Analysis of Electrodeposited Cadmium Oxide Thin Films and their Possible Applications

Nnabuchi M.N., Onyishi S.O.
Ebonyi State University, Abakiliki Ebonyi State, Nigeria
mnnnabuchi@yahoo.com, onyishis@gmail.com

Abstract

Thin films of cadmium oxide (CdO) were electrodeposited on ITO substrate from aqueous solution of cadmium chloride. The optical studies showed that CdO thin films have high average transmittance of over 76% in the visible region and 95% and above in the near infrared region. The direct band gap as observed in the work is between 2.70eV and 2.80eV. The XRD studies revealed amorphous CdO thin films. These characteristic properties make this film good candidates for applications in photovoltaic, transparent electrodes, photodiodes, photo-transistors, liquid crystal displays etc.

Key words CdO, XRD, Band gap, Electrodeposition

Introduction:

Oxides of metals are becoming important and prominent groups of materials in optoelectronic devices and other devices due to their versatile structural and optical characteristics. These characteristics include among others, semi-conductivity, optical, electrochemical, opto-electronics, thermal, magnetic, electric, catalytic and sensor properties (Ezeokoye, et al, 2013). Other optical properties which make these materials attractive include high percentage transmittance, remarkable luminescence characteristics, good band gap invisible spectral domain (Lokhande et al, 2009). These diversities are due to electronic structure of metal oxides when compared with other classes of materials. The beauty of these materials are found in the symmetry, oxidation states, coordination numbers, density, stoichiometry and acid-base surface properties they exhibit (Harbeke, 1972). These characteristics made them good candidates for applications in photovoltaic, transparent electrodes, photo-transistors, photodiodes, liquid crystal displays, anti-reflection coatings and infrared detectors.

Cadmium oxide thin film is the n-type semiconductor which exhibits salt structure, FCC with wide optical band gaps, high transmittance and high conductivity (Ortega et al, 1999).

In the recent past, this film has attracted attention because of its attractive properties as well as wide range of technical applications in transparent electrodes, photovoltaic, saucers, display devices and others.

Researchers have used different methods to prepare this material in the recent past. These methods include sputtering, spray pyrolysis, pulsed laser deposition, sol-gel spin coating, activated reactive evaporation, electrochemical, metal organic chemical vapour deposition, chemical bath deposition or solution growth method etc (Ortega,1992). In this research work Electrodeposition method was used to deposit cadmium oxide thin film. The deposited CdO thin films were characterized using X-ray and UV-VIS spectrophotometer in order to find their possible applications.

Methods and Materials:

Cadmium oxide thin films were electrodeposited on an indium doped tin oxide (ITO) glass substrates. These substrates were first cleaned in water and ethanol and afterwards dried in open air.

The bath was composed of cadmium chloride ($CdCl_2$. 2 ½ $H_2$0) which is the source of Cd+, citric and Na0H. Cadmium chloride was the source of cadmium ion and these constituted the electrolyte. The EG and G Princeton Applied Research potentiostat driven by a software model 270 Electrochemical Analysis system was used to deposit the cadmium oxide thin films. The cell consists of ITO glass substrate as a working electrode, a platinum wire as a counter electrode and a silver-silver chloride as the reference electrode separately.

The electrodeposition of the thin films were carried out at room temperature. The deposition process was carried out at different deposition parameters as presented in table 1 below.

Sample	Dip Time (Minutes)	Ext Voltage (V)	I (mA)	V (V)	pH	CdCl2 ½$H_2$0		Citric Acid		Na0H	
						Con. M	Vol Ml	Conc. M	Vol ml	Conc. M	Vol ml
S_1	1.0	2.0	1.407	-3.79	8.6	0.05	20.0	0.05	20.0	1.0	4.0
S_2	2.0	2.0	1.190	-1.06	8.6	0.05	20.0	0.05	20.0	1.0	4.0
S_3	3.0	2.0	1.380	-1.22	8.6	0.05	20.0	0.05	20.0	1.0	4.0

Table 1: Deposition parameters of the grown CdO Thin films.

