JOURNAL OF APPLIED SCIENCES RESEARCH

ISSN: 1819-544X
EISSN: 1816-157X
2016 January; 12(1): pages 44-48

Published BY **AENSI Publication**
http://www.aensiweb.com/JASR
Open Access Journal

A review on the sputtering deposition film growth

Ho SM

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

Received 2 January 2016; Accepted 22 February 2016; Published 25 February 2016

Address For Correspondence:
Ho SM, Faculty of Science, Technology, Engineering and Mathematics, INTI International University, Putra Nilai, 71800, Negeri Sembilan, Malaysia.
Tel: +606-7982000; E-mail: soonmin.ho@newinti.edu.my

ABSTRACT
Currently, sputter deposition method is one of the most leading deposition techniques. In this work, the preparation, properties and application of thin films which prepared using sputtering process were discussed. In order to investigate the properties of thin films, x-ray diffraction and scanning electron microscopy characterization were performed. Experiment findings indicated that the growth parameters influenced the properties of thin films.

KEYWORDS: Thin films; Sputter process, semiconductor, chalcogenide metal

INTRODUCTION

Sputter deposition is used to prepare thin films on suitable substrate in a vacuum chamber. It is very useful method to make thin films especially when using materials that are non-conductive. During the deposition process, magnets are applied to ionize the target material and encourage it to settle on the substrate in the form of thin films. This technique offers many advantages such as enable to control the size and volume distribution of particles over a wide range [21], easy to obtain a films with the desired stoichiometrical composition [17], high film growth rate [20] and control the uniformity of the thin films [24]. In addition, this method could be used for mass production with a large area deposition [38] and generally, low temperature is required to produce small and continuous films on the substrates.

In this work, an investigation focused on the deposition of various types of thin films using sputter deposition method. The films have been characterized by XRD, SEM, and UV-Visible spectrophotometer. Lastly, optical properties were studied for band gap calculation.

2. Literature survey:

There are different types of thin films have been prepared using sputtering method. CdTe films have been deposited onto different substrates such as glass, silicon and aluminium oxide by Chen *et al.*, [21]. According to X-ray diffraction patterns, they found that the films prepared on glass and silicon has a better crystal quality than aluminium oxide. In addition, field emission scanning electron microscopy (FESEM) results displayed a continuous and dense morphology of films which deposited on glass and silicon substrates.

The influence of annealing temperature such as room temperature, 100, 150 and 200 °C on the structure of CdS films has been reported by Islam *et al.*, [35]. The obtained XRD patterns reflect that the annealed films contained both cubic and hexagonal structures. Meanwhile, there is no peak found for the films deposited at room temperature. They also suggest that the band gap increases and the dislocation densities are reduced with the decrease of the substrate temperature during the RF sputtering process. On the other hand, Kim *et al*., [38] concluded that the average transmittances of the annealed CdS films increased with the annealing temperature to reach a maximum value of 72.25% at 400 °C. then, decreased to a minimum value of 49.11% at 600 °C. Furthermore, they observe that the resistivity below 10^3 order Ωcm and carrier concentration above 10^{16} carriers/cm^3 is suitable for the requirements of window layers at this deposition conditions. The sputtered CdS films with n-type semiconductor characteristics were used for photoconductive sensor devices were reported by Hur *et al*., [34]. The films were prepared at room temperature on glass substrates show polycrystalline phases and smooth surface morphologies based on XRD and SEM analysis, respectively. They also reported that the deposition rate of the films decreases with increasing working pressure. This is due to the scattering effect of the particles detached from the target by argon plasma.

The growth of RF-sputtered zinc sulfide thin films deposited at various substrate temperatures in the range of 25 to 300 °C for photovoltaic application was reported by Chelvanathan *et al*., [20]. XRD data analysis show that all films have cubic structure with (111) plane as the preferential orientation. However, higher substrate temperature up to 200 °C increases the film crystallinity and grain size evident by the increase in peak intensity. The influence of substrate temperatures on the optical properties of ZnS films was investigated by Dong *et al*., [24]. The films grown at 350 °C display a relatively high transmittance of 80% in the visible region with an energy band gap of 3.79 eV. They also reported that the obtained ZnS films are suitable for use as the buffer layer of the $Cu(In,Ga)Se_2$ solar cells.

