Structural and Optoelectronic Properties of Polycrystalline CdS Thick Film Prepared by Screen Printing

B.Y. Bagul[1,2], P.S. Sonawane[2], A.Z. Shaikh[2], Y.N. Rane[3], S.R. Gosavi[3,*]

[1] *Vasantrao Naik Arts, Commerce and Science College Shahada, 425409, M.S., India*
[2] *Material Research Laboratory, P.G. Department of Physics, Pratap College, Amalner, 425401, M.S., India*
[3] *Material Research Laboratory, C. H. C. Arts, S. G. P. Commerce, and B.B.J.P. Science College, Taloda, 425413, (M.S.) India*

(Received 15 July 2018; revised manuscript received 21 October 2018; published online 29 October 2018)

The paper describes structural, optical and electrical properties of CdS thick film prepared by using screen printing method. For the preparation of CdS thick film, powder of CdS nanoparticles was prepared by using chemical precipitation method using cadmium acetate and sodium sulfide as a source of Cd and S respectively. XRD pattern confirms the formation of pure hexagonal CdS phase with crystallite size of the order of 19.41 nm and 21.14 nm respectively, for as prepared and annealed CdS thick films. The surface morphology studies shows that the films covered with spherical grains uniformly distributed over the substrate free from crack and pinholes where as elemental analysis revealed the presence of Cd and S elements in the prepared film. The absorption spectra of as prepared and sintered CdS thick film were recorded by using JASCO V-630 spectrophotometer in the wavelength range of 400-900 nm from which energy band gap has been determined and is found to be 2.47 eV and 2.39 eV for as prepared and sintered CdS thick film, respectively. Electrical analysis showed the semiconducting behavior of the prepared material.

Keywords: II-VI semiconductors, Metal chalcogenide, Thick film, Optical properties, Electrical properties.

DOI: 10.21272/jnep.10(5).05018 PACS numbers: 61.72.uj, 77.84.Bw, 85.40.Xx, 73.61.Ga, 51.50. + v

1. INTRODUCTION

In the last few decades, material belongs to II-VI class, such as cadmium sulphide (CdS) in thick or thin film form has attracted considerable attention of the researchers for their potential applications in a variety of optoelectronic devices [1-3] and thin film transistors [4]. It is favorite material for photovoltaic and photoelectrochemical solar cells because of its direct band gap with high absorption coefficient [5], good stability and low cost [6]. The knowledge of structural, optical and electrical properties of CdS films is very important in the field of optoelectronic devices. In this context, there are various chemical methods were employed for the preparation CdS/CdTe solar cells such as vacuum deposition, closed space sublimation, sputtering, screen printing and sintering method etc. [7]. Screen printing is a dominant method of thick film deposition because it is inexpensive, convenient technique for large area preparation of the films and suitable for coating surfaces of any structure and morphology and film with excellent quality [8].

In the present work, chemically precipitated powder of CdS nanoparticles was used for the preparation of CdS thick film using screen printing technique and the structural, morphological and optoelectronic properties of screen printed CdS thick film sintered at 250°C have been investigated.

2. EXPERIMENTAL DETAILS

2.1 Preparation of CdS Thick Film

In the present work, powder of CdS nanoparticles was prepared by the chemical precipitation method using AR grade cadmium acetate $Cd(CH_3COO)_2.2H_2O$ and sodium sulfide ($Na_2S.9H_2O$) as a starting compounds. Chemical reaction was carried out at room temperature. 50 ml solution of 1M $Cd(CH_3COO)_2.2H_2O$ and 1M $Na_2S.9H_2O$ were prepared separately using deionized water, mixed in 250 ml beaker and the mixture continuously and vigorously stirred for 3 hours and consequently a dark yellow CdS precipitate formed which was filtered out and washed several times with distilled water and methanol. Finally, the product was dried for 24 hours in open air. When the precipitate was completely dried, it was then crushed to fine powder by grinding process using a mortar and pastel. The obtained powder was used for the preparation of CdS thick film by using screen printing method. A paste for the preparation of CdS thick film was prepared by mixing synthesized powder with $CdCl_2$ used as an adhesive agent, grinding in a mortar followed by addition of poly vinyl alcohol as a binder. The prepared paste was screen printed on glass substrates which have been cleaned using the standard procedure reported earlier [9]. The obtained film was dried at 120°C for three hours in order to reduce the solvents partially and to avoid the cracks in the film [10, 11]. The CdS thick film was then annealed in a muffle furnace in an open atmosphere at 250°C for one hour so as to stabilize the film and to burn the organic materials [11]. Thickness of the prepared CdS thick film was measured by using weight difference method and was found to be of the order of 8.5 μm.