The deposition processes involve the dissociation of cations and anions and subsequent movement of these ions towards the electrodes due to applied eternal voltage. These ions deposit on the electrode (ITO) as thin films. The films were removed from the electrolyte after stipulated time and washed in distilled water before air drying them. Some of the optical and solid state properties of the films were determined using UNICO-UV-21O2PC spectrophotometer while the X-ray diffraction pattern was obtained using MD1O diffractometer in 2 range of 1O – 8O degrees using CuKα radiation of wavelength

The optical and solid state properties investigated include the absorbance, transmittance, refractive index, absorption coefficient, extinction coefficient and band gap. These optical properties and band gap of the films were deduced from mathematical expressions relating them, which were obtained from earlier reports of (Pankove, 1971; Ezema and Okeke, 2002, 2003, Nnabuchi and Okeke,2OO4.

Results and Discussion

The spectral absorbance of the three samples of CdO thin films prepared at different deposition times are as shown in fig 1. It indicates that the films have low absorbance in the UV region which decreased with increasing wavelength towards the NIR regions but increased with increase in deposition time. The films generally exhibited poor absorbance throughout the UV-VIS-NIR region which is in agreement with (Balu et al, 2012; Uplane, et al, 2000; Hiie et al, 2006; Cruz, et al, 2005; Hussein et al, 2008 and Lokhande et al, 2004.

Fig. 2 is the transmittance spectra of as deposited films. The films show high transmittance in the ultraviolet, visible and infra red regions of the electromagnetic spectrum. The transmittance decreased as the deposition time is increased. This high transmittance property makes the films good materials for solar thermal applications in flat-plate collectors, house heating for solar chick brooding etc. This is also in agreement with other reports such as (Mohamed, 2008; Ezeokoye, 2013; Rusu, et al 2005).

The band gap is as shown in figure 3 below which is observed to be 2.80eV, 2.75eV and 2.70$_e$V respectively. This indicates that the band gap decreases as deposition time increases. This decrease of band gap with increase in deposition time of deposited CdO thin film may be due to increase in the amount of disorder in the material and increase in the density of defect state. This property may make the material suitable for optical memory devices

Figure 4 shows maximum refractive index of the films to be 1.37, 1.38 and 1.45 respectively. This shows that refractive index of the deposited film increases as deposition time increases which can be applied in antireflection devices, optical detectors and in modeling optical coatings.

Plots of optical conductivity against hv are as shown in figure 5. It has maximum values of $2.7 \times 10^{13}S^{1}$, $2.8 \times 10^{13}S^{1}$ and $4.0 \times 10^{13}S^{1}$ at wavelengths, 400nm and decreased to zero at wavelengths, 800nm, 980nm and 1050nm respectively. It equally indicates an increase in optical conductivity as deposition time is increased

Figure 6 indicates the plots of extinction coefficient against photon energy. It increased from zero at photon energy of 1.50eV, 1.25eV and 1.23eV to maximum values of 0.023, 0.025 and 0.039 at photon energy of 3.25eV, 3.25eV and 2.25eV and decreased with increase in photon energy but increased as deposition time is increased. This property can be useful in modeling optical coatings and other optoelectronic devices.

As shown in figure 7 the plots of absorption coefficient against photon energy.It indicates that it increased from zero at photon energy 1.50eV, 1.30eV and 1.20eV to maximum values 7.8×10^5, 8.5×10^5 and 1.1×10^6 at photon energies 3.25eV respectively. It also shows that absorption coefficient increases with increase in deposition time.

Figure 8 shows the XRD spectra of the deposited CdO thin films S_1, S_2 and S_3. The film structure was investigated by X-ray diffraction (XRD) technique using CuKα radiation of wavelength λ = 1.54O8Å. The samples showed amorphous CdO thin films throughout the deposition time.

Conclusion:

Thin films of cadmium oxide (CdO) have been deposited on ITO glass substrate by electrodeposition method using cadmium chloride, citric acid , Na0H and distilled water. The XRD investigation revealed amorphous cadmium oxide (CdO) films. The optical properties of the films within the UV-VIS-NIR indicate that the films can find applications in photodiodes, transparent electrodes, phototransistor, solar thermal devices particularly in antireflection coating as well as other optoelectronic devices.

