

STRUCTURAL AND OPTICAL CHARACTERISTICS OF SOL GEL SPIN-COATED NANOCRYSTALLINE CdS THIN FILM

M.A.Olopade^{1*}, A.M. Awobode², O.E.Awe² & T.I. Imalerio³

¹Department of Physics, University of Lagos, Nigeria

²Department of Physics, University of Ibadan, Nigeria

³Physics Advance Laboratory, Sheda Science and Technology Complex, Abuja, Nigeria

*Email: molopade@unilag.edu.ng

ABSTRACT

Cadmium Sulphide (CdS) thin films were deposited onto glass substrates by sol-gel spin-coating method, from a precursor solution of cadmium acetate, 2-methoxy ethanol and Polyethylene Glycol (PEG). The films have high transparency (more than 75%) in the spectral range from 400nm to 800nm. The analysis of absorbance spectra shows that the optical band gap energy ranges between 2.18 and 2.50 eV. Correlations between the various spinning speed of the respective thin films were established.

Keywords: *Spinning speed, CdS, Spin-coating method, Structural and Optical Characteristics.*

1. INTRODUCTION

CdS is a II – VI compound semiconductor and has an energy band gap of 2.42eV. CdS thin films belonging to the Chalcogenide family are used as window material for CdS/CdTe solar cells [1]. They are also useful as buffer materials for solar cells and continue to be a subject of intense research due to their potential applications in high-efficiency solar devices [1]. Also, CdS thin film is one of the important materials for application in electro-optical devices such as photo-conducting cells, photo-sensors, transducers, laser materials, optical wave guides and non-linear integrated optical devices [2]. There are many methods of fabricating CdS thin films. These include spray pyrolysis [3], chemical bath deposition [4], molecular beam epitaxy [5], close space sublimation [6], successive ionic layer adsorption and reaction [7], screen printing [8], physical vapour deposition [9] and spin coating method [10].

Apart from the success of solar cells and modules containing a CdS buffer, there are concerns considering the usual CdS layer deposited by chemical bath deposition (CBD). One of these concerns is that only a very small amount is used, due to the thin layer of the buffer and this method is associated with the use of large area of liquids [11].

In comparison with other techniques, sol-gel method is more suitable to prepare optical materials as it permits molecular – level mixing and processing of the raw materials and precursors at relatively lower temperature and produces nano-structured bulk, powders and thin films [12-14]. Sol-gel is quite a suitable method to produce CdS thin films for photovoltaic application for which large-area devices are required at low-cost [1]. It also does not limit the choice of the substrate material [1]. Optical experiments provide a very good way of examining the properties of semiconductors. In particular, measuring the absorption coefficient at various energies gives information about the band gap of the material [3]. The knowledge of these band gaps is extremely important for understanding the electrical properties of a semiconductor, and it is therefore of great practical interest [7]. In this paper, we have investigated the preparation of nano crystalline CdS film using sol-gel spin coating method, and also discuss the optical properties of CdS thin films prepared at various spin speeds.

2. EXPERIMENTAL PROCEDURE

CdS thin films were deposited onto glass substrates by spin-coating method. Solutions for CdS were prepared from Cadmium acetate (BDH), 2-Methoxy ethanol, Thiourea (BDH) and polyethylene glycol (PEG 200, Merck). 2-Methoxy ethanol and PEG were used as the solvent and the stabilizer respectively. A volume of 0.4ml Poly ethylene glycol was dissolved in 20ml of 2-methoxy ethanol and stirred for 1 hour. Thereafter, 0.0186M of CdAc was added and the mixture stirred for 30mins. After this, 0.01582M of Thiourea was dissolved in 5ml of 2-Methoxy ethanol and added drop wisely to the solution that has been stirred for 30mins. The entire solution precipitated and 2 drops of HNO_3 was added to have a clear solution. The stirring continued for another 1hour. Thereafter, it was filtered and aged for 48hours.

Soda Lime Glass (SLG) substrates of $1.5 \times 1.5 \text{ cm}^2$ were treated by ultrasonic cleaning in acetone and then rinsed with deionized water. The sol solution was dropped onto the SLG substrates at speeds of 1600, 1800, 2000 and 2200 rpm for 30seconds respectively. After deposition by spin coating the film was dried in air at 200°C for 3mins to

remove solvent and residual organics and film densification. The coating and drying processes were repeated 10 times to obtain thick films.

