



IJRASET

International Journal For Research in
Applied Science and Engineering Technology



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 9 Issue: III Month of publication: March 2021

DOI: <https://doi.org/10.22214/ijraset.2021.33252>

www.ijraset.com

Call:  08813907089

E-mail ID: ijraset@gmail.com

Effect of Deposition Time Period on the Structural properties of Kesterite $\text{Cu}_2\text{ZnSnS}_4$ Thin films

A. Anis Fathima¹, S. Nivetha², S. Prabakar³, S. Srikanth⁴, R.T. Karunakaran⁵, U. Karunanithi⁶, M. Narendhera Ganth⁷

^{1, 2, 3, 4, 5, 6, 7}Department of Physics, Government Arts College, Udumalpet, Tiruppur, Tamilnadu, India

Abstract: $\text{Cu}_2\text{ZnSnS}_4$ thin films have been prepared by chemical phase synthesis at different deposition time period followed by chemical bath deposition method. The X-ray diffraction pattern confirms the formation of CZTS thin films with tetragonal kesterite structure. Current-Voltage characterization studies reveal that CZTS thin films exhibits ohmic contact with high electrical conductivity. These results show that the as prepared CZTS thin film is well opted for solar cell applications.

Keywords: Deposition time period, XRD, kesterite, I-V characteristic, Ohmic contact

I. INTRODUCTION

$\text{Cu}_2\text{ZnSnS}_4$ is tetragonal kesterite quaternary semiconductor compound. Its structural and electrical properties are optimum as an absorber layer for photovoltaic and thin film solar cell application. Now, CZTS is a good absorber material, low cost, earth abundant and non-toxic alternative to CuInGaSe_2 and CdTe is a scarcity, inexpensive and toxic element. CZTS thin films have been prepared by two types such as physical and chemical methods. Several film deposition processes are vacuum based methods such as Radio Frequency magnetron sputtering [1] Reactive sputtering [2] and Co-evaporation [3]. The solution based routes are Spray pyrolysis [4] Chemical bath deposition [5] Sol Gel spin and dip coating [6,7] and Electro deposition [8]. In this current work, $\text{Cu}_2\text{ZnSnS}_4$ thin film is prepared by chemical bath deposition technique. The CZTS thin films were scrutinized by XRD and I-V characteristics studies.

II. EXPERIMENTAL DETAILS

$\text{Cu}_2\text{ZnSnS}_4$ thin films have been prepared for different deposition time periods by chemical bath deposition method. Precursor solutions were prepared by 0.2 M Copper chloride, 0.1 M Zinc chloride, 0.1 M Tin chloride and 0.4 M Thiourea dissolved in 15 ml of de-ionized water separately and a small amount of stabilizing agent Triethanolamine is added to each of these solutions sustaining the pH at 12. The final precursor solution is stirred for 15 minutes using a magnetic stirrer which in turn changes the colour of the solution from sky blue to golden yellow. The cleaned Si substrates were immersed inside the solution for different deposition time periods maintaining the bath temperature at 65°C , further the deposited thin films were annealed at 100°C for 1 hr.

III. STRUCTURAL ANALYSIS

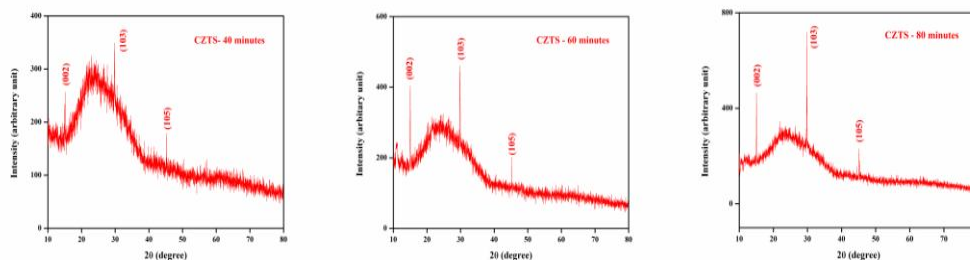


Figure 1 XRD pattern of CZTS thin film deposited at different time period

Figure 1 XRD pattern reveals that all the three CZTS thin films exhibiting a polycrystalline nature for different deposition time periods and deposited films demonstrating $2\theta = 15^\circ, 29.8^\circ$ and 45° can be attributed to the (002), (103) and (105) planes respectively. The crystalline nature of all three CZTS thin films is almost the same. This XRD pattern matches well with the standard XRD pattern of CZTS (JCPDS NO: 26-0575). The XRD study confirms the formation of CZTS thin films of tetragonal kesterite structure [16-18].