Cu_2SnS_3 and Cu_3SnS_4 thin films were prepared using magnetron sputtering method by Fernandes *et al*., [28]. The obtained films are p-type semiconductors as shown in optical studies. Furthermore, they show high absorbance value close to 10^4 cm^{-1}. The band gap was 1.35, 0.96 and 1.6 eV for tetragonal Cu_2SnS_3, cubic Cu_2SnS_3 and orthorhombic Cu_3SnS_4, respectively.

On the other hand, $CuInSe_2$ films were prepared by Zhang *et al*., [56] on glass substrate using magnetron sputtering and post-selenization process. All these films show chalcopyrite structure as indicated in X-ray diffraction and Raman spectra analysis. The band gap of films was about 1 eV.

The influence of various deposition conditions on $CuInS_2$ films were determined by Guan *et al*., [29]. They concluded that the optimized conditions as a sputtering power of 80-120 W, a sputtering gas pressure of 0.6-0.8 Pa, a heat treatment temperature of 450-470 °C and a holding time of 2-3 hours based on experimental results. The band gap was estimated to be 1.48-1.5 eV.

Preparation and characterization of Cu_2ZnSnS_4 thin films have been discussed by many scientists using r.f. sputtering process. The solar cell prepared with the Cu_2ZnSnS_4 thin films deposited by the single sputtering process followed by annealing at 500 °C indicate an efficiency of 4.4% as reported by Ryota *et al*., [48]. Meanwhile, Xie *et al*., [55]) have reported that the Cu_2ZnSnS_4 thin films were prepared through sputtering, followed by a sulfurization process. The thin films based solar cells were also fabricated and an efficiency of 4.04% was achieved. On the other hand, Seol *et al*., [51] have reported that Cu_2ZnSnS_4 films were deposited on corning glass substrates without substrates heating by rf magnetron sputtering. The obtained as-deposited films were amorphous. However, the annealed films indicate kesterite structure as shown in XRD pattern. In terms of optical studies, they claim that the optical absorption coefficient was 1 $x10^4cm^{-1}$. Meanwhile, band gap energy was about 1.51 eV. It means that band gap energy was more appropriate for photovoltaic materials.

The smooth $Cu(In_{1-x}Al_x)Se_2$ thin films surfaces with good adhesion to the substrate were grown successfully by Badrul *et al*., [17]. All the films indicate uniform and very clear columnar grains as shown in SEM studies. In optical investigations, the films prepared in the absence of aluminium indicate band gap of 1.05 eV. Meanwhile, the films prepare in the presence of aluminum show a higher band gap value (1.35 eV).

Finally, there are some disadvantages could be found in this deposition technique. For example, lower plasma density and slow deposition speed if compared to arc technology. On the other hand, the production cost will be an important factor in order to choose the deposition method. For instance, chemical bath deposition (Table 1), electro deposition method (Table 2) and successive ionic layer adsorption and reaction method (Table 3) are considered as very simple and economical deposition techniques if compared to other deposition techniques. As a result, there are many binary, ternary and quaternary thin films were successfully prepared by many researchers using the above deposition methods.

Table 1: Thin films prepared by chemical bath deposition method

Thin films	Researcher(s)
CdS	Humaira *et al*., [33] Demir & Gode, [23] Ersin & Suleyman, [26]
CdSe	Nikam *et al*., [44]
Mg-Cd-S	Caballero-Briones *et al*., [19]
ZnS	Jet *et al*., [36] Anuar *et al*., [1]