2.2 Characterization of the Prepared Film

The CdS thick film prepared by using screen printing technique was further characterized by using XRD,

* srgosavi.taloda@gmail.com

FESEM and UV-VIS spectroscopy. X-ray diffraction (XRD) analysis is carried out for the determination of structure and crystallite size. The surface morphology and chemical composition of the films were analyzed by field emission scanning electron microscopy (FESEM) and energy dispersive X-ray spectroscopy (EDS). The optical properties of the films were determined by JASCO V-630 UV-VIS spectrophotometer.

3. RESULT AND DISCUSSIONS

The crystallite size and crystal structure of the CdS thick films was determined by using XRD pattern. Fig. 1 (a) shows XRD pattern of synthesized powder of CdS nanoparticles, which showed well resolved peaks indicating the formation of pure CdS compound. The XRD pattern of as-prepared and annealed CdS thick film deposited by using screen printing method are as shown in Fig. 1(b) and Fig. 1(c), respectively. The sharp intense peaks of CdS thick films confirm the good crystalline nature and besides no other impurity peaks are seen, suggesting the formation of single phase CdS. The influence of the annealing on the crystallinity of the films was also observed. The well-defined peaks at $2\theta \approx 25.51°$, 27.2°, 28.88°, 37.35°, 44.40°, 48.52° and 52.55° correspond to reflections from (1 0 0), (0 0 2), (1 0 1), (1 0 2), (1 1 0), (1 0 3) and (2 0 1) planes of pure hexagonal CdS phase, respectively [12]. The average crystallite size was calculated for well-defined peaks for both films using the Debye-Scherer's formula [10]. It was found to be 19.41 nm and 21.14 nm respectively, for as prepared and annealed CdS thick films.

Fig. 2(a) and 2(b) shows FESEM images of as prepared and annealed CdS thick films, respectively. FESEM images reveal the uniform distribution of spherical clusters without cracks and pinholes. Agglomeration of smaller spherical grains to form large particles was seen in the FESEM image of the annealed CdS thick film.

The quantitative analysis of cadmium (Cd) and ulphur (S) present in the thick films were carried out using EDS technique. Fig. 3 represents the EDS spectra of CdS screen printed thick film.

The average atomic percentage has been estimated as 49.12: 50.88 for Cd: S respectively indicating that the film contains cadmium sulphide with cadmium deficiency and it is nearly stoichiometric. However, in addition to Cd and S, there are other peaks corresponding to C, O etc. were found on the EDS spectra which can be attributed to those originating from organic binder used during the film preparation.

Fig. 4 (a) and (b) shows the optical absorption spectra of as prepared and annealed screen printed CdS thick films in the wavelength range of 410-900 nm which is used to obtain the information regarding the optical band gap and transition involved. From Fig. 4, it can be seen that the absorption edge shifts towards the higher wavelength after annealing. It means that the band gap of CdS thick film decreases after annealing.

The theory of optical absorption gives the relation between the absorption coefficient α and the photon energy $h\nu$, for direct allowed transition as,