Acknowledgement

The Authors thank the director and management of material science laboratory and nanoscience research group at University of Nigeria Nsukka for their assistance during this research.

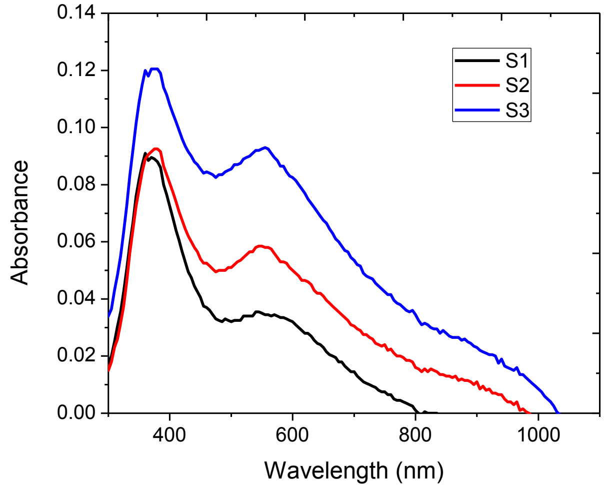

Figure 1: Spectral Absorbance of the CdO thin films.

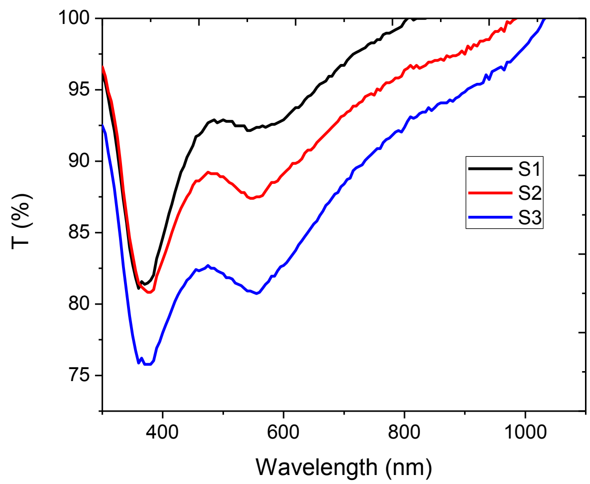

Figure 2: Spectral transmittance of the CdO thin films.

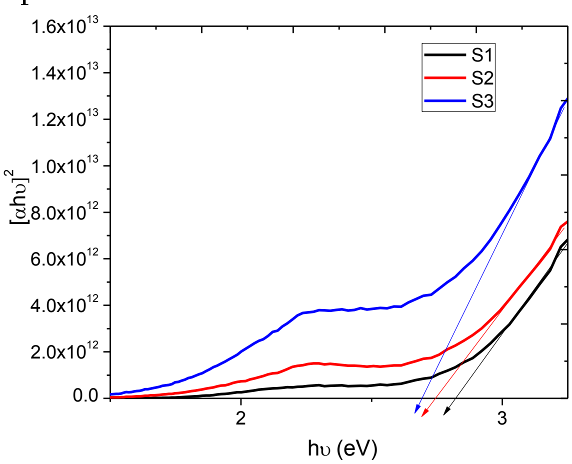

Figure 3: Plots of $[\alpha h\nu]^2$ against hν for CdO think films.

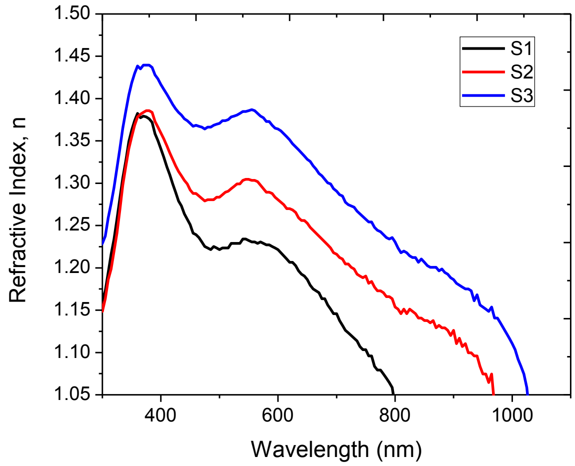

Figure 4: Plots of n against hv for CdO thin films.