ZnSe	Anuar *et al*., [2]
Sb_2S_3	Ezema *et al*., [27]
CuS	Anuar *et al*., [3]
PbS	Raniero *et al*., [47]
PbSe	Anuar *et al*., [4]
SnS	Anuar *et al*., [5]
In_2S_3	Asenjo *et al*., [15]
$ZnIn_2Se_4$	Babu *et al*., [16]
MnS	Anuar *et al*., [9]
$Pb_{1-x}Fe_xS$	Joshi *et al*., [37]
MnS_2	Anuar *et al*., [10]
NiS	Anuar *et al*., [14]
Cu_4SnS_4	Anuar *et al*., [11]
Bi_2S_3	Ubale, [54]
FeS	Anuar *et al*.,[12]
$Ni_3Pb_2S_2$	Ho, [32]
SnS_2	Li *et al*., [40]
Ni_4S_3	Anuar *et al*., [7]
SbCuS	Ekuma *et al*., [25]
Cu_2S	Anuar *et al*., [8]
$Zn_xCd_{1-x}S$	Song & Lee, [53]
$CuInSe_2$	Bari *et al*., [18]
NiSe	Hankare *et al*., [31]

Table 2: Thin films prepared by electro deposition method.

Thin films	Researcher (s)
(Cd,Bi)S	Mishra *et al*., [43]
In_2S_3	Maqsood *et al*., [42]
Cu_2ZnSnS_4	Lin *et al*., [41]
ZnTe	Skhouni *et al*., [52]
SnS	Priscilla *et al*., [46]
$CuGaSe_2$	Lee *et al*., [39]
Cu_4SnS_4	Anuar *et al*., [13]
$Cu(In,Al)Se_2$	Deepa *et al*., [22]
ZnS	Anuar *et al*., [14]

Table 3: Thin films prepared by successive ionic layer adsorption and reaction

Thin films	Researcher(s)
CoS	Sartale & Lokhande, [50]
CdS,	Guzeldir *et al*., [30]
CuS	Guzeldir *et al*., [30]
ZnS	Guzeldir *et al*., [30]
SnS_2	Sankapal *et al*., [49]
CdSe	Panthan *et al*., [45]

ACKNOWLEDGMENTS

INTI International University is gratefully acknowledged for the financial support of this study.

REFERENCES

1. Anuar, K., R. Nani, S.M. Ho, 2011a. Atomic force microscopy studies of zinc sulfide thin films. *Int. J. Adv. Eng. Sci. Technol.,* 7: 169-172.
2. Anuar, K., S.M. Ho, W.T. Tan, Kelvin, 2011b. Saravanan N. Composition, morphology and optical characterization of chemical bath deposited ZnSe thin films. Eur. J. Appl. Sci., 3: 75-80.
3. Anuar, K., S.M. Ho, W.T. Tee, K.S. Lim, N. Saravanan, 2011c. Morphological characterization of CuS thin films by atomic force microscopy. Res. J. Appl. Sci. Eng. Technol., 3: 513-518.
4. Anuar, K., S.M. Ho, N. Saravanan, 2011d. 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.
5. Anuar, K., S.M. Ho, S. Atan, M.J. Haron, 2011e. 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.
6. Anuar, K., S.M. Ho, W.T. Tan, C.F. Ngai, 2011f. Influence of triethanolamine on the chemical bath deposited NiS thin films. Am. J. Appl. Sci., 8: 359-361.
7. Anuar, K., W.T. Tan, N. Saravanan, S.M. Ho, 2011g. Influence of pH on the properties of chemical bath deposited Ni_4S_3 thin films. Bangladesh J. Sci. Ind. Res., 46: 243-246.
8. Anuar, K., S.M. Ho, K.S. Lim, N. Saravanan, 2011h. SEM, EDAX and UV-Visible studies on the properties of Cu_2S thin films. Chalcogenide Lett, 8: 405-410.

