be easily obtained these parameters. Also, the long wavelength refractive index (n_∞) for these samples was determined from the interception of the vertical axis in Figure 6 that listed

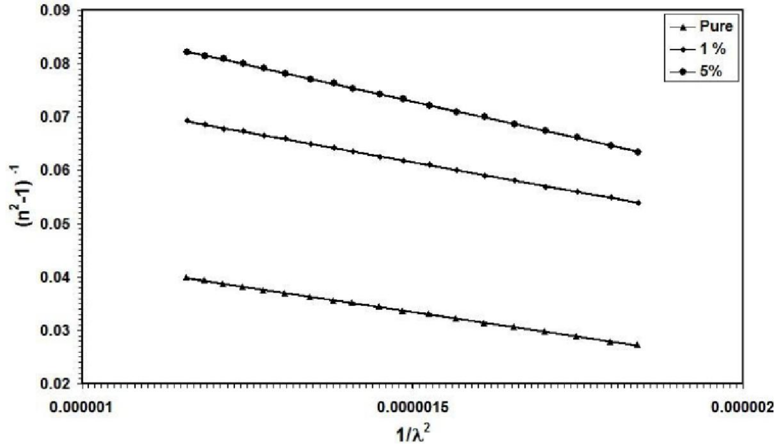

Figure 7 : The $(n^2-1)^{-1}$ versus $(1/\lambda^2)$ for pure and Co-doped CdO films

in TABLE 1.

The M_{-1} and M_{-3} moments of the optical spectra can be obtained from the following relations[29]:

$$E_o^2 = \frac{M_{-1}}{M_{-3}} \quad (7)$$

$$E_d^2 = \frac{M^3_{-1}}{M_{-3}} \quad (8)$$

The obtained values are given in TABLE 1. It is seen that M_{-1} and M_{-3} moments decrease with the increasing of the Co contain in CdO thin films.

For the definition of the dependence of the refractive index (n) on the light wavelength (λ), the single-term Sellmeier relation can be used[30]:

$$n^2(\lambda) - 1 = S_o.\lambda_o^2 / 1 - (\lambda_o/\lambda)^2 \quad (9)$$

Where λ_o is the average oscillator position and S_o is the average oscillator strength. The parameters S_o and λ_o in Eq. (9) can be obtained experimentally by plotting $(n^2 - 1)^{-1}$ against λ^{-2}. From Figure7, the slope of the resulting straight line gives $1/S_o$, and the infinite-wavelength intercept gives $1/S_o\lambda_o^2$, these parameters are listed in TABLE 1, which decreased with increasing Co contain in CdO thin film.

CONCLUSION

Cobalt doped CdO thin films were deposited on glass substrate using spray pyrolysis technique. Additive of Co on Urbach energy and dispersion parameters of CdO thin films that observed. Increases of Co contain in CdO thin film increasing the reflectance, optical conductivity, and skin depth, in addition increasing Urbach energy that inversely dependence with energy gap that changed from 2.53 to 2.47 eV. While the transmittance and dispersion parameters such as E_d, E_o, M_{-1}, M_{-3}, S_o, and λ_o are decreased with increasing Co contain in CdO thin film.

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