Deposition and Characterization of CdS Thin Film by Chemical Bath Method.

I.A. Ezenwa[1] and A.J. Ekpunobi[2]

[1]Department of Industrial Physics, Anambra State University, Uli, Anambra State, Nigeria.
[2]Department of Physics and Industrial Physics, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria.

*E-mail: amakaezenwaosie@yahoo.com

ABSTRACT

CdS thin films were grown on glass substrates using chemical bath deposition. We studied optical properties which include absorbance, reflectance, transmittance, refractive index, dielectric constant, optical conductivity, and extinction coefficient, using a Janway 6405 UV/Visible spectrophotometer. Surface morphology and structural characterization of the films were carried out using an Olumpus Optical microscope and an MD-10.3 mini diffractometer with CuKα radiation, respectively. A bandgap of 2.49eV and refractive index of 2.60 at 400nm was obtained for CdS thin film. XRD measurements indicate crystallization of CdS in the hexagonal phase.

(Keywords: bandgap, chemical bath, semiconductor)

INTRODUCTION

CdS is a II – VI semiconductor which has a number of important applications. It is widely used as window layer of CdTe – or $CuInSe_2$ – based solar cells. It is also essential in the preparation of light emitting phosphors and these phosphors are useful in applications such as color displays, x-ray instruments, luminescent dials, fluorescent lamps, and cathode ray tubes. CdS photoconductive cells are used in photographic exposure meters for cameras, where it acts as a light sensitive resistor. It also has applications in electro-photographic systems in photocopiers. Because of this wide range of applications, CdS is one of the most studied and important semiconducting material. Different methods have been used for its deposition which included thermal evaporation, chemical vapor deposition, electro-deposition, chemical bath deposition, spray pyrolysis, molecular beam epitaxy, etc. Here we report the synthesis of CdS thin film using a simple, reproducible and cost effective technique called the chemical bath deposition.

MATERIALS AND METHODS

We synthesized all the films for this experiment using chemical bath deposition (CBD).

The deposition of CdS thin film by CBD was based on the reaction between cadmium bromide ($CdBr_2$) and thiourea ($CS(NH_2)_2$, using TEA ($N(CH_2CH_2OH)_3$) as a complexing agent and ammonia solution as a pH adjuster. The reaction mechanism is of the form:

$$CdBr_2 .4H_20 + TEA \rightleftharpoons Cd(TEA)^{2+} + 2HOBr + 2H_20$$

$$Cd(TEA)^{2+} \rightleftharpoons Cd^{2+} + TEA$$

$$(NH_2)_2CS + OH^- \rightleftharpoons CH_2N_2 + H_20 + HS^-$$

$$HS^- + OH^- \rightleftharpoons H_20 + S^{2-}$$

$$Cd^{2+} + S^{2-} \longrightarrow CdS$$

Various parameters which include concentration of sulphide ion source, deposition time were optimized.

<u>Optimization of Deposition Time for CdS Thin Film</u>

For the optimization of deposition time, the volumes of cadmium bromide solution, thiourea, TEA, ammonia solution and temperature (300K) were kept constant, while the deposition time was altered as shown in Table 1.

Table 1: Optimization of Deposition Time for CdS Thin Film

Slide No.	Vol. of Complexing agent (TEA) (mls)	Vol. of $CdBr_2$ (mls)	Vol. of thiourea (mls)	Vol. of ammonia solution (mls)	Time (hrs)	Thickness (μm)
Cd_1	5.0	5.0	5.0	5.0	2.0	0.519
Cd_2	5.0	5.0	5.0	5.0	4.0	1.126
Cd_3	5.0	5.0	5.0	5.0	6.0	1.207
Cd_4	5.0	5.0	5.0	5.0	8.0	1.215
Cd_5	5.0	5.0	5.0	5.0	10.0	1.216

Optimization of Sulphide Ion Source for CdS Thin Film

For the optimization of sulphide ion source, the volumes of $CdBr_2$ solution, TEA, ammonia solution, deposition time and temperature (300K) were kept constant, while the volume of thiourea was altered as shown in Table 2.

