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REVIEW ARTICLE

SYNTHESIS AND PROPERTIES OF CADMIUM OXIDE THIN FILMS: A REVIEW

Ho Soonmin*

Faculty of Science, Technology, Engineering and Mathematics, INTI International University, Putra Nilai, 71800, Negeri Sembilan, Malaysia

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A B S T R A C T

Cadmium oxide thin films are important materials for applications in various photoelectric, solar cell, optoelectronic and other kinds on devices. There are several physical or chemical synthetic methods have been used to prepare transparent CdO films as described by many researchers. The X-ray diffraction study has confirmed the formation of CdO with nano-size scale. CdO films are *n*-type semiconductors and possess a direct band gap of 2.25 to 2.72eV as shown in optical property studies.

INTRODUCTION

Metal chalcogenide thin films [1-30] and metal oxide films [31-39] are of considerable interest in terms of technological applications and have been successfully investigated in the last decades. Cadmium oxide thin films are materials from combinations of group II and group VI. Generally, these materials indicate high optical transmission, low electrical resistivity and high transparency in the visible region of the electromagnetic spectrum. Recently, these materials have been intensively investigated as a potential candidate material for solar cells, smart window, gas sensors, IR detector, photodiode, conducting electrode, anti-reflection coatings and liquid crystal display. In this work, preparations of cadmium oxide thin films were carried out by using various deposition techniques. The obtained films were studied using various investigations such as XRD, SEM, TGA, UV-Visible spectrophotometer.

Literature review

Spray pyrolysis technique was employed by Desai *et al*., 2015 [40] to prepare CdO films onto soda lime glass substrate. During the experiment, the cadmium acetate solution was used as a precursor and the deposition was carried out at 250, 300, 350 and 400 °C. They suggest that the formation of CdO films by decomposition of cadmium acetate after 250 °C as indicated in thermogravimetric analysis. At the same time, they point out that the loss of water from the precursor take place in the range of 25-140 °C. In the XRD analysis, all the samples are polycrystalline in nature and show prominent peaks correspond to (111) and (200) planes. Further, they claim that the intensity corresponds to these peaks gets enhanced with substrate temperature, indicating films have better crystallinity when the films sprayed at higher substrate temperature. Also, the FWHM results show that the grain size increases (34.94, 47.02, 52.81, 56.37 nm) with increase in substrate temperature from 250 to 400.

CdO films are spray deposited at room temperature as described by Uplane *et al*., 1999 [41]. The obtained films are yellowish, uniform and the film thickness was in the range of 0.4 µm. They proposed that cadmium chloride solution was sprayed over the hot substrates kept at 400 °C. Then, cadmium chloride decomposes in order to produce CdO films on glass substrate. The band gap was about 2.45 eV and n-type electrical conductivity was supported as indicated in optical studies and thermoelectric power studies, respectively. On the other hand, Lokhande and Uplane, 2001 [42] studied the influence of deposition temperature on spray deposited cadmium oxide films. First of all, they claim that the obtained films were polycrystalline with preferred orientation along (111), (200), and (220) direction. Then, the electrical resistivity studies indicate that resistivity of these films is in the order of 10^{-4} ohm-cm. Finally, they found that band gap energy varies from 2.37 eV to 2.25 eV with increase in substrate temperature from 523 K to 723 K.

Chemical bath deposited CdO films have been synthesized on glass and quartz substrate from alkaline media at room temperature as proposed by Metodija *et al*., 1996 [43]. XRD studies and optical properties indicate that CdO films prepared from a bath without KBrhave a preferred crystalline orientation in (200) direction and 2.63 eV. Meanwhile, the films prepared from a bath containing KBr show orientation in the (111) direction and band gap about 2.57 eV.

Successive ionic layer adsorption and reaction method (SILAR) was used to prepare CdO films as reported by Urbiola *et al*., 2015 [44]. They found that the annealing temperature affects the grain size and film density. They observe that the reducing film thickness and surface roughness with increasing of annealing temperature from 200 to 500 °C as indicated in SEM results. In XRD studies, the relative intensity of the cubic phase of CdO peaks increases and full width at half maximum (FWHM) reduces when the annealing temperature increases. Lastly, they conduced that the films prepared at the deposition temperature of 500 °C have good crystallinity and suitable electrical conductivity for application in solar cell as transparent conductive oxide layer.