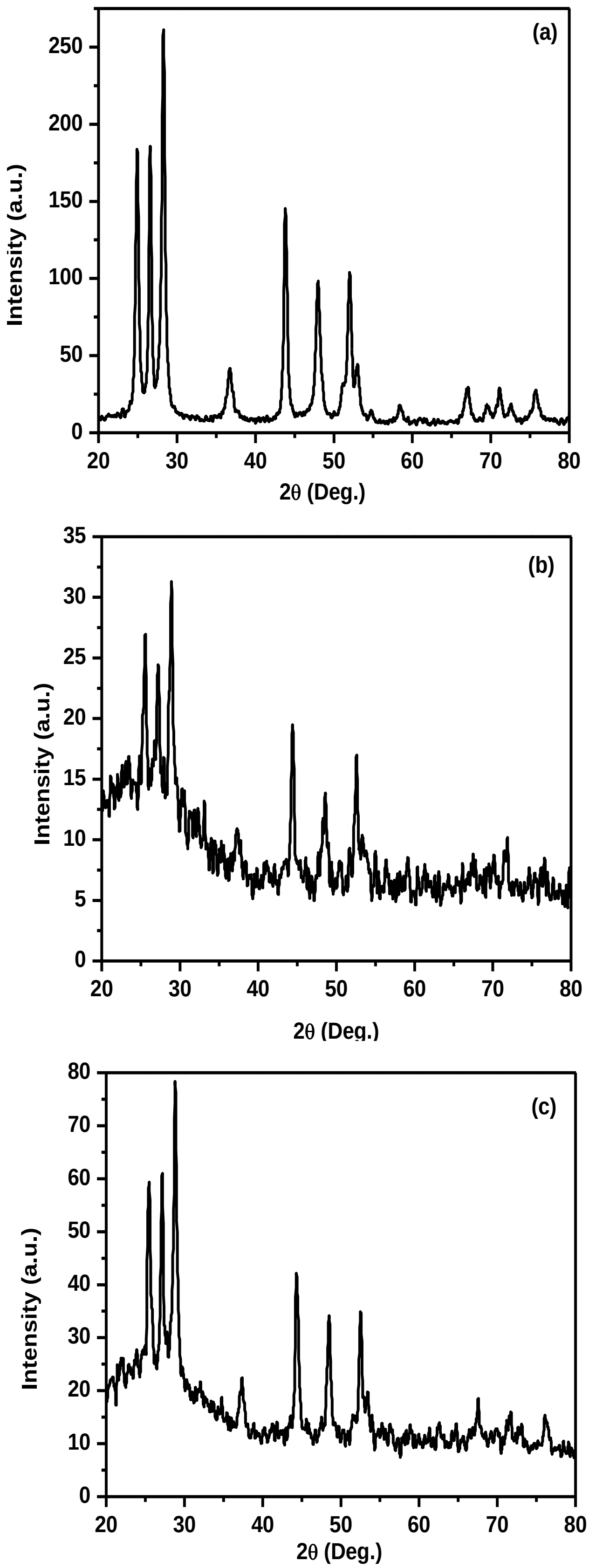

Fig. 1 – XRD pattern of (a) CdS powder, (b) as-deposited CdS thick films and (c) annealed (250°C) CdS thick films