Structural, surface morphology and optical characterization of the films were carried out using an x-ray diffractometer with CuKα radiation, an Olympus Optical microscope and a Janway 6405 UV/ Visible spectrophotometer respectively. From the spectrophotometer, the absorbance in arbitrary units was measured. Parameters such as transmittance (T), reflectance (R), refractive index (n), extinction coefficient (K), dielectric constant (ε) and optical conductivity (σ) were then calculated.

RESULTS AND DISCUSSION

Figures 1 and 2 are plots of thickness against time and sulphide ion concentrations, respectively. Figure 1 indicates that thickness has a linear relationship with time of growth. The implication of this relation is that the longer the time, the more the molecular flux to the surface of the substrate.

Figure 2 indicates that thickness increased up to a point after which it began to reduce. The films have its maximum thickness of 1.206μm at 7.50mls of thiourea solution.

Figure 3 is a plot of absorption coefficient squared (α^2) as a function of photon energy for CdS thin film. From this graph, a bandgap of 2.49eV was obtained for CdS thin film. This value compares well with the values of 2.42eV obtained by Fumitaka Goto et al. and 2.44eV by Kainthla.

Figures 4 and 5 are plots of transmittance in the visible and UV region respectively for CdS thin films. Sample Cd_1 shows a transmittance range 0f 37% to 88% in the visible region (400-680) nm and an irregular transmittance in the UV region.

Figure 6 is a plot of absorbance against wavelength. Sample Cd_1 has an absorbance range of 0.438 to 0.057 in the wavelength range of (400-680) nm, while sample Cd_{11} has 0.830 to 0.293 in the same range. It can be seen that the absorbance decreases as the wavelength increases.

Figures 7, 8, and 9 are plots of refractive index (n), extinction coefficient (k) and optical conductivity (σo) as functions of photon energy. The refractive index decays with decrease in photon energy, with a range 1.69 – 2.60 at photon energy range of 1.83eV to 3.11eV for Sample Cd_1, extinction coefficient value of 3.50 x 10^{-2} and optical conductivity (σo) value of 6.790 x 10^{13} S^{-1} was obtained at photon energy of 3.11eV for the same sample. Because of the high value of refractive index, CdS could be useful in poultry production and solar cells.

Figure 10 is a plot of reflectance against wavelength for CdS thin film.

Table 2: Optimization of Sulphide Ion Source for CdS Thin Film.

Slide Number	Vol. of complexing agent (TEA) (mls)	Vol. of $CdBr_2$ (mls)	Vol. of thiourea (mls)	Vol. of ammonia solution (mls)	Time (hrs)	Thickness (μm)
Cd_{11}	5.0	5.0	2.5	5.0	4.0	0.899
Cd_{12}	5.0	5.0	5.0	5.0	4.0	1.192
Cd_{13}	5.0	5.0	7.5	5.0	4.0	1.206
Cd_{14}	5.0	5.0	10.0	5.0	4.0	1.194
Cd_{15}	5.0	5.0	12.5	5.0	4.0	1.199

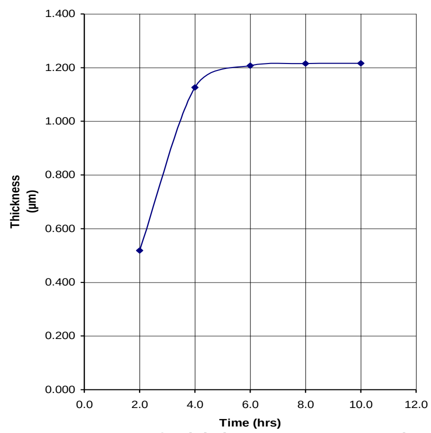

Figure 1: Plot of Thickness versus Time for CdS Thin Film.

