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Study of thin films $(ZnO)_{(0.4)}(CdO)_{(0.6)}$ composite properties

BENATTOU Halima[1*], BENRAMDANE Noureddine[1]

[1] *Laboratoire d'Elaboration et Caractérisation des Matériaux, Djillali Liabes University, Sidi Bel-Abbes, Algeria*
*Corresponding author *Email: h.benattou@gmail.com*

Abstract

Thin-films $(ZnO)_{(0.4)}(CdO)_{(0.6)}$ composites were grown by the spray pyrolysis technique on glass substrates heated to a temperature of 350°C. The structural properties have been identified using X-ray diffraction spectra. The deposited films are of polycrystalline natures. Both the two materials mixed (ZnO and CdO) were well observed in the X-ray diffraction plot. The optical properties were also studied using UV- Vis optical spectroscopy. transmittance and reflectance are measured in the wavelength range of 200nm to 2500nm. The evaluation of the optical gap shows that this composite has two gaps, the first concerns the ZnO and the second concerns the CdO.

***Keywords**: Thin films; ZnO; CdO; Composite materials; Structural and optical properties*

1. Introduction

The composite materials investigation started more than one century ago. The efforts to design a new product did not stop because of the particular interest related to these materials. The major interest was the possibility to obtain diverse properties according to the constitute phase's characteristics. The applications of these materials were especially in the electronic engineering fields such as transparent conducting materials such as oxides in thin films. They have electrical conductivity and optical transparency satisfactory for modern technological applications (like transparent electrodes in solar cells, and screens with liquid crystals). It results in a strong demand for dielectric materials with well-defined properties and materials transparent to the electromagnetic waves in defined wavelength ranges. However, the properties of the natural materials generally do not satisfy the modern requirements of the industry. Artificial materials having at the same time a larger gap, high transparency, high permittivity, and high conductivity were then used in the objective to meet these needs. The cadmium oxide and the Zinc oxide are two materials that belong to transparent conducting oxides (TCO), of group II-VI of the semiconductors. Both are n-type semiconductor components [1, 2]. The band gap energy of the ZnO is 3.3ev [3, 4]. Its resistivity is in the order of 10^3 Ω.cm [5]. The zinc oxide in thin films is used in a variety of applications such as Electronic systems like varistors employed at the time of large cuts of electroluminescence [6,7]; Sensors of chemicals in thin films. CdO thin films have band gap energy of about 2.3ev [8, 9,10]. Its resistivity is in the order to 10^{-2} Ω.cm [11] at ambient temperature. CdO thin films are used in photodiodes, Phototransistors, Photovoltaic cells, transparent electrodes, and the detectors IR. For the ZnO and CdO applications mentioned above, we were interested in this work in the structural and optical properties study of the composition of ZnO and CdO materials.

2. Experimental details

The films were deposited by the chemical Spray Pyrolysis technique. the starting product used is ($Zn(NO3)_2$ $6H_2O$), and ($Cd(NO_3)_2$ $4H_2O$); they are dissolved in distilled water. We have chosen molarity of 0.1mol. The material composition's result was the mixture of 40% of ZnO solution and 60% CdO solution The chosen crystallization temperature is 350°c. The properties extraction of thin films is done in several techniques: X-ray diffraction (XRD) to bring out structural properties. JASCO V-570 spectrophotometer operating in ultraviolet-visible – near-infrared spectral range (200nm-2500nm) used for optical characterization.

3. Results and discussion

Structural characterization by X-ray diffraction (XRD)

The $ZnO_{(0.4)}CdO_{(0.6)}$ diffraction spectrum given in “Fig.1” is very rich in diffraction peaks, which means that the film produced is well crystallized. The most intense peak is that of (200) at 2θ = 38.5°. It characterizes the CdO phases with a cubic with centered faces (CFC). Not only, they are also the characteristic peaks of ZnO as (002) at 2θ = 34.421°. We report the presence of other peaks on the same spectrum, they are also of significant intensity. All these peaks belong to ZnO of the compact hexagonal system, and CdO of a face-centered cubic. The different peak's presence in the diffraction spectrum confirms ZnO and CdO co-existing in thin films crystallized.

