

Structural and Optical Properties of CdS Thin Film Grown by Chemical Bath Deposition

S. Rajpal, V. Bandyopadhyay*

Department of Applied Physics, Birla Institute of Technology, Mesra, Ranchi, 835215 Jharkhand, India

(Received 12 May 2013; revised manuscript received 06 July 2013; published online 12 July 2013)

In this work we report synthesis and optical characterization of CdS thin films coated on glass substrate. The films were deposited using chemical bath deposition method. Scanning Electron microscopy shows a uniform film of CdS film at particular concentration and dipping time. The Energy Dispersive spectroscopy reveals the presence of Cd and S in the CdS film. X-Ray diffraction confirms the cubic structure of CdS deposited on glass and amorphous nature of glass. Optical and photoluminescence studies were done using UV-Visible spectroscopy and Photoluminescence spectroscopy respectively. We have determined bandgap by analyzing UV-Visible spectra results. Wettability studies were done using Optical Contact Angle, which confirms the hydrophobic nature of the CdS films.

Keywords: CdS thin film, Chemical Bath Deposition (CBD), Thin films, Glass.

PACS numbers: 73.90. + f, 88.40.jm

1. INTRODUCTION

CdS thin films have received considerable attention during recent years because of their numerous excellent properties in optoelectronic fields. CdS thin film has a broad range of application in important technical fields such as heterojunction solar cells [1, 2], light emitting diodes [3], large screen liquid crystal devices [4], gas sensors [5] and field effect transistors [6, 7].

CdS thin film belongs to Cadmium Chalcogenide family. It is an II-VI wide direct band gap (2.42 eV) semiconductor. This particular property makes it a key element for solar cell applications.

In last decades, efforts have been devoted to the preparation of high quality CdS nanostructures and its investigation [8]. Many techniques for deposition of CdS thin films were reported, such as sputtering, electro-deposition, metal vapor oxide deposition (MOCVD), sputtering, spray deposition [9] and chemical bath deposition method. We have chosen chemical bath deposition route to deposit CdS thin film over glass sample because it offers deposition over a large area. It also includes other advantages, such as low temperature operation and economic. Many authors have also obtained highest efficiency using this method to grow buffer layer for CdTe and CIGS solar cells [10, 11]. In this work we report CdS film grown on the glass substrates at $80 \pm 2^\circ\text{C}$ by CBD method and its characterization by various techniques like XRD, SEM, UV-VIS spectroscopy and PL spectroscopy.

2. EXPERIMENTAL PROCESS

The CdS thin films were deposited from a solution of analytical grade cadmium nitrate and thiourea in an alkaline solution of ammonia and distilled water. Commercial glass slides used as substrates, were cleaned in acetone ultrasonically. The glass slides were kept vertically in a closed beaker. We prepared different types of samples by varying the dipping times and concentration of the dipping solution.

In a beaker containing 50 ml of distilled water, 2 ml

of Cadmium Nitrate was added. Another 5 ml of liquid Ammonia was added to it. Mixture was then stirred for a particular time and 10 ml of thiourea was added to it. The process of stirring was continued. Distilled water was added to make the total volume to 125 ml. During the whole process pH value was controlled between 9.5-10 by addition Ammonium Acetate. Temperature of the solution was maintained at $80 \pm 2^\circ\text{C}$. Solution was stirred using magnetic stirrer [12].

Glass substrate was mounted vertically on the beaker containing the solution. After the deposition was complete, the substrates were removed from the bath and were allowed to dry in air. The dried samples were rinsed with acetone and finally dried.

3. RESULTS AND DISCUSSION

3.1 Structural Analysis

Scanning electron microscopy (SEM) was performed for magnified image of the so prepared sample. Figure 1 shows 10,000 times magnified topographical image of CdS sample. In this image spherical shape of CdS nanoparticles deposited are confirmed. Energy Dispersion X-ray analysis (EDX) was also done to confirm the presence of possible elements in the deposited film. Fig. 2 is the EDX spectrum of CdS deposited over glass and it reveals the presence of Cd and S, over Si (as because of deposition over glass sample). The occurrence of platinum peak (Pt) is because the sample was coated with platinum to facilitate electron conduction during SEM characterization.