It is noticed that increasing the deposition time period, the intensity of plane (103) get increased. when increasing deposition time period at 40, 60 and 80 minutes, the crystalline (grain) sizes are increasing in the range 44 nm, 86 nm and 134 nm and also film thickness are increasing in the range is 2808 Å, 3310 Å and 5012 Å respectively (Table 1). The crystalline size and micro strain can be calculated from the XRD pattern for different CZTS thin films. The average crystalline size (D) of CZTS thin film was calculated from the full width half maximum (FWHM) at (002), (103) and (105) planes using Scherrer formula $D = \frac{0.91}{\beta \cos \theta}$. Where, θ is the Braggs angle (diffraction angle) of the related peak, λ is the wavelength of the X-ray source, β is the full width half maximum (FWHM) [16-18]. The average grain size calculated for different deposition time period of CZTS thin films using at (002), (103) and (105) planes are tabulated.

The microstrain (ϵ) can be estimated by the following relation

$$\epsilon = \frac{\beta \cos \theta}{4}$$

The dislocation density (δ) can be estimated by the following relation

$$\delta = \frac{1}{D^2}$$

Table 1 shows the grain size (D), microstrain (ϵ), dislocation density (δ) values of CZTS thin films.

Table 1 Comparison Of Structural Parameters of CZTS Thin Films

Deposited time period (minutes)	Annealed temperature (°C)	hkl plane	Lattice Constant C (Å)	Dislocation density (Lines/m ²) 10 ¹⁰	Micro Strain (ϵ) (Lines ⁻² m ⁴) 10 ⁻⁴	Grain Size D (nm)	Average Grain Size (nm)
40	100	002	11.7810	0.000023	11.31	62.53	44.36
		103	9.4717	0.000031	8.39	42.76	
		105	10.0772	0.000046	8.64	27.79	
60	100	002	11.8600	0.000006	5.91	119.69	86.91
		103	9.4730	0.000008	4.20	85.50	
		105	10.1073	0.000012	4.33	55.55	
80	100	002	11.7688	0.000006	5.90	119.70	133.91
		103	9.4730	0.000002	2.10	171.00	
		105	10.0986	0.000003	2.19	111.04	

IV. ELECTRICAL CHARACTERIZATION

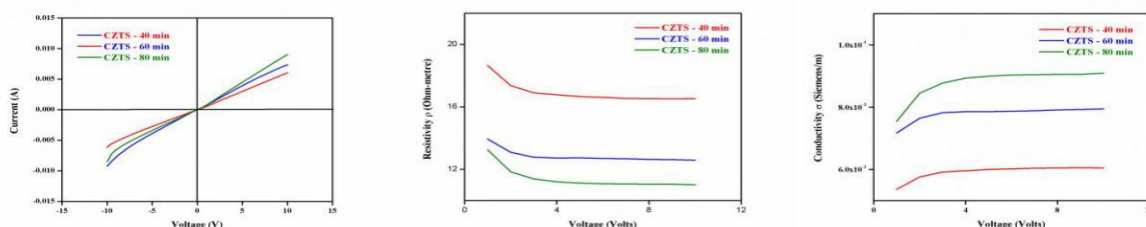


Figure 2(a) Current-Voltage (b) Resistivity – Voltage (c) Conductivity – Voltage plot of CZTS thin film deposited at different time period

Figure 2(a) shows the current – voltage (I-V) characteristic of CZTS thin films examined with I-V Interface set up measured in the dark region. The I-V measurement shows that current is directly proportional to the applied voltage and all the three CZTS thin films exhibits ohmic (Mott-Gurney) contact for dark region [17, 22]. Electrical parameters of CZTS film can be estimated by following relation (Table 2) $\rho = \frac{RA}{L}$ and $\sigma = \frac{1}{\rho}$ Where, ρ is the resistivity of a material (Ohm-metre), R is the resistance of a material (Ohms), A is the cross- sectional area of the deposited material (m^2), L is the length of the film, σ is the electrical conductivity of a material. Figure 2(b) and 2(b) the resistivity decreases with increasing the electrical conductivity of CZTS thin films. The decrease in the resistivity range is due to the improvement in the crystallinity of film and an increase in the film thickness when there is an increase in the film deposition time period [23, 24].