The thicknesses of the CdS films were measured with Dektak 8 Profilometer after etching a step between film and substrate with a 10Vol% HCl solution. The surface morphology of deposited films was characterized using a scanning electron microscope [SEM, EVO/MA 10(ZEISS)]. The crystallinity of CdS thin films were analyzed with an X-ray Diffractometer (PANalytical) using Cu-K α radiation of wavelength, 1.5418Å.

The stoichiometries of the films were determined by using 25KV in an EDS analyzer installed in the scanning electron microscope. ES analysis was made for 150second and measured peaks were compared with the database to distinguish the chemical elements. The CdS transmittance spectrums were measured in the 400-800nm range using AVEC spectrophotometer. On the premise that CdS is a direct band gap material, $(\alpha h\nu)^2$ was plotted against photon energy (hv). The band gap energy was obtained by extrapolating the linear portion of the plot towards the photon energy axis. The value of the energy where this extrapolated line intercepted the energy axis is taken to be the band energy.

3. RESULTS AND DISCUSSION

We observed that film thickness increases with increasing number of cycle for a determined spinning speed [15]. This makes film with controlled thickness to be deposited. The average baked thickness was evaluated to be about 20nm per coating cycle. Generally, the thickness of the coating depends on the speed at which solution level falls, concentration, and viscosity of the respective solution, temperature and relative humidity.

Fig.1 (a) shows typical X-Ray Diffraction (XRD) pattern for a CdS film prepared by 10 cycles spin-coating of CdS films followed by post-deposited heat treatment. The presence of small peaks in the pattern indicates that the films are nanocrystalline in nature [16]. The X-ray diffraction pattern shows that the CdS films exhibit hexagonal structure with (002) orientation. The average size of grains has been obtained from the XRD pattern using the following Scherrer's formula [17].

$$D = \frac{K\lambda}{\beta \cos\theta}$$

where D is the grain size, K is a constant taken to be 0.94 [17]; β is the full width at half maximum (FWHM) and λ is the wavelength of the x-rays. The CdS crystallite sizes have been determined from the width of the XRD to be 5.5nm to 6.8nm for the CdS films. The observed unsharp peaks are an indication that the average crystallite size is small. Due to size effect the peaks in the diffraction pattern broaden and their widths become large as the particles become smaller.

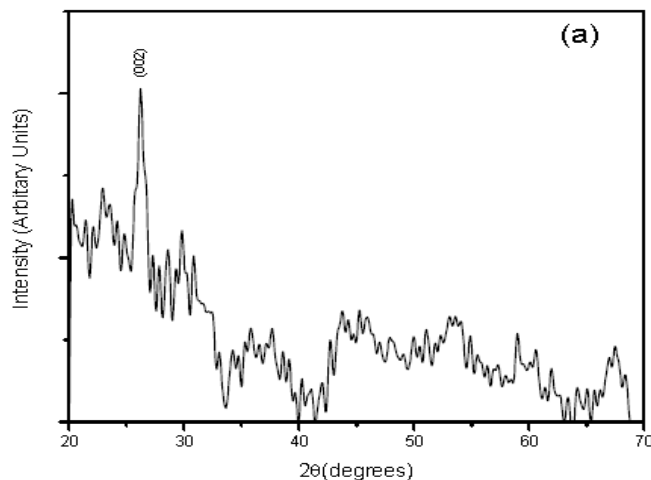


Fig.1 (a): X-ray Diffraction pattern of CdS film deposited at speed of 1800rpm (10 cycles)

Fig. (1b) shows the surface image of the CdS thin film. A continuous film was formed from the aggregation of granules as shown in this figure, although a surface image of the precursor film was very smooth. Our film had larger and densely packed grains than the film reported in Ref [18].