Further detailed structural analysis of thin film CdS glass was performed using an X-ray diffractometer (XRD). During the characterization procedure of XRD, $\text{CoK}\alpha$ ($\lambda = 1.546 \text{ nm}$) laser is used. Fig. 3, shows the diffraction pattern of CdS deposited on glass. Here, four peaks were identified; (111) at 26.81° , (220) at 44.27° , (311) at 52.34° and (420) at 72.71° . All these peaks were matched with standard data card of CdS (JCPDS card no. 89-0019). This proves that our deposited sample is in same cubic phase as that of the stan-

* vivek.nano.bitm@gmail.com

standard result [13]. Another important result derived from the XRD pattern is that the broadening of peak near 26° this correlates that fact that our sample deposited on glass, which is of amorphous nature. The average particle size of CdS nanoparticles deposited over glass were also determined using Debye-Scherrer's formula [14].

$$D_{avg} = \frac{0.89\lambda}{\beta \cos \theta}$$

Here, 0.89 is the Scherrer factor for spherical nanoparticles, λ implies the wavelength of the X-ray used, β is the full width half maxima (FWHM) of the diffraction peak (in radians) and θ is the maximum scattering angle. The average particle size of the CdS nanoparticle came around 22 nm.

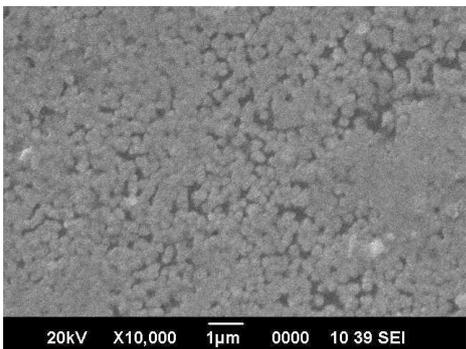


Fig. 1 – SEM image of CdS nanoparticles deposited on glass at 10,000x magnification

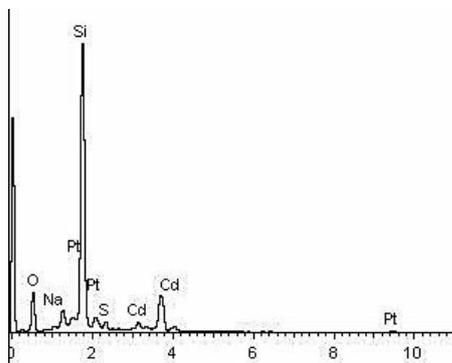


Fig. 2 – EDX spectra of CdS deposited on glass

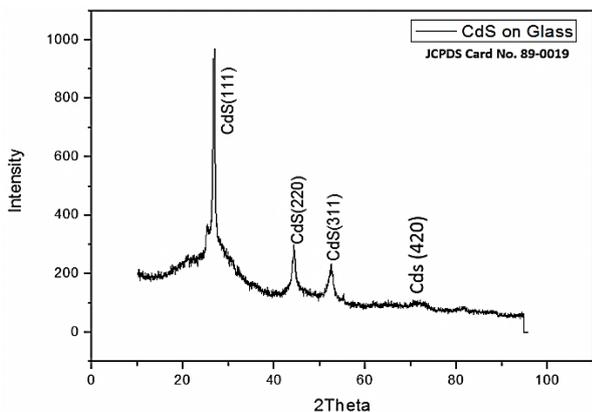


Fig. 3 – XRD results of CdS deposited on glass. JCPDS card number is written in bold

Wettability studies are important parameters to consider, when this thin film deposition of CdS over glass substrate is used for solar cell or smart window applications. From this techniques, we are able to know the surface nature of any sample, whether it is hydrophobic or hydrophilic. We have performed wettability studies of our samples and compared with the results of normal glass. Wettability study was performed using Optical contact angle (OCA).

