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Characterization of Zn-Doped CdO Nanoparticles Thin Films Synthesized by Pulsed Laser Deposition

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ABSTRACT

In this investigation, thin films of CdO:Zn were synthesized by using the technology of pulsed lasers. Additionally, the effect of different concentrations of Zn doping on the material's physical properties was investigated. According to XRD research, the films have a polycrystalline structure, and it was discovered that the size of the crystallites changes depending on the amount of Zn doping. The morphology of the produced films reveals that there are spherical nanoparticles distributed evenly all over the surface of the films and ranging in size from nanometer to nanometer. The increase in Zn doping concentrations resulted in an improvement of the material's optical characteristics. The results of the Hall effect observations show that each of the films possesses n-type conductivity. This property, combined with the films' low resistivity, enables them to be utilized in a wide variety of contexts. In addition to this, each of the films has a large concentration of carrier molecules.

Keywords: CdO; PLD; XRD; band gap; Hall effects

I. INTRODUCTION

Due to its narrow band gap (2.2–2.7eV), n-type conductivity, and good transparency in the near-infrared spectrum, as well as its favorable electrochemical properties, Cadmium Oxide (CdO) is well known as one of the preferred II–IV compound metal oxide semiconductors in a wide range of applications [1-3In addition, CdO thin films have found use in a wide variety of applications, such as gas sensors [4], antibacterial agents [5], heterojunction diodes [6], translucent conducting oxide [7], nonlinear optical devices [8] and solar cells [9]. [4-9] CdO thin films were made using various techniques such chemical bath deposition (CBD) [10], successive ionic layer reaction andadsorption [11], magnetron sputtering [12], physical vapor deposition (PVD) [13], deposition by pulsed laser [14], spin coating [15], chemical spray method [16], and atmospheric-pressure chemical vapor deposition (APCVD) [17]. In the work that we are doing, we are going to investigate how the structural, morphological, optical, and electrical properties of Zn-doped CdO thin films are affected by the concentration of Zn doping (0, 1, 3, and 5%), and we will do this using the pulsed laser methodology.

II. EXPERIMENTAL

On BK7 glass and silicon substrates, thin CdO:Zn films with doping concentrations of 0%, 1%, 3%, and 5% were deposited using a procedure that involved the use of a pulsed laser. Both the CdO and the Zn granules that were utilized came from Sigma-Aldrich and had a purity level of 99.9%. For the purpose of fabricating thin coatings, CdO:Zn pellets of varying doping concentrations were utilized. These pellets were then subjected to a vacuum pressure of 10-5 mbar. The laser had an energy of 200 mJ, and there were 200 separate blasts. In addition, the substrate was heated to a temperature of 300 degrees Celsius, and the distance from the objective to the substrate was five centimeters. Reflectometer measurements were used to determine the thickness of CdO:Zn thin layers, which came out to be 150.4 nanometers on average.

III.RESULTS AND DISCUSSION

X-ray diffratometer was used to examine the structural characteristics. Figure 1 depicts the diffraction spectra for CdO:Zn thin films. All films are polycrystalline CdO with a favored orientation along (111). There are no apparent concentrations of zinc metal or zinc oxide. The typical crystallite size of CdO:Zn thin films has been calculated using Sherrer's equation [18]:

$$D_A = \frac{0.94\lambda}{\beta cos\theta} (1)$$

Where D_A, λ, β, and θ are the size of ,thewavelength of X-ray is about (1.54056 Å), the full width at half maxima, and the Bragg's angle, respectively. The average crystallite size was found to vary with Zn doping concentrations, the calculated values were tabulated in table 1. The microstrain ε of CdO:Znthin films has beenestimatedby the following formula [19]:

$$\varepsilon = \frac{\beta}{4 \tan\theta} (2)$$

The calculated values of microstrain are listed in table 1.

Table 1 the average size of crystallite and microstrain of CdO:Zn thin films.

Sample	Average Crystallite size D_A (nm)	Micro Strain $\varepsilon \times 10^{-3}$
CdO pure	23	4.97
CdO:Zn1%	40	1.97
CdO:Zn3%	36	3.07
CdO:Zn5%	26	4.07