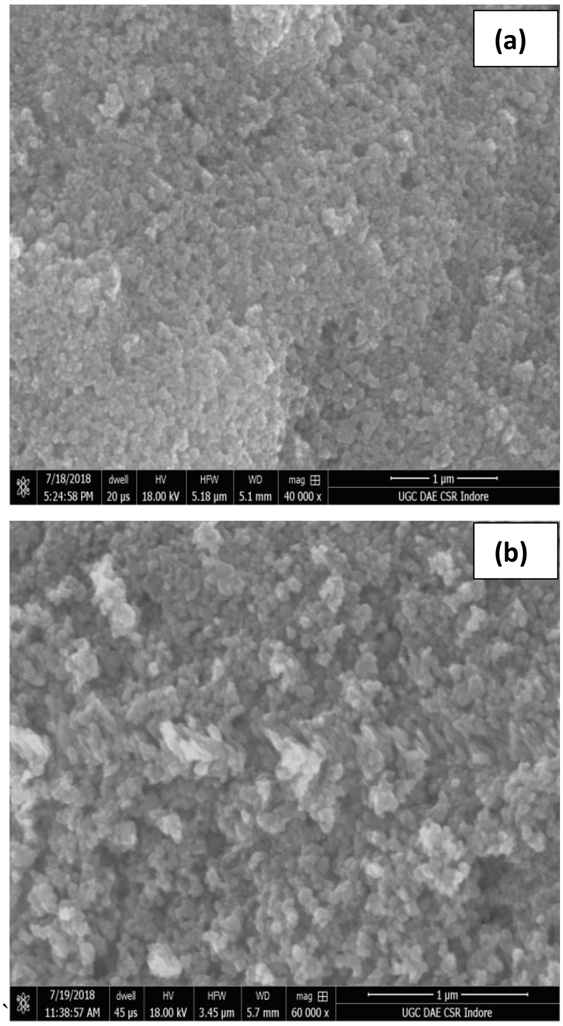

Fig. 2 – FESEM images of CdS thick film prepared on amorphous glass substrate a) as prepared, b) annealed at 250°C

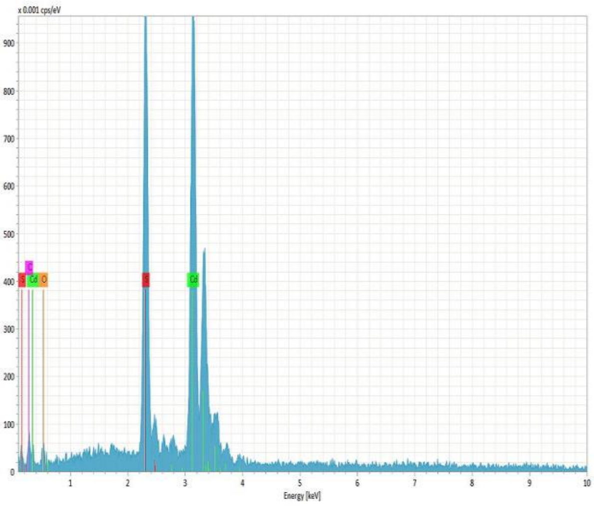

Fig. 3 – EDAX spectra of screen printed CdS thick film

$$\alpha = \frac{A(h\nu - E_g)^2}{h\nu}, \quad (1)$$

where $h\nu$ is the photon energy, E_g is the optical band gap, A is a constant.

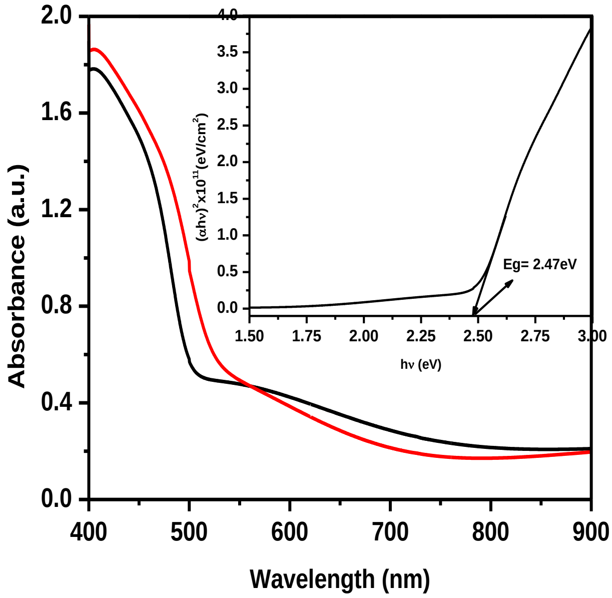

Fig. 4 – Absorption spectra of (a) as-deposited CdS thick films and (b) annealed (250°C) CdS thick films

From optical study it is clear that, the band gap decreases from 2.47 eV to 2.39 eV after annealing of the CdS thick film, which might be due to the increase in the crystallite size of the material after annealing [13]. The value of band gap closely agrees with the value reported earlier [6].