9. Anuar, K., S.M. Ho, 2010a. Deposition and characterization of MnS thin films by chemical bath deposition method. Int. J. Chem. Res., 1: 1-5.
10. Anuar, K., A.H. Abdullah, S.M. Ho, N. Saravanan, 2010b. Influence of deposition time on the properties of chemical bath deposited manganese sulfide thin films. Av. Quinm., 5: 141-145.
11. Anuar, K., K. Zulkefly, S. Atan, W.T. Tan, S.M. Ho, N. Saravanan, 2010c. 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.
12. Anuar, K., S.M. Ho, S. Atan, N. Saravanan, 2010d. X-ray diffraction and atomic force microscopy studies of chemical bath deposited FeS thin films. Studia UBB. Chemia., 55: 5-11.
13. Anuar, K., K. Zulkefly, S. Atan, H. Jelas, W.T. Tan, S.M. Ho, 2010e. Effects of deposition potential on Cu_4SnS_4 thin films prepared by electrodeposition technique. Arabian J. Sci. Eng., 35: 83-92.
14. Anuar, K., S.M. Ho, H.A. Abdul, K. Noraini, N. Saravanan, 2010f. Influence of the deposition time on the structure and morphology of the ZnS thin films electrodeposited on indium tin oxide substrates. Digest J. Nanomater. Biostructures., 5: 975-980.
15. Asenjo, B., C. Guilln, A.M. Chaparro, E. Saucedo, V. Bermudez, D. Lincot, J. Herrero, M.T. Gutirrez, 2010. Properties of In_2S_3 thin films deposited onto ITO/glass substrates by chemical bath deposition. J. Phys. Chem. Solids., 71: 1629-1633.
16. Babu, P., M.V. Reddy, N. Revathi, K.T.R. Reddy, 2011. Effect of pH on the physical properties of $ZnIn_2Se_4$ thin films grown by chemical bath deposition. J. Nano- Electron. Phys, 3: 85-91.
17. Badrul, M., A.W. Rachmat, S.L. Eun, H.K. Kyoo, 2007. One step deposition of $Cu(In_{1-x}Al_x)Se_2$ thin films by RF magnetron sputtering. J. Ceram. Process. Res., 8: 252-255.
18. Bari, R.H., L.A. Patil, P.S. Sonawane, M.D. Mahanubhav, V.R. Patil, P.K. Khanna, 2007. Studies on chemically deposited $CuInSe_2$ thin films. Mater. Lett., 61: 2058-2061.
19. Caballero-Briones, F., O. Calzadilla, F. Chale-Lara, V. Rejon, J.L. Pena, 2015. Mg-doped CdS films prepared by chemical bath deposition. Optical and electrical properties. Chalcogenide Lett., 12: 137-145.
20. Chelvanathan, P., Y. Yusoff, F. Haque, M. Akhtaruzzaman, M.M. Alam, Z.A. Alothman, M.J. Rashid, K. Sopian, N. Amin, 2015. Growth and characterization of RF-sputtered ZnS thin film deposited at various substrate temperatures for photovoltaic application. Appl. Surf. Sci., 334: 138-144.
21. Chen, H.M., F.Q. Guo, B.H. Zhang, 2009. Properties of CdTe nanocrystalline thin films grown on different substrates by low temperature sputtering. J. Semicond, 30: 053001-1-053001-5.