The lattice parameters of ZnO and CdO are calculated from formula (1) and (2) [12]. They are a= 4.67Å for CdO, and a= 3.26 Å, c= 5.19 Å for ZnO.

$$d_{hkl} = a / [(4/3).(h^2 + k^2 + hk) + l^2.a^2/c^2]^{(1/2)} \qquad (1)$$

$$d_{hkl} = \frac{a}{\sqrt{(h^2+k^2+l^2)}} . \text{ Avec } a = b = c \qquad (2)$$

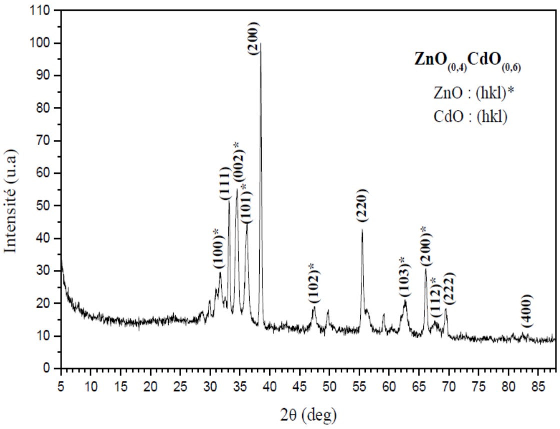

Figure 1. $(ZnO)_{(0.4)}(CdO)_{(0.6)}$ diffraction pattern

The width at mid-height, intervened in Scherrer's formula (formula 3), is obtained by fitting the most intense peak to Lorentz's law.

$$G = \frac{k\cdot\lambda}{W\cdot cos(\theta)} \qquad (3)$$

Where, G is average grain size in Å. K is a forme factor varied between 0.7 and 1.7.

w: is the width at mid-height of the most intense diffraction peak (in rad).

λ: Wavelength of the incident beam (in Å).

θ : Bragg angle (in rad).

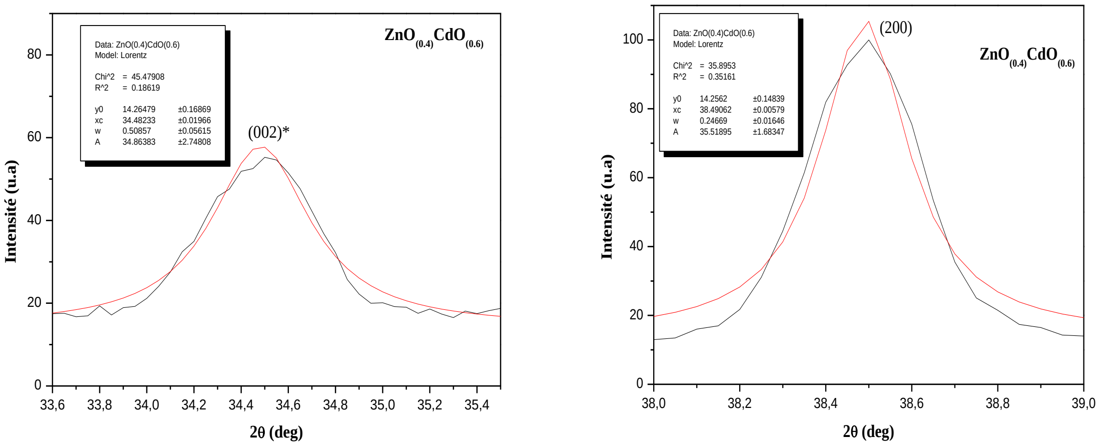

Figure 2. Adjustment by Lorentz's law on the two peaks (002)* and (200)

The crystallites (G) sizes of the two components ZnO and CdO calculated, are of the order of 173.655Å and 358.004Å respectively.