CdO films have been prepared by Sahin, 2013 [45] by using SILAR method in the presence of saccharin. It is known to be employed as a strong leveling agent for the surface and a grain refiner, further by reducing of the internal stresses in the deposited thin films. The researcher concludes that surface morphology and the grain size of the CdO films could be controlled by saccharin percentage. The SEM results show that the grain size was found to be 1390, 1510, 1471 and 1720 nm for 1,3,6 and 12% for saccharin added films, respectively.

CdO thin films of thicknesses ranging from 200 nm to 600 nm have been successfully deposited on glass substrate using chemical bath deposition method from a bath containing cadmium ammine complex ions as reported by Varkey and Fort, 1994 [46]. The obtained films show n-type semiconducting with band gap about 2.3 eV. These films have transmittance of over 85 % in the range of 530-900 nm.

Reactive dc magnetron method was used to produce CdO films onto glass substrates as described by Dhivya *et al*., 2014 [47]. The deposition was carried out for various deposition times such as 5, 10 and 15 minutes in order to produce thin films with varying thicknesses (122, 204 and 294 nm). In the XRD studies, the films prepared for 5 minutes show amorphous in nature. It is observed from XRD patterns that as the deposition time increases (10 and 15 minutes), the peak intensities along the orientation direction (111) will also be increased. Meanwhile, the SEM investigation shows that the amount of deposited films increases with increasing deposition time. They also explain there is enhanced grain growth and nucleation at increased growth deposition, which resulting to the formation of densely arranged particles.

Influence of sputtering power on the physical properties of CdO films has been investigated by Dhivya *et al*., 2015 [48]. They choose reactive dc magnetron sputtering method due to many reasons such as large area uniform coating, high stability of the deposited materials, high deposition rate and good film adherence over substrate. The film thickness was measured by stylus probe measurement and they observed that the thicknesses varies from 210, 240, 320 and 410 nm at sputtering power of 20, 30, 40 and 50 W, respectively. On the other hand, the crystallite size was calculated using Debye Scherrer relation. They conclude that the crystallite size increases (13, 16, 21 nm) with increasing power (20, 30, 40 W) and at the highest power (50 W), it reduces (20 nm). They explain that at highest power the surplus energy of the sputtered atoms along with the higher deposition rate resulting in a deterioration of crystallite growth process.

Lamb and Irvine, 2011 [49] have reported the preparation of CdO films by using metal organic chemical vapour deposition technique. The preferential orientation of (111) peak was found as shown in XRD studies. They conclude that band gap was about 2.5 eV and the obtained films display the higher transmittance in the visible region as indicated in optical property investigation.

Sol gel spin coating technique was used to prepare CdO films on indium tin oxide coated substrate as reported by Sanjeev *et al*., 2016 [50]. They select this deposition technique due to this technique is low cost atmospheric process and can be easily adaptable to industrial use. The obtained films were polycrystalline with cubic structure and the crystallize size is in the range 24-27 nm as shown in XRD patterns. The films indicate an increase in band gap value (2.58 to 2.72 eV) with increasing in the ion fluence ($1X10^{12}$ to $3X10^{12}$ ions/cm^2)as shown in optical properties studies.They describe that this phenomena due to the increase in the degree of disorder in the films. The presence of the high content causes expanding of the localized energy levels.

Seval *et al*., 2009 [51] have prepared CdO films by using sol-gel spin coating method on the glass substrate. The obtained films have been annealed at various temperatures such as 400, 500 and 600 °C for 1 hour. XRD investigation reveals that the annealed CdO films were polycrystalline with (111) preferential orientation. The optical band gap value was measured and determined by using UV-Spectrophotometer technique. The band gap value reduced with increasing the annealing temperatures.

CdO films have been prepared under room temperature by using pulsed laser deposition method as described by Quinines-Galvan *et al*., 2016 [52]. It can be seen that the as-deposited films were polycrystalline cubic structure with a prominent orientation in the (200) plane. However, the annealed films have not preferred orientation. The SEM micrographs show that as-deposited films are produced by a distribution of quasi-spherical shaped aggregates with boundaries not well defined and the sizes in the order of a few hundred of nanometers. However, the annealed films show well defined grains with sizes in the range of 60-80 nm. Further, they explain that these phenomena resulting in the increase of surface density.