Table 2 Electrical Parameters Of Czts Thin Films For Different Deposition Time Periods

Deposition Time Period (minutes)	Film Thickness (nm)	Applied voltage (V)	Current I (A)	Resistance R (Ohms)	Resistivity \square (Ohmmeter)	Conductivity \square (Siemens/meter)
40	281	1.00E+00	5.36E-04	1.87E+03	1.33E+03	5.36E-02
		2.00E+00	1.15E-03	1.74E+03	1.18E+03	5.76E-02
		3.00E+00	1.78E-03	1.69E+03	1.14E+03	5.92E-02
		4.00E+00	2.38E-03	1.68E+03	1.12E+03	5.96E-02
		5.00E+00	3.61E-03	1.67E+03	1.11E+03	6.00E-02
		6.00E+00	3.61E-03	1.66E+03	1.11E+03	6.02E-02
		7.00E+00	4.23E-03	1.66E+03	1.11E+03	6.04E-02
		8.00E+00	4.84E-03	1.65E+03	1.10E+03	6.05E-02
		9.00E+00	5.45E-03	1.65E+03	1.10E+03	6.05E-02
		1.00E+01	6.05E-03	1.65E+03	1.10E+03	6.05E-02
60	331	1.00E+00	7.18E-04	1.39E+03	1.39E+01	7.17E-02
		2.00E+00	1.53E-03	1.31E+03	1.31E+01	7.65E-02
		3.00E+00	2.35E-03	1.28E+03	1.28E+01	7.82E-02
		4.00E+00	3.14E-03	1.27E+03	1.27E+01	7.86E-02
		5.00E+00	4.69E-03	1.27E+03	1.27E+01	7.86E-02
		6.00E+00	4.69E-03	1.27E+03	1.27E+01	7.87E-02
		7.00E+00	5.41E-03	1.27E+03	1.27E+01	7.89E-02
		8.00E+00	6.10E-03	1.26E+03	1.26E+01	7.91E-02
		9.00E+00	6.75E-03	1.26E+03	1.26E+01	7.92E-02
		1.00E+01	7.35E-03	1.26E+03	1.26E+01	7.94E-02

80	501	1.00E+00	7.55E-04	1.33E+03	1.33E+01	7.17E-02
		2.00E+00	1.69E-03	1.18E+03	1.18E+01	7.65E-02
		3.00E+00	2.64E-03	1.14E+03	1.14E+01	7.82E-02
		4.00E+00	3.58E-03	1.12E+03	1.12E+01	7.86E-02
		5.00E+00	5.42E-03	1.11E+03	1.11E+01	7.86E-02
		6.00E+00	5.42E-03	1.11E+03	1.11E+01	7.87E-02
		7.00E+00	6.33E-03	1.11E+03	1.11E+01	7.89E-02
		8.00E+00	7.25E-03	1.10E+03	1.10E+01	7.91E-02
		9.00E+00	8.15E-03	1.10E+03	1.10E+01	7.92E-02
		1.00E+01	9.02E-03	1.10E+03	1.10E+01	7.94E-02

V. CONCLUSION

Cu₂ZnSnS₄ thin films have been prepared by chemical phase synthesis at different deposition time period. The XRD analysis the result shows that all the films are polycrystalline nature and confirms the formation of CZTS thin films are tetragonal kesterite structure. When increases the film deposition time period, the crystalline size and film thickness are also increases. Current-Voltage characterization studies revealed CZTS thin films exhibits ohmic contact and high electrical conductivity. This CZTS thin film is well suitable for solar cell application.

