

Research Article

Structural, Optical, and Morphological Properties of the Cadmium Oxide Thin Film

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Abstract

Cadmium oxide nanoparticles CdO NPs has been prepared by laser ablation in ethanol at 600 pulses and 600 mJ as laser energy. The structural, optical, and morphological properties of the cadmium oxide CdO thin film deposited on a glass substrate have been studied. X-ray diffractometer (XRD 6000, Shimadzu, X-ray, diffractometer) with $CuK\alpha$ radiation at a wavelength of ($\lambda = 0.154056$ nm) was utilized to investigate the structural properties of CdO NPs. The optical absorption of colloidal CdO NPs was measured using a spectrophotometer (Cary, 100 cans plus, UV-Vis-NIR, Split Beam Optics, Dual detectors) in the range of (200–900) nm. The morphology of the CdO NPs was investigated by using AFM (AA 3000 Scanning Probe Microscope). The thickness of the films was measured using ellipsometer (Angstrom sun Technologies Ins).

Keywords: Nanoparticles, laser ablation, XRD, AFM, CdO.

الخلاصة

حضرت جسيمات أكسيد الكاديوم النانوية باستخدام تقنية السقواء الليزري في محلول الايثانول عند 600 نبضة و600J كطاقة ليزرية. درست الخصائص التركيبية والبصرية والتضاريسية التشكيلية لغشاء رقيق من جسيمات أكسيد الكاديوم النانوية المرسبة على قاعدة زجاجية. كانجهاز تداخل الأشعة السينية ذات $CuK\alpha$ عند طول موجي $\lambda = 0.1540$ nm لملانما لتقصي الخصائص التركيبية للغشاء الرقيق لجسيمات أكسيد الكاديوم النانوي. قيس الأطنصاصية البصرية للمحلول الغروي لجسيمات أكسيد الكاديوم النانوي باستخدام مقياس الطيف (Cary, 100 cans plus, UV-Vis-NIR, Split Beam Optics, Dual detectors) في المدى 200-900 nm. أستقصى على تشكيل السطح للغشاء الرقيق لجسيمات أكسيد الكاديوم النانوية باستخدام مطياف القوى الذرية (AA 3000 Scanning Probe Microscope). قيس سمك الأغشية الرقيقة باستخدام مقياس السمك (Angstrom sun Technologies Ins).

Introduction

In general metal oxides can be possessed a transparent conducting property which is called transparent conducting oxides (TCO's). Andreas Stadler in his paper and Habubi with his coworkers as well as Khudheir *et al.* in 2012 said that the most of the studies of transparent conducting metal oxides are anion deficient (Oxygen deficient) and hence are always n-type conductors [1] [2] [3]. The transparent conducting metal oxides are also considered as oxide semiconductors. Metal oxide thin films (MOTF) are very important in the field of science and technology, it can be shown different properties of metals, semiconductors and insulators with enhanced electrical and optical properties. Some of MOTFs applications are referred in papers of Radi, Yu Yang, and also Radi as electrodes in optoelectronic devices, display devices and pho-

tovoltaic cells respectively [4], [5] and [6]. The n-type cadmium oxide CdO thin films exhibit rock salt structure (FCC) with band gap of 2.2eV. Ortega *et al.* in their paper emphasized that CdO thin film has a good optical conductivity and transmission in the visible region [7]. The main aim of this study is to create a simple, non-vacuum and economic deposition technique for efficient transparent conducting CdO thin films where there are many techniques exist to prepare the thin films such as spray pyrolysis[8], sputtering[9], sol-gel spin coating[10], activated reactive evaporation[11], metal Organic Chemical Vapor deposition [12], pulsed laser deposition[13]. In this study CdO films were synthesized using laser ablation in ethanol. Optical properties such as transmission, bandgap, refractive index, absorption coefficient, extinction coefficient, dielectric constant (imaginary and real)

and Urbach energy were studied for CdO NPs thin films deposited on FTO substrate.

Materials and Methods

The laser type Nd:YAG was selected for the ablation operating at 10 Hz repetition rate, with 7 ns pulse width and wavelength of 1064 nm. The laser pulses were focused by a 20 cm positive lens onto a cleaned 2 mm thick CdO bulk sample (99.99% purity provided by Porch Company) immersed in ethanol at laser energy (400 mJ) with an ablation time of 20 min. The energy of laser pulse was measured using calibrated Joule meter after taking into account the effect of ethanol transmittance. The CdO target was placed in the bottom of a quartz vessel filled with 10 ml of ethanol. Structural properties of CdO NPs deposited on a glass substrate was investigated by X-ray diffractometer (XRD 6000, Shimadzu, X-ray, diffractometer) with $\text{CuK}\alpha$ radiation at a wavelength of ($\lambda = 0.154056$ nm). Optical absorption of colloidal CdO NPs was measured using a spectrophotometer (Cary, 100 cans plus, UV-Vis-NIR, Split Beam Optics, Dual detectors) in the range of (200–900) nm. Morphological of the CdO NPs was emphasized by using AFM (AA 3000 Scanning Probe Microscope). The thickness of the films was determined using ellipsometer (Angstrom sun Technologies Ins). Measurements were carried out at room temperature at 200 nm thickness.