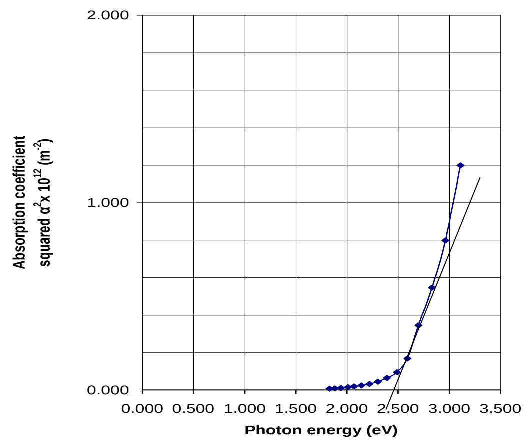

Figure 3: Plot of Absorption Coefficient Squared (α^2) against Photon Energy for CdS Thin Film.

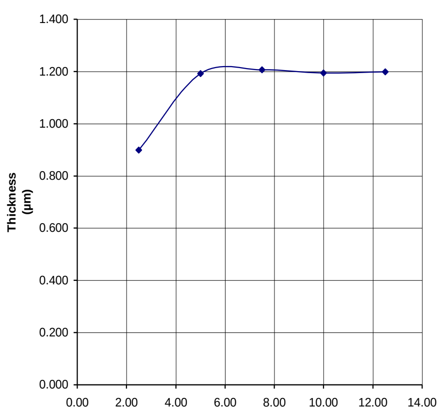

Figure 2: Plot of Thickness versus Sulphide Ion Concentration for CdS Thin Film.

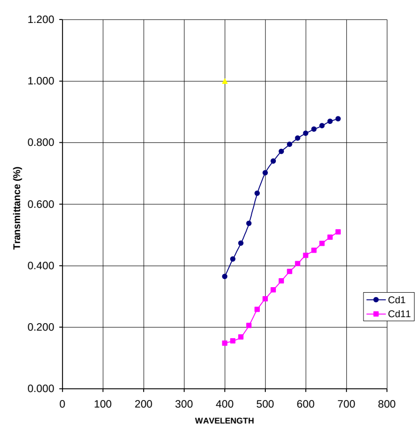

Figure 4: Plot of Transmittance versus Wavelength for CdS Thin Film (slide Cd_1 and Cd_{11}) (vis-region).

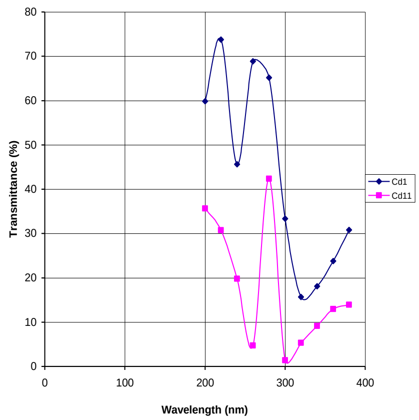

Figure 5: Plot of Transmittance versus Wavelength for CdS Thin Film (slide Cd_1 and Cd_{11}) (UV-region).

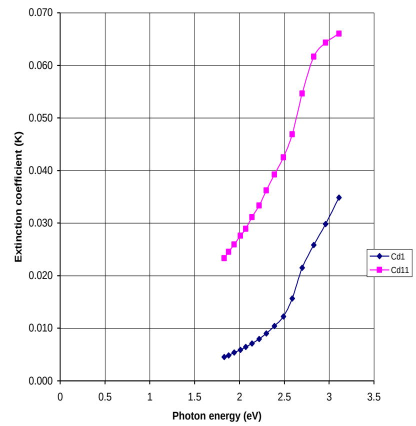

Figure 8: Plot of Extinction Coefficient versus Photon Energy for CdS Thin Film (slide Cd_1 and Cd_{11}).