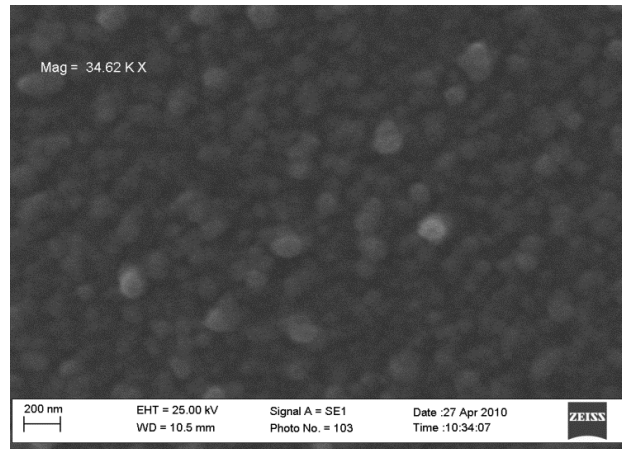


Fig.1 (b) SEM micrograph of CdS thin film deposited at speed of 1,600rpm (10 cycles).

The optical band gap has been obtained from the plot of $(ahv)^2$ against $h\nu$ [shown in Figures 3(a)-(d)] via extrapolating the straight line portion of the curve to intercept the energy axis. The band gap energy obtained as intercept on $h\nu$ axis were found to be in the range of 2.18-2.40eV.

The value of energy band gap of the film obtained using the absorption spectra are closer to the bulk band gap (2.42eV) and the closest is the film deposited at 1,600rpm which gave the value 2.40eV.

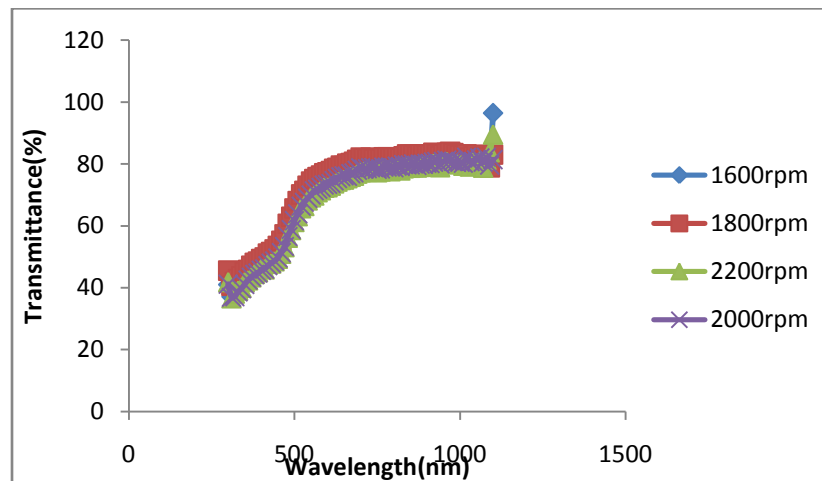


Figure 2: Variation of transmittance of CdS film with wavelength at different spinning speed

The transmittances of our deposited films vary between 75% - 82% as shown in Figure 2.

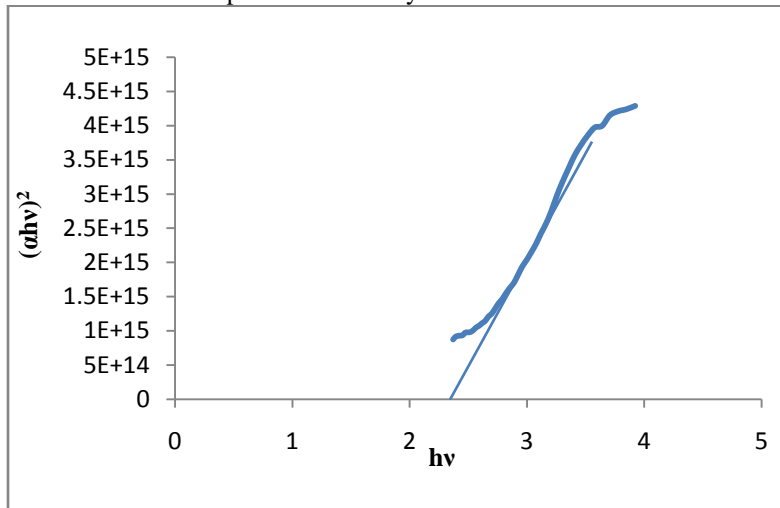


Figure 3 (a) $(\alpha hv)^2$ as a function of photon energy (hv) for films deposited at 1600rpm-2.40eV.