CONCLUSION

The structural, morphological and opticalproperties were characterized by using XRD, SEM and UV-Visible spectrophotometer, respectively. The obtained films are polycrystalline with cubic structure as shown in XRD pattern. CdO films are *n*-type semiconductors and possess a direct band gap of 2.25 to 2.72 eV as shown in optical property studies.

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Reference

1. Wei AX, Zhao XH, Liu J and Zhao Y. 2013. Investigation on the structure and optical properties of chemically deposited ZnSe nanocrystalline thin films. Physica B., 410: 120-125.
2. Anuar K, Ho SM and Saravanan N. 2011. Preparation of lead selenide thin films by chemical bath deposition method in the presence of complexing agent (tartaric acid). *Turk. J. Sci. Technol*., 6:17-23.
3. Ezema FI, Ekwealor ABC, Asogwa PU, Ugwuoke PE, Chigbo Cand Osuji RU. 2007. Optical properties and structural characterizations of Sb_2S_3 thin films

deposited by chemical bath deposition technique. *Turk. J. Phys*., 31: 205-210.
4. Anuar K, Ho SM, Atan Sand Haron MJ. 2011. The effect of the pH value on the growth and properties of chemical bath deposited SnS thin films. *Res. J. Chem. Environ*., 15: 45-48.
5. Raniero L, Ferreira CL, Cruz LR, Pinto ALand Alves RM. 2010. Photoconductivity activation in PBS thin films grown at room temperature by chemical bath deposition. Physica B, 405: 1283-1286.
6. Anuar K, Ho SM, Tan WTand Ngai CF. 2011. Influence of triethanolamine on the chemical bath deposited NiS thin films. *Am. J. Appl. Sci*., 8: 359-361.
7. Anuar K and Ho SM. 2010. Deposition and characterization of MnS thin films by chemical bath deposition method. *Int. J. Chem. Res*., 1:1-5.
8. Anuar K, Ho SM, Atan Sand Saravanan N. 2010. X-ray diffraction and atomic force microscopy studies of chemical bath deposited FeS thin films. Stud. U. Babes Bol. Chem., 55: 5-11.
9. Song WC and Lee JH. 2009. Growth and characterization of $Zn_xCd_{1-x}S$ films prepared by using chemical bath deposition for photovoltaic devices. *J. Korean Phys. Soc*., 54: 1660-1665.
10. Anuar K, Zulkefly K, Atan S, Tan WT, Ho SMand Saravanan N. 2010. Preparation and studies of chemically deposited Cu_4SnS_4 thin films in the presence of complexing agent Na_2EDTA. *Indian J. Eng. Mater. Sci.*, 17: 295-298.
11. Anuar K, Nani R and Ho SM. 2011. Atomic force microscopy studies of zinc sulfide thin films. Int. J. Adv. Eng. Sci. Technol., 7: 169-172.
12. Ubale AU. 2010. Effect of complexing agent on growth process and properties of nanostructured Bi_2S_3 thin films deposited by chemical bath deposition method. Mater. Chem. Phys., 121:555-560.
13. Anuar K, Ho SM, Tan WT, Kelvin and Saravanan N. 2011. Composition, morphology and optical characterization of chemical bath deposited ZnSe thin films. *Eur. J. Appl. Sci*., 3: 75-80.
14. Asenjo B, Guilln C, Chaparro AM, Saucedo E, Bermudez V, Lincot D, Herrero J and Gutirrez MT. 2010. Properties of In_2S_3 thin films deposited onto ITO/glass substrates by chemical bath deposition. J. Phys. Chem. Solids, 71: 1629-1633.
15. Anuar K, Ho SM, Tee WT, Lim KSand Saravanan N. 2011. Morphological characterization of CuS thin films by atomic force microscopy. Res. *J. Appl. Sci. Eng. Technol*., 3: 513-518.
16. Gopakumar N, Anjana P and Vidyadharan PP. 2010. Chemical bath deposition and characterization of CdSe thin films for optoelectronic applications. *J. Mater. Sci*., 45: 6653-6656.