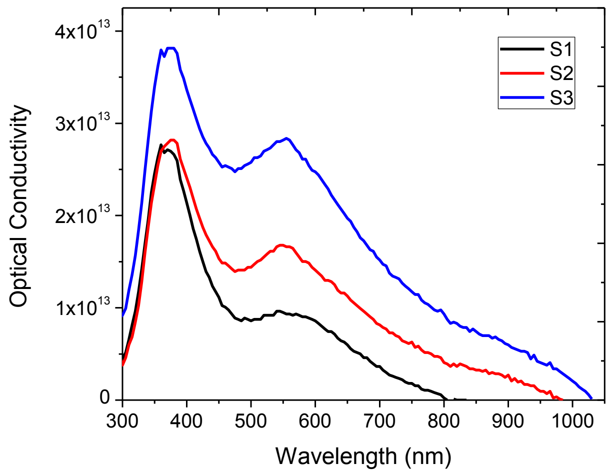

Figure 5: Plots of optical conductivity against wavelength for CdO think films.

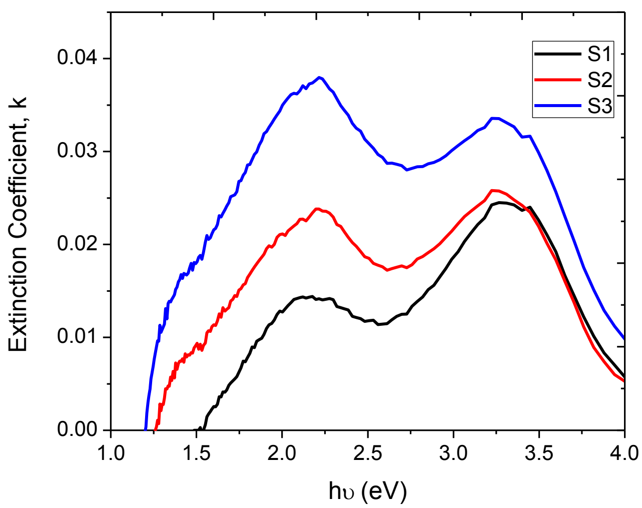

Figure 6: Plots of extinction coefficient against hv for CdO thin films.

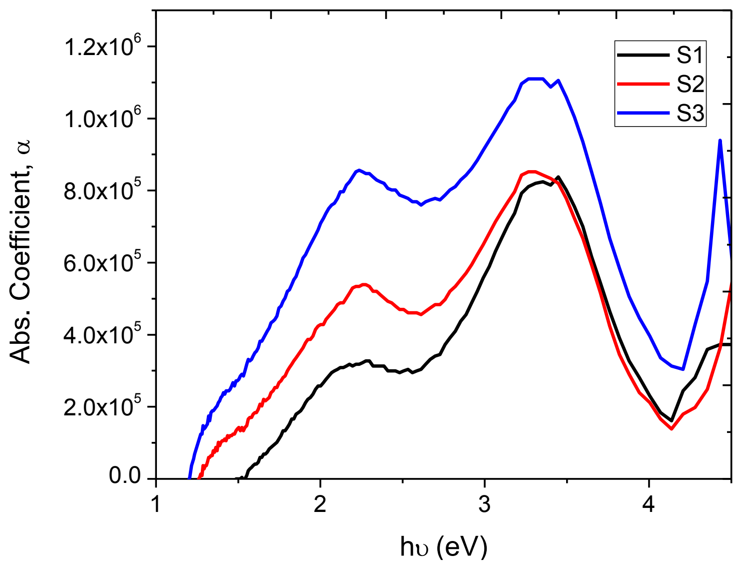

Figure 7: Plots of absorption coefficient against hv for CdO thin films.