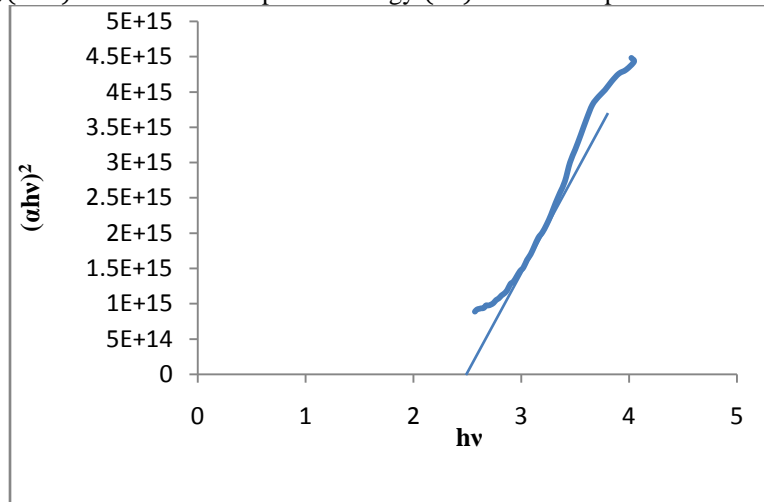


Figure 3 (b) $(\alpha hv)^2$ as a function of photon energy (hv) for films deposited at 1800rpm-2.50eV.

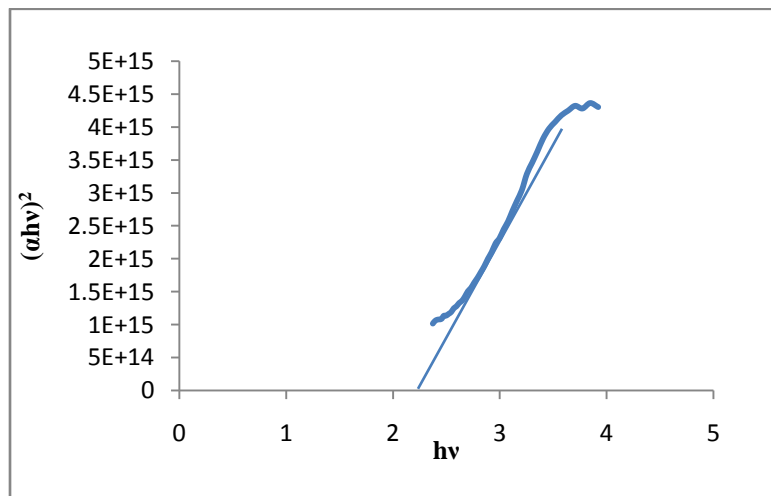


Figure 3(c) $(\alpha hv)^2$ as a function of photon energy (hv) for films deposited at 2000rpm-2.18eV.

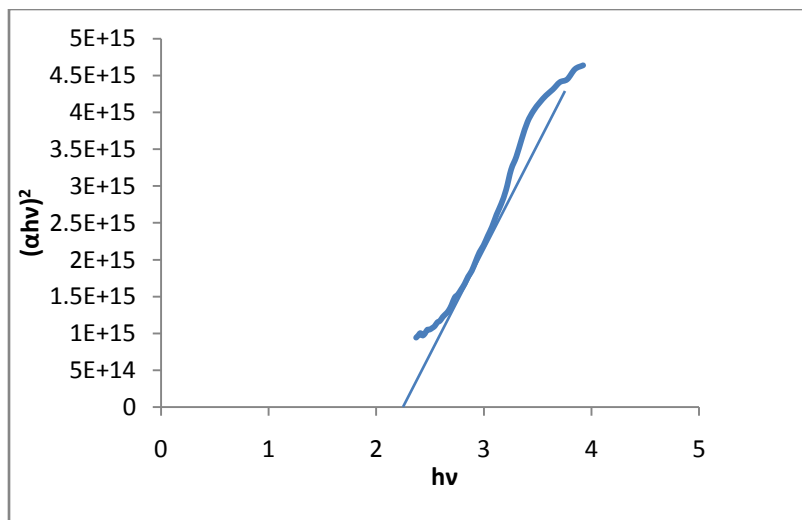


Figure 3(d) $(\alpha hv)^2$ as a function of photon energy ($h\nu$) for films deposited at 2200rpm-2.30eV.