B. Optical characterization by UV-Vis spectrophotometer:

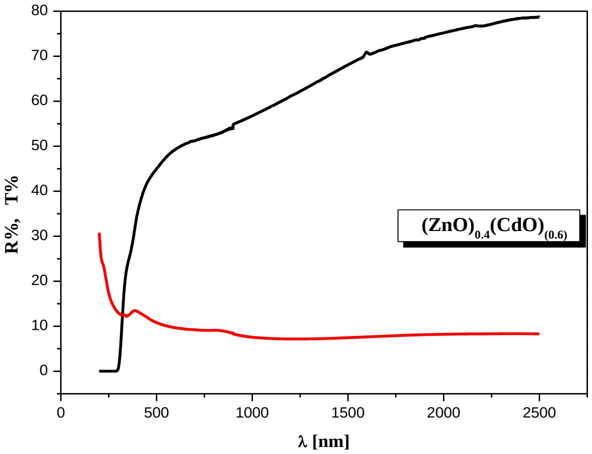

Figure 3. reflectance and transmittance spectrum of the thin-films

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In “Fig.3”, The reflectivity reaches 20% in the visible (between 300nm to 800nm) and slightly exceeds 30% in the UV (<300nm). The transmittance increases abruptly, and it reaches up to 80% in the near-infrared, and in the visible, it exceeds 40%. The maximum of the reflectance corresponds to the minimum of the transmittance and vice versa. The absorption coefficient of the material was calculated according to the following formula:

$$\alpha = \frac{1}{d}.Ln\left(\frac{1-R}{T}\right) \tag{4}$$

Where d is the thickness of the deposited film. R and T are the film’s reflectance and transmittance.

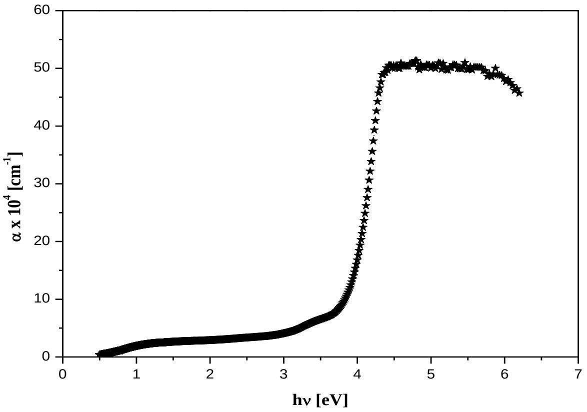

Figure 4. the absorption spectrum of $(ZnO)_{(0.4)}(CdO)_{(0.6)}$ thin film

In the absorption spectrum of the material in “Fig.4”, there are three distinct regions: the first corresponds to low energies where the absorption of the films is residual; a second region where we can clearly notice a quadratic increase; the third region at high energies where a large amount of the light intensity is absorbed.

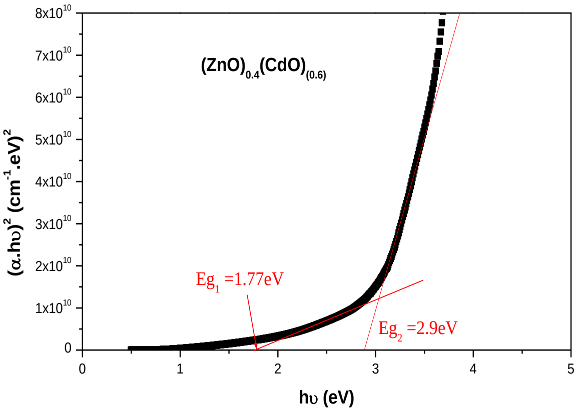

Figure 5. Optical gaps of $ZnO_{(0.4)}CdO_{(0.6)}$ thin films

In “Fig. 5”, the curve $(\alpha h\upsilon)^2$ as a function of photon energy (hυ) presents two linear parts in the vicinity of the fundamental absorption threshold of which we can suggest that our thin films have a two direct optical gap of the order of Eg_1= 1.77ev and Eg_2= 2.9eV. The one is close to that of ZnO of the compact hexagonal system, and the second is also close to that of CdO of the centered face’s cubic system.