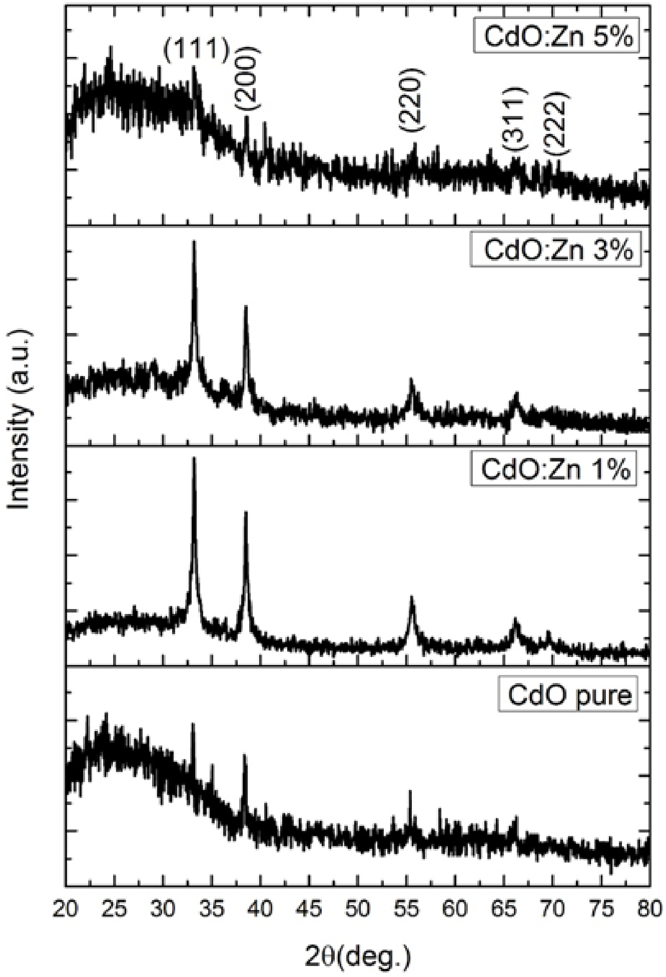

Fig.1 XRDpatterns CdO:Zn thin films

The morphology of thin layers made of CdO:Zn was examined using scanning electron microscopy. As can be seen in Figure 2, none of the films contain any voids or fractures; additionally, one can plainly make out spherical nanoparticles distributed along the surface of thin films. In addition, the concentrations of Zn doping have been shown to cause changes in the diameters of these particles.

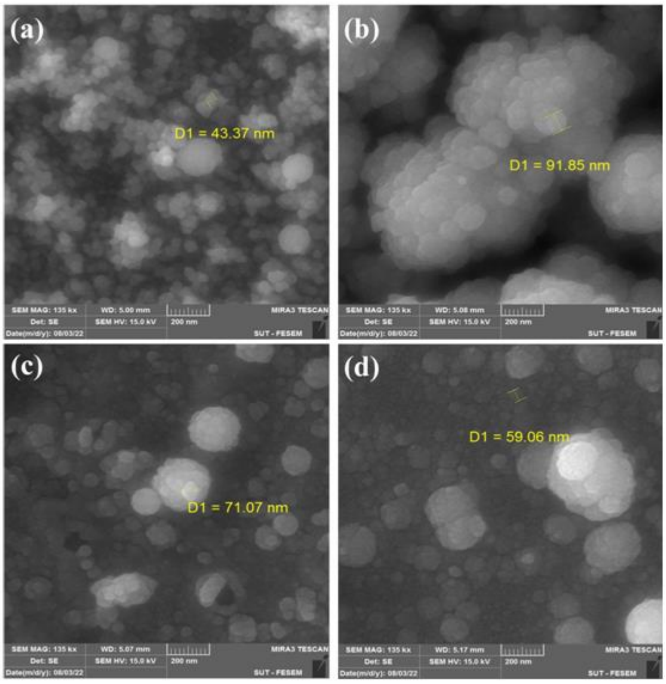

Fig.2 FESEM micrographs of a) pure CdO, b) CdO:Zn 1% , c) CdO:Zn 3%, and d) CdO:Zn 5%

The UV-Vis-NIR spectrophotometer was used to examine the optical characteristics of CdO:Zn thin films at wavelengths between 300 and 1100 nm.The transmittance spectra of the CdO:Znthin filmswereshown in fig.3, the transmittancespectrahave the same manner with increasing wavelength. Moreover CdO:Zn5% filmshave the highest transmittance about65% in the NIR region due to the minimal scattering radiation occurred on the surface of nanoparticles.The following equation [20] was used to calculate the absorption coefficient:

$\alpha = -\frac{1}{x}\ln(T)$(3)

Where α is absorptioncoefficient, *x*, and *T* are film thickness and transmittance of the films.

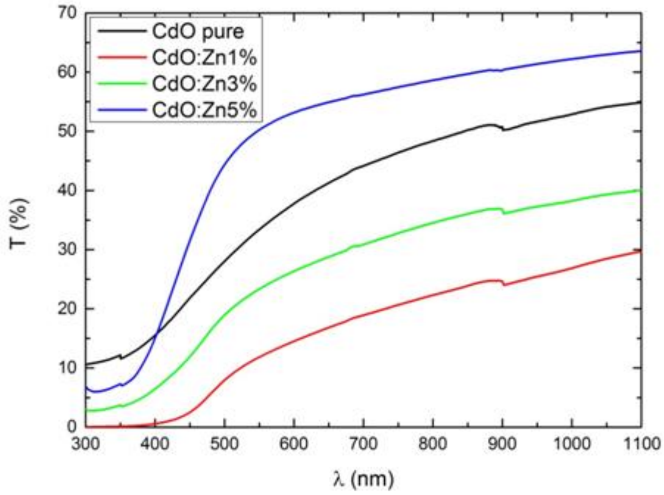

Fig.3trasmittance spectra of CdO:Zn thin films

Absorption coefficientsforCdO:Znfilmswere found to decrease with increasing wavelengthas shown in fig.4. Further,αwas found to vary with Zn doping concentrations andhave high values($\alpha \geq 10^6$) $m^{-1}$for all films.