22. Deepa, K.G., N.L. Shruthi, M.A. Sunil, J. Nagaraju, 2014. $Cu(In,Al)Se_2$ thin films by one-step electrodeposition for photovoltaics. Thin Solid Films., 551: 1-7.
23. Demir, R., F. Gode Structural, 2015. optical and electrical properties of nanocrystalline CdS thin films grown by chemical bath deposition method. Chalcogenide Lett., 12: 43-50.
24. Dong, H.H., H.A. Jung, N.H. Kwun, S.H. Kwan, G.S. Young, 2012. Structural and optical properties of ZnS thin films deposited by RF magnetron sputtering. Nanoscale Res. Lett., 7: doi:10.1186/1556-276X-7-26.
25. Ekuma, C., M. Nnabuchi, A. Nwabueze, I. Owate, 2010. Optical characterization of chemically deposited SbCuS thin films. Ceram. Trans., 222: 243-249.
26. Ersin, Y., K. Suleyman, 2015. The effects of coumarin additive on the properties of CdS thin films grown by chemical bath deposition. Ceram. Int., 41: 4726-4734.
27. Ezema, F.I., A.B.C. Ekwealor, P.U. Asogwa, P.E. Ugwuoke, C. Chigbo, R.U. Osuji, 2007. Optical properties and structural characterizations of Sb_2S_3 thin films deposited by chemical bath deposition technique. Turk. J. Phys., 31: 205-210.
28. Fernandes, P.A., P.M. Salome, A.F. Cunha, 2010. A study of ternary Cu_2SnS_3 and Cu_3SnS_4 thin films prepared by sulfurizing stacked metal precursors. J. Phys. D: Appl. Phys., 43: DOI: http://dx.doi.org/10.1088/0022-3727/43/21/215403.
29. Guan, R., X. Wang, Q. Sun, 2015. Structural and optical properties of $CuInS_2$ thin films prepared by magnetron sputtering and sulfurization heat treatment. J. Nanomater., Article ID 579489, in press.
30. Guzeldir, B., M. Saglam, 2012. Ates A. Deposition and characterization of CdS, CuS and ZnS thin films deposited by SILAR method. Acta Phys. Pol. A. 121: 33-35.
31. Hankare, P.P., B.V. Jadhav, K.M. Garadkar, P.A. Chate, I.S. Mulla, S.D. Delekar, 2010. Synthesis and characterization of nickel selenide thin films deposited by chemical bath method. J. Alloys and Compd., 490: 228-231.
32. Ho, S.M., 2014. Influence of complexing agent on the growth of chemically deposited $Ni_3Pb_2S_2$ thin films. Oriental J. Chem., 30: 1009-1012.
33. Humaira, T., R. Rose, M. Abhinav, Y. Sagar, C. Connor, N. Jagjit, K. Ramki, 2015. In situ localized surface plasmon resonance (LSPR) spectroscopy to investigate kinetics of chemical bath deposition of CdS thin films. J. Phys. Chem., 119: 5033-5039.
34. Hur, S., E. Kim, J. Lee, G. Kim, S. Yoon, 2008. Characterization of photoconductive CdS thin films