4. Conclusion

The $(ZnO)_{(0.4)}(CdO)_{(0.6)}$ material composites in thin films were grown on glasses substrates by spray pyrolysis method. The samples were characterized by XRD and UV-Vis-NIR spectroscopy. The diffraction spectrum reveals the presence of both ZnO compact hexagonal system and CdO in the centered face's cubic system. In the optical study, it was found that the absorption of CdO is intense over the visible range; it extends to the UV range. Also, ZnO film has high transparency in the visible and the near-infrared region of the solar spectrum. Therefore, the absorption and transmittance of the $(ZnO)_{(0.4)}(CdO)_{(0.6)}$ composites can be enhanced,

it reached 80% and improved by the mixing of the two materials. We conclude that the $(ZnO)_{(0.6)}(CdO)_{(0.4)}$ composites have a good visible light response. Ultimately, we

summarize that it is useful to the synthesis of composites with Zinc Oxide and Cadmium Oxide in an aqueous solution.

References

[1]. R. Ferro, J. A. Rodriguez, O. Vigil, Chemical composition and electrical conduction mechanism for CdO:F thin films deposited by spray pyrolysis, Materials Science and Engineering: B, Vol. 87, 2001, pp. 83-86.

[2]. R. E. Hummel, Electronic properties of materials, Third Edition, Springer, 2000, pp. 178.

[3]. S. Tewari, A. Bhattacharjee, P. P. Sahay, Studies on AC conductivity of spray deposited ZnO thin films, Physical Sciences and Technology, Vol. 5, No. II, 2010, pp. 216-219.

[4]. B. Ergin, E. Ketenci, F. Atay, Characterization of ZnO films obtained by ultrasonic spray pyrolysis technique, International Journal of Hydrogen Energy, Vol. 34, 2009, pp. 5249 –5254.

[5]. Ü. Özgür, Ya. I. Alivov, C. Liu, A. Teke, M. A. Reshchikov, S. Doğan, V. Avrutin, S. J. Cho and H. Morkoç, A comprehensive review of ZnO materials devices, Journal of Applied Physics, Vol. 98, 2005, pp. 041301.

[6]. R. N. Viswanath, S. Ramasams, R. Ramanoorthy, P. Jayavel, T. Nagarajan, Preparation and characterization nanocrystalline ZnO based materials for varistor applications, Nanostructured Materials, Vol. 6, 1995, pp. 993-996.

[7]. T. Pauporté, D. Lincot, Electrodeposition of semiconductors for optoelectronic devices: results on zinc oxide, Electrochimica Acta, Vol. 45, 2000, pp. 3345 - 3353.

[8]. B. J. Lokhande, P. S. Patil, M. D. Uplane, Studies on cadmium oxide sprayed thin films deposited through non aqueous medium, Materials Chemistry and Physics, Vol. 84, 2004, pp. 238-242.

[9]. M. D. Uplane, P. N. Kshirsagar, B. J. Lokhande, C. H. Bhosale, Characteristic analysis of spray cadmium

oxide thin films, Materials Chemistry and Physics, Vol. 64, 2000, pp. 75-78.

[10]. K. Ouari, N. Benramdane, Z. Kebbab, A. Nakrela, R. Desfeux, Theoretical and experimental study of CdO, Journal of Active and Passive Electronic Devices, Vol. 7, 2012, pp. 29-37.

[11]. K. Gurumurgan, D. Mangalaraj, Sa. K. Narayandass, Characterization of cadmium oxide thin films deposited by spray pyrolysis, Journal of Crystal Growth, Vol. 147, 1995, pp. 355-360.

[12]. Jean- Jacques Rousseau, Ain Gibaud, 'Cristallographie géométrique et radiocristallographie, Cours et exercices corrigés', 3^{e} édition, Dunod, Paris, 2000, 2007, ISBN 978-2-10-050198-4.