Fig. 4a, b shows the OCA image of uncoated glass and CdS deposited glass respectively. The contact angle for the uncoated glass we used, was found to be $49.73^\circ \pm 2.13^\circ$. This clearly confirms the hydrophilic nature of the uncoated glass. Whereas, if we compare its result with CdS deposited glass, the contact angle comes as $97.85^\circ \pm 2.29^\circ$. This shows that our samples of CdS deposited on glass have hydrophobic nature [15, 16].

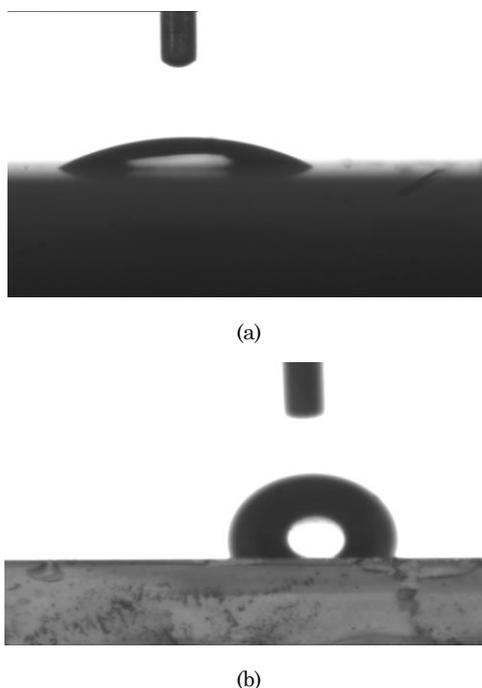


Fig. 4 – Optical Contact Angle Images: OCA image of uncoated glass (a), OCA image of CdS deposited glass (b)

3.2 Optical Analysis

Optical analysis of CdS samples deposited over glass were performed using UV-Visible spectroscopy and Photo-luminescence spectroscopy. These two characterization techniques are generally used for bandgap determination and purity approximation respectively.

UV-visible spectroscopy was performed in room temperature and at a region from 300 nm to 800 nm. The UV-visible spectrum of CdS deposited glass is shown in Fig. 5. The bulk bandgap of CdS is 2.42 eV, as reported by earlier researcher [17]. But, our sample showed a characteristic bandgap of 2.39 eV. We have determined bandgap by Tauc's formula [18], which is defined as-

$$(\alpha hv)^{1/n} = A(hv - E_g)$$

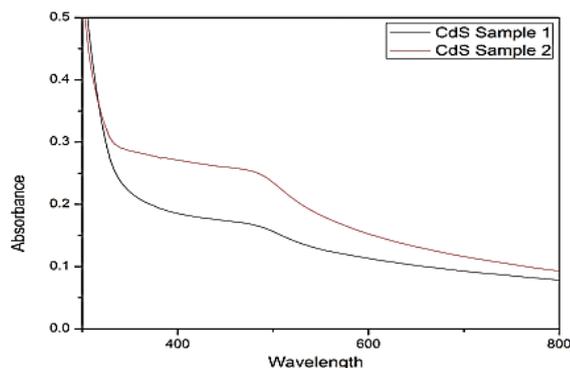


Fig. 5 – UV-Visible spectra of CdS deposited on glass

Where, α is the absorption coefficient, h is the Planck's constant, ν is the frequency of vibration, A is the proportionality constant and E_g is the characteristic bandgap.

Photoluminescence analysis of the CdS deposited over glass were performed to analyze the purity of deposition. Fig. 6 shows the photoluminescence spectra. During this characterization, Xenon lamp source at 280 nm as an excitation wavelength is used. The photoluminescence originates from the recombination of surface states. In the spectra of CdS deposited on glass, we find two major PL peaks, in a range from 520 nm to 360 nm, respectively. Here, the peak at 512.84 nm corresponds to emission of near band edge excitonic peak [19]. This exhibit green band emissions corresponding to the defect related luminescence emission.