REFERENCES

- [1] A.I. Inamdar, Seulgi Lee, Ki-Young Jeon, Chong Ha Lee, R.S. Kalubarme, Chan Jin Park, Hyunsik Im, Woong Jung, Hyungsang Kim, Optimized Fabrication of Sputter Deposited Cu₂ZnSnS₄ (CZTS) Thin Films, *Solar Energy*, 91(2013) 196-203.
- [2] Wei Li, Lianbo Zhao, Kailiang Zhang, Heng Sun, Yanqing Lai, Yan Jiang, Liangxing Jiang, Fangyang Liu, Ming Jia, Fabrication of Cu₂ZnSnS₄ Thin Film Solar Cells by Reactively Sputtered Precursor, *Journal of Alloys and Compound*, 8388 (2016) 34214-21.
- [3] Ingrid Repins, Carolyn Beall, Nirav Vora, Clay DeHart, Darius Kuciauskas, Pat Dippo, Bobby To, Jonathan Mann, Co-evaporated Cu₂ZnSnSe₄ Films and Devices, *Solar Energy Materials & Solar Cells*, 101 (2012) 154–159.
- [4] Mostafa Boshta, Simona Binetti, Alessia Le Donne, Mohamed Gomaa, A Chemical Deposition Process for Low-Cost CZTS Solar Cell, *Material Technology*, 120 (2016) 837-841.
- [5] Tanka Raj Rana, N.M. Shinde, Jun Ho Kim, Novel Chemical Route for Chemical Bath Deposition of Cu₂ZnSnS₄ (CZTS) Thin Films with Stacked Precursor Thin Films, *Materials Letters*, 577 (2015) 30613-30623.
- [6] Joel Herve Nkuissi Tchognia, Youssef Arba1, Bouchaib Hartiti, Abderraouf Ridah, Effect of Sulfurization Time on Properties of Cu₂ZnSnS₄ Thin Films Obtained by Sol–Gel Deposited Precursors, *Opt Quant Electron*, 48 (2016) 134-140.
- [7] Suresh Kumar, Bharath Kasubosula, Mihkel Loooris, Jaan Raudoja, Valdek Mikli, Mare Altosaar, Maarja Grossberg, Synthesis of Cu₂ZnSnS₄ Solar Cell Absorber Material by Sol-Gel Method, *Energy Procedia*, 102 (2016) 102 -109.
- [8] C. P. Chan, H. Lam, C. Surya, Preparation of Cu₂ZnSnS₄ Films by Electro Deposition using Ionic Liquids, *Solar Energy Materials*, 94 (2010) 207–221.
- [9] Ferhat Aslan, Abdullah Goktas, Ahmet Tumbul, Influence of pH on Structural, Optical and Electrical Properties of Solution Processed Cu₂ZnSnS₄ thin film absorbers, *Materials Science in Semiconductor Processing*, 43 (2016) 139– 143.
- [10] Yuxiu Sun, Kai Zong, Huijuan Zheng, Hao Wang, Jingbing Liu, Hui Yan, Mankang Zhu, Ethylene Glycol-Based Dip Coating Route For The Synthesis of Cu₂ZnSnS₄ Thin Film, *Materials Letters*, 92 (2013) 195–197.
- [11] S. Islam, M. A. Hossain, H. Kabir, M. Rahaman, M. S. Bashar, Properties of Spin Coated CZTS Thin Films, *International Journal of Thin Film*, 3 (2015) 155-161.
- [12] Jing Wang, Peng Zhang, Xuefeng Song, Lian Cu₂ZnSnS₄ Thin Films by Spin Coating Synthesis and Photoelectron Chemistry, *RSV Adv*, 4 (2014) 21318-21324.
- [13] Xiaoqi Yu, Aobo Ren, Fogen Wang, Jingquan Zhang, Wenwu, Synthesis of CZTS Films by Sol-Gel Method, *International Journal of Photo energy*, 6 (2014) 861249-861256.
- [14] Hao Guan, Hong lie Shen, Chao Gao, Xiancong, Sulfurization Time Effects of Cu₂ZnSnS₄ Films by solution Method, *J Mater Science: Mater Electron*, (2013) 1153-1158.
- [15] V.Robles, C.Guillen, J.F.Trigo, J.Herrero, Cu₂ZnSnS₄ Thin Films Obtained by Sulfurization of Evaporated Cu₂SnS₃ and ZnS Layers-Influence of The Ternary Precursor Features, *Applied Surface Science*, 4332 (2016) 32917-32928.
- [16] Sushmita Chaudhari, P.K. Kannan, Suhash Ranjan Dey, Influence of Stabilizing Agent on Dip Coating of Cu₂ZnSnS₄ Thin Film, *Thin Solid Films*, 636 (2017) 144–149.
- [17] J. Henry, K. Mohanraj, G. Sivakumar, Effect of pH-induced on The Photosensitivity of Nontoxic Cu₂ZnSnS₄ Thin Film by Chemical Bath Deposition, *Optic Internal Journal For Light And Electron Optics*, 4026 (2017) 306112-306123.