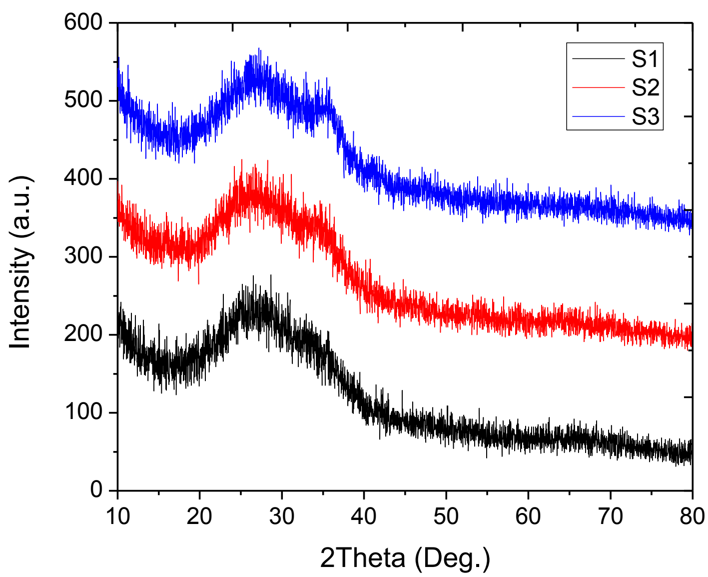

Figure 8: XRD spectra of the Cd0 thin films.

References

A.M. Hussein, M.A. Hazem. Characterization of cadmium oxide thin films prepared by electron beam evaporation technique. Sci. Tech. Adv. Mater,9, O25O16, 2OO8.

A.R. Balu, V.S. Nagarethinam, M. Sagunya. Effect of solution concentration on the structural, optical and electrical properties of SILAR deposited CdO thin films. J. Elect.Dev.12, 739 – 749, 2O12.

B.A. Ezeokoye, V.A. Ezeokoye, P.O. Offor, S.C. Utazi. Synthesis, structural and optical characterization of cadmium oxide thin films by chemical bath deposition technique, Int. J. Phy. Sci. 8(31 1597-16O1,2O13.

B.J. Lokhande, P.S. Patil, M.D. Uplane. Studies on cadmium oxides sprayed thin films through non-aqueous medium. Mater. Chem. Plugs. 84, 238-242, 2OO4.

B.J. Lokhande, R.R. Salunke, D.S. Dhawale, T.P. Gujar, Structural, electrical and optical studies of SILAR deposited cadmium oxides thin films ELSE. Mater. Bull. 4, 364-368, 2OO9.

F.I. Ezema and C.E. Okeke, Preparation and characterization of bismuth oxide thin films prepared solution growth technique. Nig. J. Phy. 48, 48-54,2OO2.

F.I. Ezema and C.E. Okeke, Chemical bath deposition of bismuth oxide thin film and its application. Greenwich J. Sci. Tech., 2OO3

H.A. Mohammed and H.M. Arh, Characterization of ITO/CdO/Glass thin films evaporated by electron beam technique. Sci. Tech. Adv. Mater. 9,(O25O16 .9,2OO8.

J. Hiie, T. Dedova, V. Valdna, Effect of cadmium ion concentration on the structural and optical properties of CdO. Thin Sol. Fil. 443, 511-512,2OO6.

J.S. Cruz, G.T. Delgado, R.C. Perez. Dependence of electrical and optical properties of spray deposited CdO thin films on substrate temperature J. Th. Sol. Fil. 83,493-5O2, 2OO5.

M.D. Uplane, P.N. Kshirsagar and B.J. Lokhande. Characteristic analysis of cadmium oxide thin films. Mater. Chem. Phy. 64, 75, 2OOO.

M. Ortega, G. Santana, A. Morale-Acevedo. Optoelectronic properties of CdO Si Heterojunction. Sup. Y. Vacio 9, 294-295,1999.

Optical Procsses in Semiconductors ,J.I. Pankove, Prentice Hall, New York,1971

Optical Properties of Semiconductor, G. Harbeke, F. Abeles(Ed in Optical Properties in Solids. North-Holland Publi. Co. Amstardam, 1972.

R.S. Rusu, G.L. Rusu. Electrical and optical characterization of CdO thin films. J. Opto. Adv. Mater. 7(2 823-828,2OO5.

The Material Science of Thin Films, M. Ohring, Academic Press, San Diego,1992.