Results and Discussion

Figure 1 show XRD patterns of CdO thin films deposited on FTO substrate. X-ray diffraction patterns of CdO thin films revealed polycrystalline nature with a cubic structure. The observed diffraction patterns were indexed with standard values (JCPDS card no.78-0653). X-ray diffraction patterns also show that various diffraction peaks at 2θ values 26.42° , 33.62° , 37.67° , 55.52° and 69.44° , were identified to originate from (200) (110) (220) (222) and (111) planes, respectively, which corresponds to CdO face centered cubic structure. The large peak at 37.67° indicates that CdO thin film is preferentially oriented along the (200) crystallographic plane. The structural properties were calculated using expressions given by Abd [14]. Crystallite size was in the order of 20 nm to 76 nm. The microstrain,

number of crystallites and dislocation density of the CdO thin film is listed in Table 1.

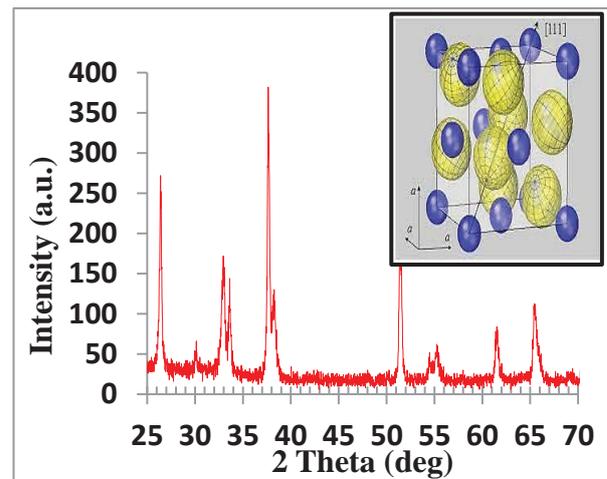


Figure 1: shows XRD patterns of the CdO thin films deposited on FTO substrate

Figure 2 shows the 2D-3D AFM images of CdO NPs thin film deposited on an FTO substrate by drop casing method. The surface of the thin film has vertically closely packed ball shaped, within the scanning area (2×2) μm . Using special software (4.62 imager), the estimated of the average grain was around 46 nm. Homogenous and a good roughness grain of CdO nanostructure were noticed. Figure 3 illustrates the UV-Vis spectra of ethanol solution containing CdO NPs prepared by laser ablation in liquid technique. The transmittance curve was subdivided into two regions at the visible and near IR regions. The transmittance curve decreases sharply from 400 nm up to 1100nm, so the CdO NPs has an acceptable transmittance in the visible range, which can be used in solar cell and a smart window and that is a good agreement with Aldwayyan *et al* [15]. Figure 4 shows the variation of $(\alpha h\nu)^2$ verses $h\nu$ for direct band gap which have been determined by the extrapolation of the linear portion versus the photon energy axis. It can be seen that the value of the energy gap was about 1.4 eV.

Table 1: Characterization of XRD patterns for CdO thin films deposited on FTO substrate.

2 Theta (deg)	FWHM (deg)	hkl planes	D (nm)	$\sigma \times 10^{14}$ lines. m ⁻²	$\eta \times 10^{-4}$ Lines ⁻² . m ⁻⁴	Nx 10 ¹⁸ 1/m ²
37.67	0.25	(200)	33.40818	8.95972	10.37171	80.9932
26.42	0.246	(110)	32.99681	9.184514	10.50102	84.06036
55.25	0.366	(220)	24.3946	16.8041	14.204	208.031
69.44	0.126	(222)	76.44941	1.711007	4.532409	6.759032
33.62	0.4	(111)	20.64165	23.4699	16.78645	343.3791