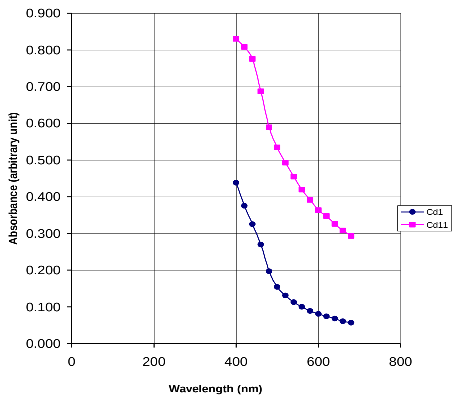

Figure 6: Plot of Absorbance versus Wavelength for CdS Thin Film (slide Cd_1 and Cd_{11})

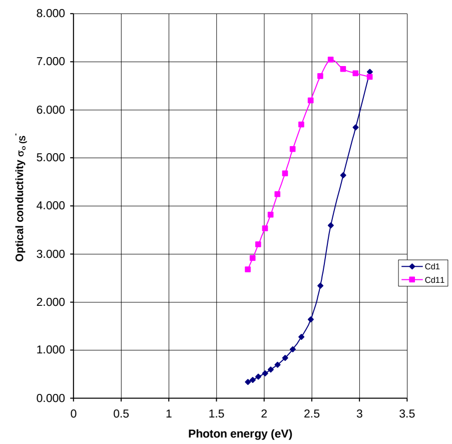

Figure 9: Plot of Optical Conductivity versus Photon Energy for CdS Thin Film (slide Cd_1 and Cd_{11}).

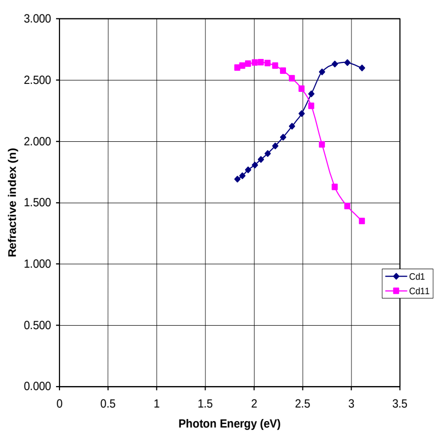

Figure 7: Plot of Refractive Index versus Photon Energy for CdS.

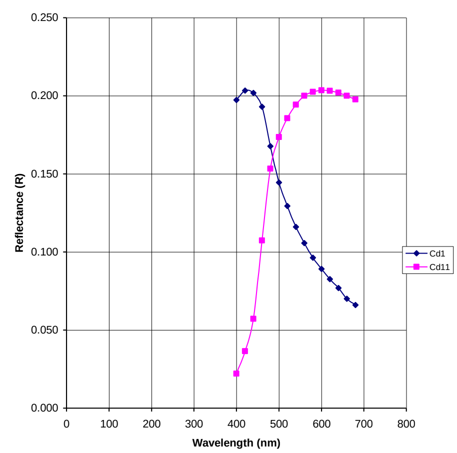

Figure 10: Plot of Reflectance versus Photon Energy for CdS Thin Film (slide Cd_1 and Cd_{11}).

The films show a very low reflectance throughout the visible region of the spectrum. This low reflectance values have useful application in antireflection coating.

Figure 11 is a plot of dielectric constant (real and imaginary) for CdS thin film. Sample Cd_1 has a real dielectric constant of 6.748 at 400nm and an imaginary dielectric constant of 0.181 at 400nm.

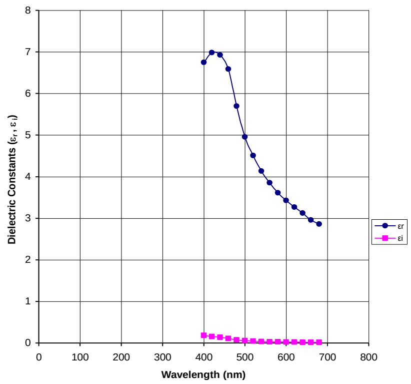

Figure 11: Plot of Dielectric Constants (ε_r, ε_i) versus Photon Energy for CdS Thin Film (slide Cd_1 and Cd_{11}).

Figures 12 and 13 show the x-ray diffraction spectral and optical micrographs of CdS thin film. According to the XRD results, the chemically deposited films of CdS are of hexagonal structure.