prepared on glass substrates for photoconductive-sensor applications. J. Vac. Sci. Technol. B., 26: 1334-1337.
35. Islam, M., M.S. Hossain, K.S. Rahman, F. Haque, M.Y. Sulaiman, K. Sopian, N. Amin, 2014. Enhancement of optical properties of CdS thin films prepared from sputtering technique: Effect of thermal annealing. Aust. J. Basic Appl. Sci., 8: 284-287.
36. Jet, M., M.T. Brock, T.S. Amanda, G.M. Frederick, 2015. Morphology and growth behavior of O_2-free chemical bath deposited ZnS thin films. *Thin Solid Films. in press.*
37. Joshi, R.K., G.V. Subbaraju, R. Sharma, 2004. $Pb_{1-x}Fe_xS$ nanoparticle films grown from acidic chemical bath. Appl. Surf. Sci., 239: 1-4.
38. Kim, N.H., S.H. Ryu, H.S. Noh, W.S. Lee, 2012. Electrical and optical properties of sputtered deposited cadmium sulfide thin films optimized by annealing temperature. Mater. Sci. Semicond. Process., 15: 125-130.
39. Lee, H., J. Lee, Y. Hwang, Y. Kim, 2014. Cyclic voltammetry study of electrodeposition of $CuGaSe_2$ thin films on ITO-glass substrates. Curr. Appl. Phys, 14: 18-22.
40. Li, J., Y.C. Zhang, M. Zhang, 2011. Preparation of SnS_2 thin films by chemical bath deposition. Mater. Sci. Forum., 663-665: 104-107.
41. Lin, Y., S. Ikeda, W. Septina, Y. Kawasaki, T. Harada, M. Matsumura, 2014. Mechanistic aspects of preheating effects of electrodeposited metallic precursors on structural and photovoltaic properties of Cu_2ZnSnS_4 thin films. Sol. Energy Mater. Sol. Cells., 120: 218-225.
42. Maqsood, A.M., N.M. Jason, V. Joshua, T. Shyam, W. Kayla, E. Robert, C.B. Ross, J.J. Bruce, 2014. Optimization of the electrodeposition parameters to improve the stoichiometry of In_2S_3 films for solar applications using the Taguchi method. J. Nanomater., DOI: http://dx.doi.org/10.1155/2014/302159.
43. Mishra, S.S.D., K.K. Saini, C. Kant, M. Pal, 2014. Preparation of mixed (Cd,Bi)S composite thin films via surfactant facilitated electro deposition process and their photoelectrochemical characterization. Mater. Chem. Phys., 146: 324-329.
44. Nikam, C.P., N. Gosavi, R.R. Ahire, S.R. Gosavi, 2015. Synthesis, structural and optoelectronic properties of nanocrystalline CdSe thin films prepared by chemical bath deposition route. J. Sci. Rev., 5: 238-244.
45. Panthan, H.M., B.R. Sankapal, J.D. Desai, C.D. Lokhande, 2003. Preparation and characterization of nanocrystalline CdSe thin films deposited by SILAR method. Mater. Chem. Phys., 78: 11-14.
46. Priscilla, D.A., A.T. Dabiel, Y. Fan, A.R. Federico, S.L. Nathan, L.B. Richard, 2014. Low temperature solution phase deposition of SnS thin films. Chem. Mater., 26: 5444-5446.
47. Raniero, L., C.L. Ferreira, L.R. Cruz, A.L. Pinto, R.M.P. Alves, 2010. Photoconductivity activation in PbS thin films grown at room temperature by chemical bath deposition. Phys. B: Condensed Matter, 405: 1283-1286.
48. Ryota, N., T. Kunihiko, U. Hisao, J. Kazuo, W. Tsukasa, K. Hironori, 2014. Cu_2ZnSnS_4 thin film deposited by sputtering with Cu_2ZnSnS_4 compound target. Jpn. J. Appl. Phys, 53: DOI: http://dx.doi.org/10.7567/JJAP.53.02BC10.
49. Sankapal, B.R., R.S. Mane, C.D. Lokhande, 2000. Successive ionic layer adsorption and reaction (SILAR) method for the deposition of large area (~$10cm^2$) tin sulfide SnS_2 thin films. Mater. Res. Bull., 35: 2027-2035.
50. Sartale, S.D., C.D. Lokhande, 2000. Deposition of cobalt sulphide thin films by successive ionic layer adsorption and reaction (SILAR) method and their characterization. Indian J. Pure Appl. Phys., 38: 48-52.
51. Seol, J., S. Lee, J. Lee, H. Nam, K. Kim, 2003. Electrical and optical properties of Cu_2ZnSnS_4 thin films prepared by rf magnetron sputtering process. Sol. Energy Mater. Sol. Cells, 75: 155-162.
52. Skhouni, O., A. El-Manouni, M. Mollar, R. Schrebler, B. Mari, 2014. ZnTe thin films grown by electro deposition technique on fluorine tin oxide substrates. Thin Solid Films., 564: 195-200.
53. Song, W.C., J.H. Lee, 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.
54. Ubale, A.U., 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.
55. Xie, M., D. Zhuang, M. Zhao, Z. Zhuang, Q. Liang, Y. Ou, X. Li, J. Song, 2013. Preparation and characterization of Cu_2ZnSnS_4 thin films and solar cells fabricated from quaternary Cu-Zn-Sn-S target. Int. J. Photoenergy, http://dx.doi.org/10.1155/2013/929454.
56. Zhang, J., H. Deng, P. Yang, J. He, T. Liu, 2013. The characterization of $CuInSe_2$ thin films by a sequential processes of sputtering and selenization. *Proc. SPIE 9068, Eighth International Conference on Thin Film Physics and Applications, 90681R*; doi:10.1117/12.2053499.