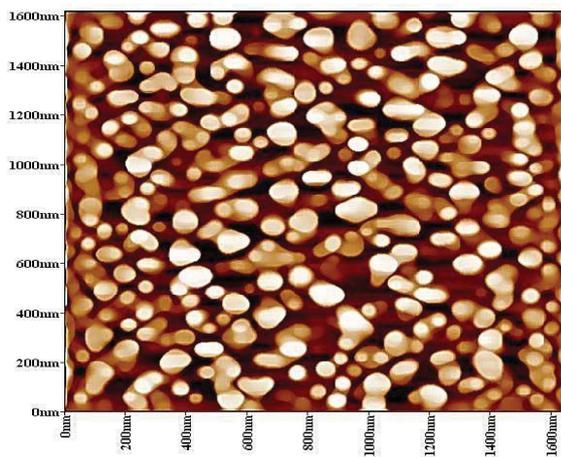
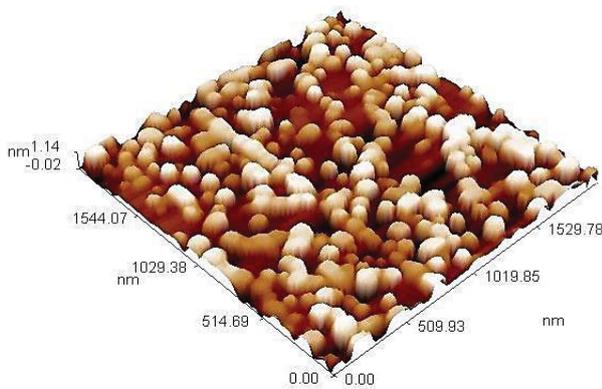


Fig.2: 2D and 3D AFM images of synthesized CdO nanoparticles.

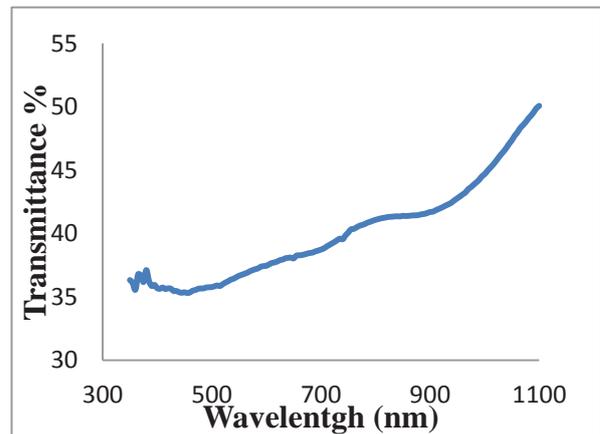


Figure 3: UV-Vis transmittance spectra of nanoparticles colloid fabricated at wavelength CdO ablated with 400 mg at 1064nm.

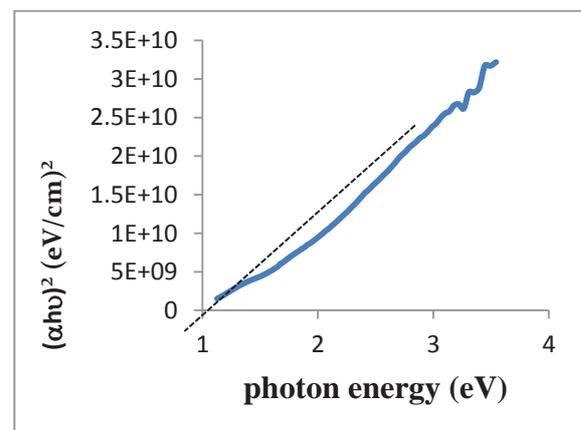


Figure.4: $(\alpha h\nu)^2$ versus photon energy plot for CdO NPs in ethanol.

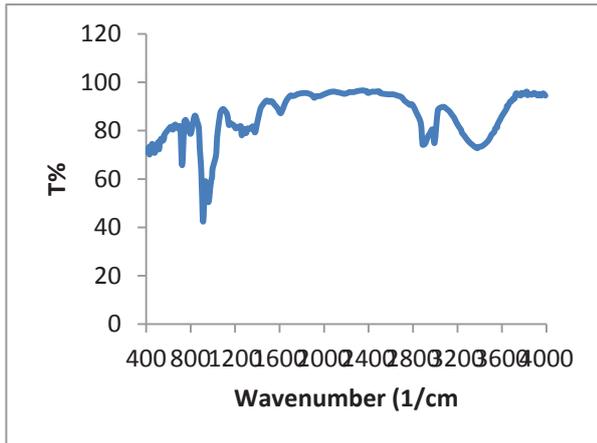


Figure 5: FTIR for CdO Nanoparticles.