17. Ho SM. 2014. Influence of complexing agent on the growth of chemically deposited $Ni_3Pb_2S_2$ thin films. *Oriental J. Chem*., 30: 1009-1012.
18. Khallaf H, Oladeji IOand Chow L. 2008. Optimization of chemical bath deposited CdS thin films using nitrilotriacetic acid as a complexing agent. Thin Solid Films, 516: 5967-5973.
19. Raniero L, Ferreira CL, Cruz LR, Pinto ALand Alves RMP. 2010. Photoconductivity activation in PBS thin films grown at room temperature by chemical bath deposition. Phys. B, 405: 1283-1286.
20. Anuar K, Ho SM, Kelvin, Tan WT and Saravanan N. 2011. Influence of pH on the morphology properties of ZnSe thin films studied by atomic force microscopy. *Eur. J. Sci. Res.,* 66: 592-599.
21. Ezema FI, Ekwealor ABC and Osuji RU. 2006. Effect of thermal annealing on the band GAP and optical properties of chemical bath deposited ZnSe thin films. Turk. J. Phys., 30: 157-163.
22. Oztas M, Bedir M, Bakkaloglu OF and Ormanci R. 2005. Effect of Zn: Se ratio on the properties of sprayed ZnSe thin films. Acta Phys. Pol., A. 107: 525-534.
23. Mahalingam T, Kathalingam A, Lee SN, Moon SWand Kim YD. 2005. Studies of electrosynthesized zinc selenide thin films. *J. New Mater. Electrochem*. Syst., 10: 15-19.
24. Venkatachalam S, Soundararajan D, Peranantham P, Mangalaraj D, Narayandass SK, Velumani Sand Schabes- Retchkiman P. 2007. Spectroscopic ellipsometry (SE) studies on vacuum-evaporated ZnSe thin films. Mater. Charact. 58: 715-720.
25. Anuar K, Tan WT, Abdullah AH, Jelas HM, Saravanan N, Ho SM and Yazid M. 2009. Chemical bath deposition of NiSe thin films from alkaline solutions using triethanolamine as complexing agent. *Orient. J. Chem*., 25: 813-816.
26. Xie M, Zhuang D, Zhao M, Zhuang Z, Ouyang L, Li X and Song J. 2013. Preparation and characterization of Cu_2ZnSnS_4 thin films and solar cells fabricated from quaternary Cu-Zn-Sn-S target. I*nt. J. Photoenergy*, http://dx.doi.org/10.1155/2013/929454.
27. Anuar K, Tan WT, Ho SM, Abdul HA, Ahmad HJand Saravanan N. 2010. Effect of solution concentration on MnS_2 thin films deposited in a chemical bath. *Kasetsart J. Nat. Sci*., 44: 446-453.
28. Anuar K, Saravanan N, Tan WT, Ho SM and TeoD. 2010. Chemical bath deposition of nickel sulphide (Ni_4S_3) thin films. *Leonardo J. Sci*., 16: 1-12.
29. Yakushev MV, Ogorodnikov II and Volkav VA. 2011. Incorporation of hydrogen in $CuInSe_2$: Improvements of the structure. *J. Vac. Sci.* Technol., A. 29, DOI: 10.1116/1.3620685.
30. Yang CL, Chen YH, Lin M, Wu SL, Liu WC, Wu XS and Zhang FM. 2016. Structural, optical and magnetic properties of Cu_2NiSnS_4 thin films deposited by facile one step electrodeposition. Mater. Lett, 166: 101-104.
31. Czapla A, Kusior E and Bucko M. 1989. Optical properties of non-stoichiometric tin oxide films obtained by reactive sputtering. Thin Solid Films, 182, 15-22.
32. Achour R, Atmane B, Mohamed Jand Boubaker B. 2015. Structural, optical and electrical properties studies of ultrasonically deposited tin oxide (SnO_2) thin films with different substrate temperatures. Superlattices Microstruct, 86, 403-411.
33. Zhang W, Ding S, yang Z, Liu A, Qian Y, Tang S, Yang S. 2006. Growth of novel nanostructured copper oxide (CuO) films on copper foil. *J. Cryst. Growth*, 291: 479-484.