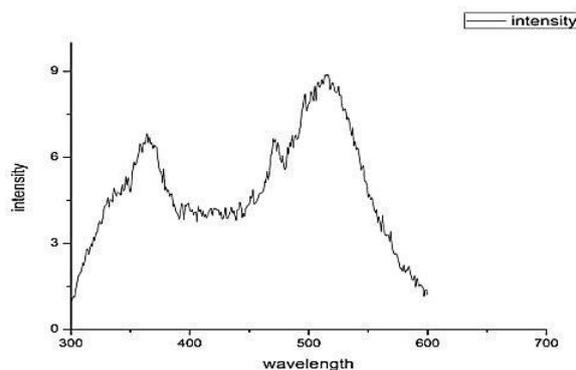


Fig. 6 – Photoluminescence spectra of CdS deposited on glass

4. CONCLUSION

The CdS thin film was successfully deposited on commercially available glass substrate using chemical bath deposition (CBD) technique. The film was characterized for optical and structural properties. The cubic phase CdS is observed by XRD analysis. The average crystallite size of CdS particle was about 22 nm. The SEM images shows uniform thin film of CdS. PL spectroscopy shows the emission at 364.34 nm and 512.84 nm. The optical band gap is measured to be 2.39 eV. And thus CdS film presented have good characteristic to be used as a window layer for photovoltaic applications.

ACKNOWLEDGEMENTS

We are grateful to Central Instrumentation facility and Dept. of Applied Physics, Birla Institute of Technology, Mesra, Ranchi for the lab facilities provided.

REFERENCES

- H.R. Motinho, D. Albin, Y. Yaan, R.G. Dheo, X. Li, C. Perkis, C.S. Jiang, *Thin Solid Films* **436**, 175 (2003).
- H. Metin, R. Esen, *Semicond. Sci. Technol.* **18**, 647 (2003).
- G.S. Vorobjov, V.O. Zhurba, A.S. Krivets, *J. Nano-Electron. Phys.* **2** No4, 47 (2010).
- A. Zeho, J.G. Vazquez Luna, *Sol. Energ. Mater. Sol. C* **68**, 217 (2001).
- J. Levinson, F.R. Shepherd, P.J. Scanlon, W.D. Westwood, G. Este, M. Rider, *J. Appl. Phys.* **53**, 1193 (1982).
- U. Pal, R. Silva-Gonzalez, G. Martinez-Montes, M. Gracia-Jimenez, M.A. Vidal, S. Torres, *Thin Solid Films* **305**, 345 (1997).
- J.H. Schon, O. Schenker, B. Batlogg, *Thin Solid Films* **385**, 271 (2001).
- T. Kippeny, L.A. Swafford, S.J. Rosenthal, *J. Chem. Educ.* **79**, 1094 (2002).
- R.M. Perez, G.S. Rodriguez, J.S. Hernandez, A.M. Avedo, A.A. Carbajal, O.V. Galan, J.C. Alanso, G.C. Puente, *Thin Solid Films* **480-481**, 173 (2005).
- Contreras, B. Egaas, K. Ramanathan, J. Hiltner, A. Swartzlander, F. Hasoon, R. Noufi, *Prog. Photovolt. Res. Appl.* **7**, 311 (1999).
- H. Khallif, I.O. Oladej, L. Chow, *Thin Solid Films* **516**, 5967 (2008).
- R. Krupa, A. Wrzesinska. *Acta Phys. Polonica A* **53**, 675 (1978).
- A. Acharya, et al., *Researcher.* **3**(1), 108 (2011).
- H.P. Klug, L.E. Alexander, *X-ray diffraction methods for polycrystalline and amorphous materials* (New York: John Wiley and Sons: 1954).
- P. Nandakumar, C. Vijayan, Y.V.G.S. Murti, *J. Appl. Phys.* **91**, 1509 (2002).
- T. Praveen, V. Parinda, A. Pushan, *Mater. Lett.* **54**, 343 (2002).
- A.I. Olivaa, O. Solis-Cantoa, R. Castro-Rodrigueza, P. Quintanaa, *Thin Solid Films* **391**, 28 (2001).
- J. Tauc, A. Menth, *J. Non-Cryst. Solids* **8**, 569 (1972).
- M. Karimi, et al., *Curr. Appl. Phys.* **9**, 1263 (2009).