Figure 6 shows the I-V dark characteristics in forward and reverse direction of Al/CdO/ p-Si/Al. The forward current of photodetector was very small at voltages less than 1 Volt. This current is known as *recombination current* which occurs at low voltages only. It is generated when each electron excited from valence band to conductive band. The second region at high voltage represented the diffusion or bending region, which depends on a series resistance. In this region; the bias voltage can deliver electrons with enough energy to penetrate the barrier between the two sides of the junction.

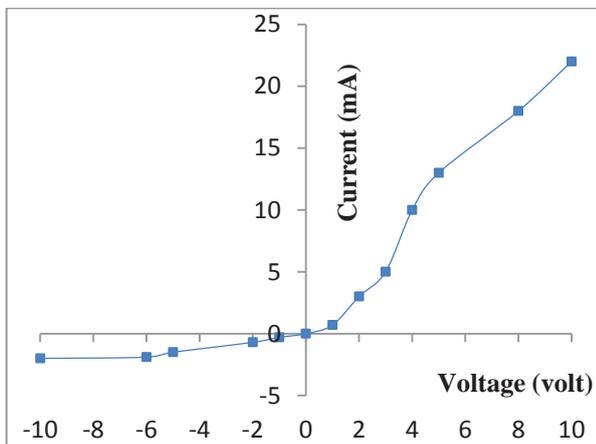


Figure 6 shows the I-V dark characteristics for CdO/Si heterojunction

Figure 7 shows that a linear relationship between $1/C^2$ and reverse bias voltage was obtained for the structure. This linear relationship represented the photodetector (CdO /Si) and (PSi/Si). The values of the built-in potential have been obtained and it had been found equal to 0.2 Volt.

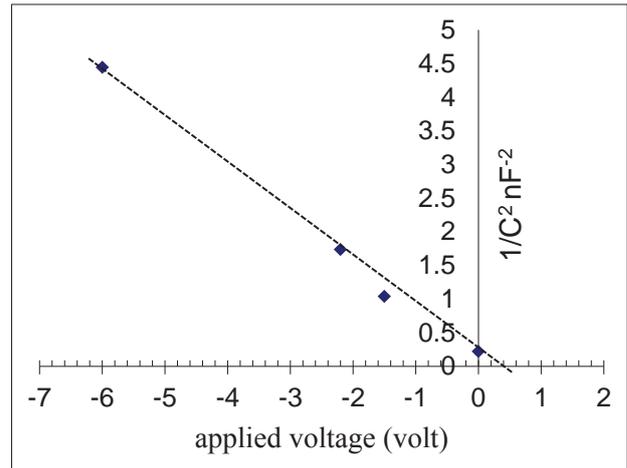
Figure 7: $1/C^2$ versus reverse voltage of CdO/PSi Photodetectors.

Figure 8 displays the responsivity as a function of wavelength for CdO/p-Si photodetector, the maximum responsivity is located in the visible region and the other at the NIR region, the spectral responsivity curve of CdO/p-Si consists of one peak of response; the peak was located at 575 to 850 nm due to the absorption edge of CdO NPs and Si nanoparticles.

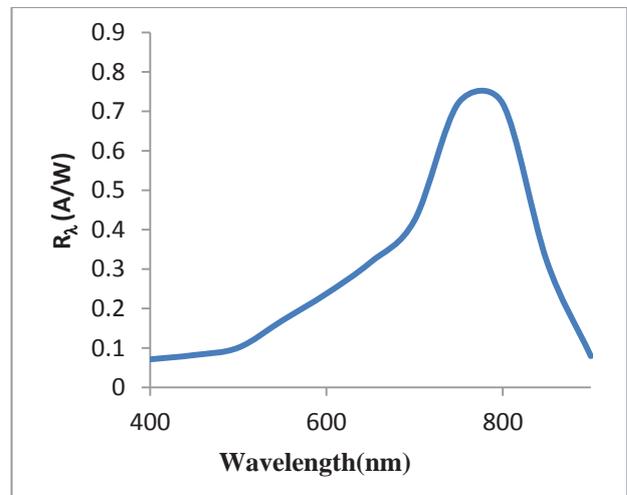


Figure 8: Spectral Responsivity plots for CdO/p-Si as a function of wavelength.

Conclusions

The synthesized CdO NPs were in nanosized of 46 nm prepared in ethanol by laser ablation in liquid method and the optical properties revealed that the direct band gap of CdO NPs indicated to the effect of quantum size. X-ray diffraction (XRD) measurement disclosed that the CdO NPs are polycrystalline and have FCC crystal structure and no other phases were noticed. Deposition of CdO NPs on silicon (Si) gave suspensions

photodetector characteristics enhanced the properties porous photodetectors. The spectral responsivity of Al/CdO /Si/Al photodetector was around 0.7 A/W at 790 nm.

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