34. Shadia JI. 2012. Properties of amorphous SnO_2 thin films, prepared by thermal evaporation. *Int. J. Mater. Chem*., 2, 173-177.
35. Shaikh SK, Inamdar SI, Ganbavle VV and Rajpure KY. 2016. Chemical bath deposited ZnO thin film based UV photoconductive detector. *J. Alloys Compd*., 664: 242-249.
36. Drevel R, Legros C, Berardan D, Ribot P, Dragoe D, Cannizzo C, Barthes-Labrousse MG, Chausse A and Andrieux M. 2015. Metal organic precursor effect on the properties of SnO_2 thin films deposited by MOCVD technique for electrochemical applications. Surf. Coat. Technol., 271: 234-241.
37. Jlassi M, Sta I, Hajji M and Ezzaouia H. 2014. Optical and electrical properties of nickel oxide thin films synthesized by sol-gel spin coating. Mater. Sci. Semicond. Processing, 21: 7-13.
38. Patil PS and Kadam LD. 2002. Preparation and characterization of spray pyrolyzed nickel oxide (NiO) thin films. Appl. Surf. Sci., 199: 211-221.
39. Sriram S and Thayumanavan A. 2013. Structural, optical and electrical properties of NiO thin films prepared by low cost spray pyrolysis technique. *Int. J. Mater. Sci. Eng*., 1: 118-121.
40. Desai SP, Suryawanshi MP, Bhosale SM, Kim JH and Moholkar AV. 2015. Influence of growth temperature on the physic-chemical properties of sprayed cadmium oxide thin films. Ceram. Int., 41: 4867-4873.
41. Uplane MD, Kshirsagar PN, Lokhande BJ and Lokhande CD. 1999. Preparation of cadmium oxide films by spray pyrolysis and its conversion into cadmium chalcogenide films. *Indian J. Pure Appl. Phys*., 37: 616-619.
42. Lokhande B J and Uplane MD. 2001. Effect of deposition temperature on spray deposited cadmium oxide films. Mater. Res. Bull., 36: 439-447.
43. Metodija ZN, Ivan SG and Biljana MS. 1996. Oriented cadmium oxide thin solid films. *J. Mater. Chem.*, 6: 761-764.
44. Urbiola IRC, Bon RR and Vorobiev YV. 2015. The transformation to cadmium oxide through annealing of cadmium oxide hydroxide deposited by ammonia free SILAR method and the photocatalytic properties. Thin Solid Films, 592: 110-117.
45. Sahin B. 2013. Physical properties of nanostructured CdO films from alkaline baths containing saccharin as additive. *Sci. World J*, http://dx.doi.org/ 10.1155/ 2013/172052.
46. Varkey AJ and Fort AF. 1994. Transparent conducting cadmium oxide thin films prepared by a solution growth technique. Thin Solid Films, 239: 211-213.
47. Dhivya P, Prasad AK and Sridharan M. 2014. Magnetron sputtered nanostructured cadmium oxide films for ammonia sensing. *J. Solid State Chem*., 214: 24-29.
48. Dhivya P, Prasad AK and Sridharan M. 2015. Effect of sputtering power on the methane sensing properties of nanostructured cadmium oxide films. *J. Alloys Compd*., 620: 109-115.
49. Lamb DA and Irvine SJC. 2011. A temperature dependant crystal orientation transition of cadmium oxide films deposited by metal organic chemical vapour deposition. *J. Cryst. Growth*, 332: 17-20.
50. Sanjeev K, Fouran S and Kapoor A. 2016. Study of valence band tailing effect induced by electronic excitations in nanocrystalline cadmium oxide thin films. Optik, 127: 2055-2058.
51. Seval A, Yasemin C, Saliha I and Mujdat C. 2009. Effect of heat treatment on physical properties of CdO films deposited by sol gel method. *Int. J. Hydrogen Energy*, 34: 5191-5195.
52. Quinones-Galvan JG, Lozada-Morales R, Jimenez-Sandoval S, Camps E, Castrejon-Sanchez VH, Campos-Gonzalez E, Zapata-Torres M, Perez-Centeno A and Santana-Aranda MA. 2016. Physical properties of a non-transparent cadmium oxide thick film deposited at low fluence by pulsed laser deposition. Mater. Res. Bull., 76: 376-383.

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