4. CONCLUSION

A simple and very cheap route has been used to obtain CdS, starting with a precursor solution based on Cadmium acetate, Thiourea, 2- Methoxy methanol and PEG spin coated onto glass substrates. We found that the film properties can be controlled by spinning speed and number of deposition cycles. The obtained films were uniform, smooth and have a good adherence to the substrates, especially for films deposited at speed of 1,600rpm. The films analyzed by x-ray diffraction technique indicated the presence of the (002) crystal planes corresponding to CdS hexagonal structure. Also, the films have good stoichiometries. The band gap energy values obtained for these samples were in the range between 2.18 and 2.40eV depending on the deposition speed and the number of cycles. Nanocrystalline CdS thin film suitable for solar cell application has been prepared. This makes it easier to grow buffer layers of CdS thin film for solar cells through the spin coating method instead of undergoing the rigors of the usual Chemical Bath deposition method. We are suggesting that the CdS buffer layer of solar cells can be deposited at 1600rpm for efficient photovoltaic cells.

ACKNOWLEDGEMENT

This research was supported by the Physics Advanced Laboratory of the Sheda Science and Technology Complex, Abuja, Nigeria under the STEP-B Programme.

REFERENCES

- [1]. M.Thambiduraia, N.Muruganb, N.Muthukumarasamya, S.Vasanthaa, R.Balasundaraprabhuc, and S.Agilana, Chalcogenide letters **vol.6, No.4**, p171-179(2009).
- [2]. K. Senthil,D. Mangalaraj, S.K Narayandass, Appl.Surf. Sci **169/170**, 476(2010).
- [3]. P.Raji, C. Sanjeeviraja, Ramachandra, Bull. Mater. Sci, **28**, 233(2005).
- [4]. Basudev Pradhan, Ashwani K. Sharma, Asim K. Ray, Journal of crystal Growth **304**,388 (2007).
- [5]. G. Brunthaler, M.Lang, A. Forstner, C. Giftge, D. Schikora, S.Fereira, H.Sitter, K.Liscka, Journal of Crystal Growth, **138**, 559(1994).
- [6]. T.L. Chu, J. Britt, C.Ferekides, C.Wang, C.Q. Wu, IEEE transactions on Electronic Devices letters, **13**,303(1992).
- [7]. Yashar Azizan Kalandarayah, M.B. Muradov, R.K.Mammedov, Ali Khodayari, Journal of Crystal Growth, **305**, 175(2007).
- [8]. D.Patidar, R.Sharma, N.Jain, T.P. Sharma and N.S. Saxena, Bull. Mater.Sci, **29**,21(2006).
- [9]. R.W. Birknoire, B.E. Mc candles, S.S. Hegedus, Solar Energy, **12**,45(1992).
- [10]. B.Bhattacharjee, D. Ganguli and S. Chaudhuri, Journal of Fluorescence, **12**,314(2002).
- [11]. Susane Siebentritt, Solar Energy **77**, 767-775(2004).
- [12]. M.D.Curran, A.E. Stiegman, Journal of Non-Cryst. Solids, **249**, 62(1999).
- [13]. H.X.Zhang, C.H. Kam, Y.Zhou,,X.Q.Han, S.Buddhudu, Y.L.Lam, J. Opt. Mater.,**15**,47 (2000).
- [14]. T. Monde, H. Fukube, F. Nemoto, T. Yoko, T. Konakanhara, J. Non. Cryst. Solids, **246**, 54 (1999).
- [15]. K. Tanaka, N. Moritake and H. Uchiki, Solar Energy Materials & Solar Cells **91**(2007) 1199-1201
- [16]. C. Suryanaraya and M. Grant Norton, X-ray diffraction: a practical approach, Springer; pg.97-125, 1998.
- [17]. V.B. Sanap and B.H. Pawar, Chalcogenide letters **vol.6, No.8**, 415-419(2009).
- [18]. R.Devi, P.Purkayastha, P.K.Kalita and B.K. Sarma, Bull. Mater. Science, **30**,123(2007).