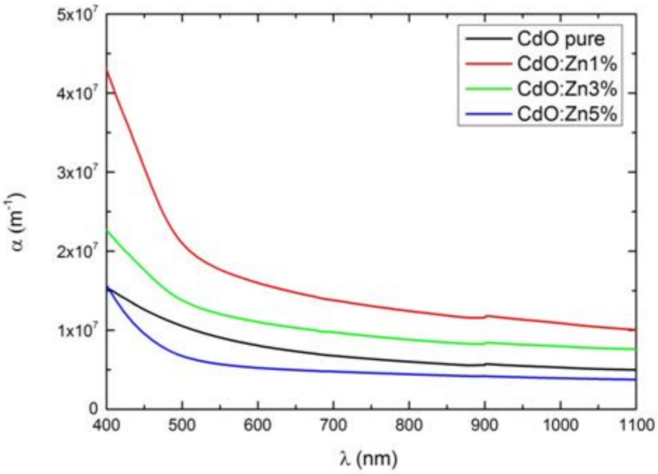

Fig.4 the absorption coefficients of CdO:Znthin films

The energy gap for CdO:Zn thin films was estimatedusingthe following equation[21]:

$(\alpha h\upsilon)^2 = B(h\upsilon - E_g)$ (4)

Where *B*is a constant,*h*υ and *Eg* arethe photon energy and energy gap. According to Fig. 5, the energy gaps increased from 2.525 eV for pure CdO to 2.747 eV, 2.673 eV, and 2.851 eV, respectively, for CdO:Zn1%, CdO:Zn3%, and CdO:Zn5% thin films.Compared to bulk CdO, the calculated values of the energy gap were higher, this might attributed to the size reduction in the nanoparticles, this findings are coincident with the work reported in ref. [22].

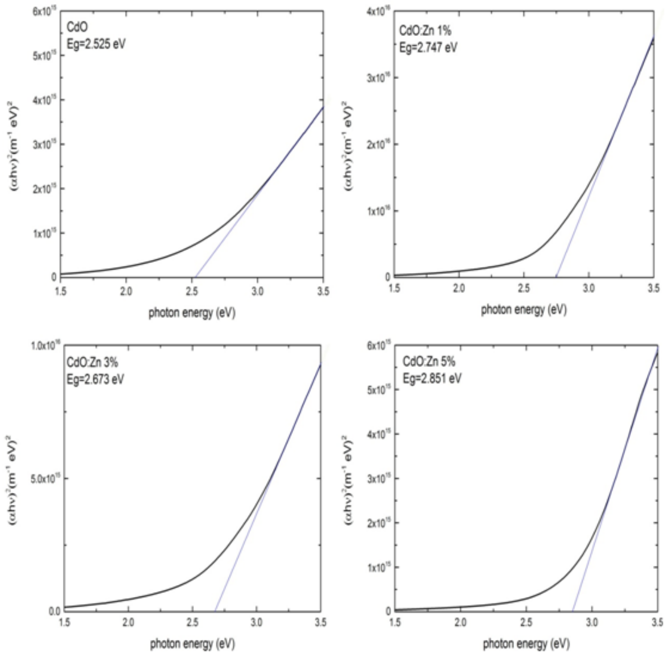

Fig.5 the band gap of CdO:Znthin films

Hall effect measurements were employed to assess the electrical properties of CdO:Zn thin films in a Van Der Pauw configuration.Hall effectcharecterestics were tabulated in table 2, according to this measurements, all films have n-type conductivity. Moreover the highest conductivity and mobility arerecored in CdO:Zn1% thin films.

Table 2 Hall effectcharacteristics of CdO:Zn thin films

Sample	Sheet Resistance Rs (Ω)	Carrier Concentration $n \times 10^{18}$ (cm^{-3})	Hall Coefficient R_H (cm^{-3} C^{-1})	Conductivity σ ($(\Omega$ $cm)^{-1}$)	Mobility μ (cm^2 V^{-1} s^{-1})	Type
CdO pure	138	1.86	-3.36	362	1210	n
CdO: Zn1%	93.3	0.874	-7.14	536	3830	n
CdO: Zn3%	129	1.72	-3.62	387	1400	n
CdO: Zn5%	123	1.86	3.35-	408	1370	n

IV.CONCLUSIONS

To summarize, the pulsed laser technique was used to produce CdO:Zn thin films. Additionally, the influence of Zn concentrations on the morphological, structural, electrical ,optical properties of the films was investigated. The crystallite size was found to vary from (23) nm to (40) nm by Zn doping concentration, as well as the micro strain was effected. SEM analysis show the films comprised of nanoparticles with sizes (43-91) nm. XRD analysis reveals the polycrystalline structure of cubic CdO. It was found that the energy difference increased from (2.525) eV to (2.851) eV when the amount of Zn in the compound was raised. The Hall effect measurements show that all of the films have n-type conductivity, and the films found to have high electrical conductivities along with large concentrations of speed carriers. These characteristics give the films that have been prepared the ability to have a variety of numerous applications in subjects that span across multiple disciplines.

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