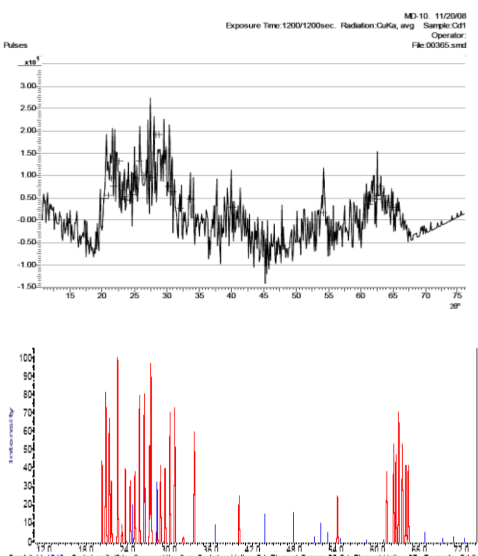

Figure 12: X-ray Diffraction Spectra for CdS Thin Film.

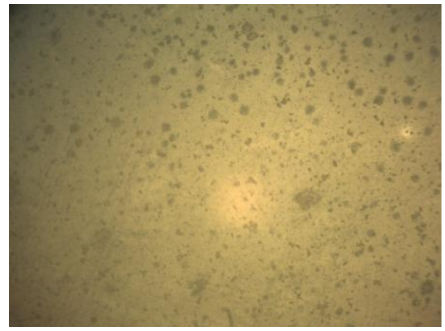

Figure 14: Micrographs of CdS Thin Film.

This crystal structure is consistent with that obtained by Fumitaka et al. (1999). It has been reported that both hexagonal and cubic CdS can be grown by chemical bath (Kaur et al. (1980). According to Kaur, Panda, and Chopra, the structure of chemically grown CdS is determined by the deposition mechanism. From the XRD measurements, a lattice constant of 5.6954Ǻ was calculated for CdS thin film in the (101) plane at a maximum intensity of $2\theta = 28.183$ using Bragg's law given by $n = 2d\sin\theta$. This is close agreement with 5.8320Ǻ reported by Sze (1981). From the micrographs, it can be seen that the surface of the film is smooth and covers the glass substrate well. The grains are very small with unequal size and shape.

CONCLUSION

We have demonstrated using chemical bath deposition technique, the synthesis of CdS thin film. A bandgap of 2.49eV was obtained for CdS thin film. An extinction coefficient and refractive index of approximately 3.50 $\times 10^{-2}$ and 2.60 at 3.11eV (400nm) was obtained for CdS thin film.

REFERENCES

1. Chopra, K.L., Major, S., and Pandya, D.K. 1982. *Thin Solid Films*. 297.

2. Fumitaka, G. and Eisuke, A. 1999. *Journal of Applied Physics*. 85(10).

3. Grahn, H.T. 1999. *Introduction to Semiconductor Physics*. World Scientific: Singapore.

4. Kaintla, R.C. 1980. Ph.D. Thesis. India Institute of Technology: Delhi, India.

5. Kaur, I., Panda, D.K., and Chopra, J. 1980. *Electrochem. Soc.* 127:943.

6. Oladeji, I.O. and Lee, C.J. 1997. *Electrochem. Soc*. 144(7).

7. Onyia, A.I. and Okeke, C.E. 1989. *J. Phys. D. Appl. Phys*. 22.

8. Sukanta, D.E. 2007. *Journal of Applied Physics*. 101: 093711.

9. Sze, S.M. 1981. *Physics of Semiconductor Devices*. Willy Interscience Publication: New York, NY. 848 – 849.

10. Wagendanstal, A. and Wang, Y. 1994. *An Introduction to Physics and Technology of Thin Films*. World Scientific Publishing Co.: Singapore.

SUGGESTED CITATION

Ezenwa, I.A. and A.J. Ekpunobi. 2010. "Deposition and Characterization of CdS Thin film by Chemical Bath Method". *Pacific Journal of Science and Technology*. 11(2):435-440.

Pacific Journal of Science and Technology