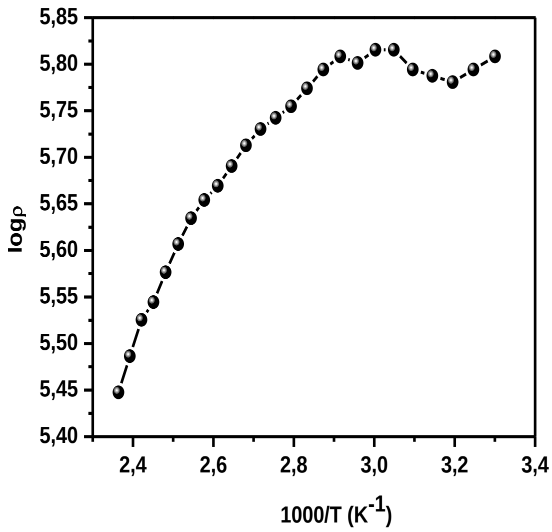

Fig. 5 – Plot of log ρ versus 1000/T for as-deposited CdS thick film prepared using screen printing method

Electrical resistivity measurement of CdS thick film was carried out by using conventional two probe method under dark. From Fig. 5, it is clear that the resistivity decreases as temperature increases, showing the semiconducting behavior of the CdS thick film. Yadav et.al. [14] also observed similar kind of result for the CdS thin film prepared by spray pyrolysis technique.

4. CONCLUSION

Herewith we report the structural, morphological and optoelectronic properties of screen printed CdS thick film prepared by using powder of CdS nanoparticles synthesized using chemical precipitation method. The films were found to be polycrystalline in nature and have hexagonal structure with (1 0 1) as a preferred orientation. FESEM studies showed that spherical particles of nanometer regime arranged as a smooth film on the substrate surface. Direct band gap was 2.47 eV and 2.39 eV for as prepared and annealed CdS thick film, respectively. Semiconducting behavior was observed by studying the electrical resistivity of the CdS thick film.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the UGC-DAE Consortium for Scientific Research Indore, for providing characterization facilities and Prin. Dr. P. V. Ramaiah of C.H.C. Arts, S.G.P. Commerce, and B.B.J.P. Science College, Taloda (M.S.) India for providing laboratory facilities required to carry out the research work.

REFERENCES

1. M. Sharma, S. Kumar, L.M. Sharma, T.P. Sharma, M. Husain, *Physica B* **348**, 15 (2004).
2. S.R. Gosavi, C.P. Nikam, A.R. Shelke, A.M. Patil, S.-W. Ryu, J.S. Bhat, N.G. Deshpande, *Mater. Chem. Phys.* **160**, 244 (2015).
3. A.A. Yadav, M.A. Barote, E.U. Masumdar, *Solid State Sci.* **12**, 1173 (2010).
4. X. Duan, C. Niu, V. Sahi, J. Chen, J.W. Parce, S. Empedocles, J.L. Goldman *Nature* **425**, 274 (2003).
5. C. Li, S. Yang, B. Zheng, T. Zhou, H. Yuan, D. Xiao, *Thin Solid Films* **520**, 2520 (2012).
6. V. Kumar, D.K. Sharma, M.K. Bansal, D.K. Dwivedi, T.P. Sharma, *Sci. Sintering* **43**, 335 (2011).
7. T. Arita, A. Hanafusa, N. Ueno, Y. Nishiyama, S. Kitamura, M. Murozono, *Sol. Energy Mater.* **23**, 371 (1991).
8. D. Patidar, S. Kumar, R. Sharma, N.S. Saxena, K. Sharma, T. P. Sharma, *Indian J. Pure Appl. Phys.* **44**, 729 (2006).
9. R.C. Pawar, C.S. Lee, *Mater. Chem. Phys.* **141**, 686 (2013).
10. R.A. Zargar, S. Chackrabarti, S. Joseph, Mohd.S. Khan, R. Husain, A.K. Hafiz, *Optik* **126**, 4171 (2015).
11. Vipin Kumar, D.K. Sharma, Kapil Sharma, D.K. Dwivedi, *Optik* **156**, 43 (2018).
12. JCPDS card no. 80-0006 (CdS, hexagonal structure).
13. M. Thambidurai, N. Murugan, N. Muthukumarasamy, S. Vasantha, R. Balasundaraprabhu, S. Agilan, *Chalcogenide Lett.* **6**(4), 171 (2009).
14. A.A. Yadav, M.A. Barote, E.U. Masumdar, *Solid State Sci.* **12**, 1173 (2010).