- [18] Kunihiro tanaka, Yuki Fukui, Noriko Moritake, Hisao Uchiki, Chemical Composition Dependence of Morphological and Optical Properties of CZTS Thin Films Deposited by Sol-Gel Sulfurization and CZTS Thin Film Solar Cell Efficiency, *Solar Energy Material and Solar Cells*, 95 (2011) 838-842.
- [19] G. Rajesh, N. Muthukumarasamy, E. P. Subramaniam, S. Agilan, Dhayalan Velauthapillai, Synthesis of Cu₂ZnSnS₄ Thin Films by Dip-Coating Method Without Sulphurization, *Journal Sol-Gel Sci Technol*, 66 (2013) 288-292.
- [20] Kazuya Maeda, Kunihiro Tanaka, Yuya Nakano, and Hisao Uchiki, Annealing Temperature Dependence of Properties of Cu₂ZnSnS₄ Thin Films Prepared by Sol-Gel Sulfurization Method, *Japanese Journal of Applied Physics*, 50 (2011) 1-5.
- [21] P.Prabeesh, P.Saritha, I.Packia Selvam, S.N.Potty, Fabrication of CZTS Thin Films by Dip Coating Technique for
- [22] Mukesh Kumar, Ashish Dubey, Nirmal Adhikari, Swaminathan Venkatesan and Qiquan Qiao, Strategic Review of Secondary Phases, Defects and Defect-Complexes in Kesterite CZTS-Se Solar Cells, *Energy & Environmental Science*, 11 (2015) 3134-3159.
- [23] Renuka Digraskar, Swapnali Dhanayat, Ketan Gattu, Sandeep Mahajan, Deepak Upadhye, Anil Ghule, Economic Approach For Fabricating Nontoxic Cu₂ZnSnS₄ (CZTS) Thin Films For Solar Cell Applications, Published by AIP Conf. Proc. 1512 (2013) 236-240
- [24] V. Balasubramanian, V. Chandrasekaran, Influence of Deposition Time and Temperature on Forward Bias Current- Voltage Characterization of Bi₂S₃ Thin Films, *International Journal of Current Research*, 6 (2014) 7822-7825.
- [25] V. Balasubramanian, P. Naresh kumar, D. Sengottaiyan, Effect Of Annealing Temperature on The Current-Voltage and Hall Effect Studies of Bi₂S₃ Thin Films, *Advanced Applied Science Research*, 4 (2015) 190-195.
- [26] Tuan Truong, Man, Kyoo Ho Kim, Synthesis of CZTS Thin Film by Sulfurization Dip coated Precursor, *Journal of Ceramic Processing Research*, 13 (2012) 301-304.
- [27] Lei Qiu, Jiaxiong Xu, Weitong Cai, Zhiwei Xie, Yuanzheng Yang, Fabrication of Cu₂ZnSnS₄ Thin Films by Microwave Assisted Sol-Gel Method, *Super lattices and Microstructures*, 126 (2019) 83-88.
- [28] M. Yamazaki, M. Nakagawa, K. Jimbo, Y. Shimamune, and H. Katagiri, Photoluminescence Study of Cu₂ZnSnS₄
- [29] Satoru seto, Hideaki Araki, "Annealing Behavior of Photoluminescence Spectra on CZTS Single Crystals", *Phys. Status Solidi C*, pp.1600158-1600163 (2017).
- [30] Yusuke Miyamoto, Kunihiro Tanaka, Masatoshi Oonuki, Noriko Moritake, and Hisao Uchiki, Optical Properties of Cu₂ZnSnS₄ Thin Films Prepared by Sol-Gel and Sulfurization Method, *Japanese Journal of Applied Physics*, 47 (2008) 596-597.
- [31] Mukesh Kumar, Ashish Dubey, Nirmal Adhikari, Swaminathan Venkatesan and Qiquan Qiao, Strategic Review of Secondary Phases, Defects and Defect-Complexes in Kesterite CZTS-Se Solar Cells, *Energy & Environmental Science*, 11 (2015) 3134-3159.



10.22214/IJRASET



45.98



IMPACT FACTOR:
7.129



IMPACT FACTOR:
7.429



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Call : 08813907089  (24*7 Support on Whatsapp)