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# Growth and Characterization of $CuInTe_2$ Thin Films: Review

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**Abstract:** Thin films such as copper indium ditelluride could be used as absorber in low cost solar cell technology. In this study, synthesis and characterization of $CuInTe_2$ films will be discussed, analyzed and reported. EDAX spectra show that close to ideal stoichiometric ($CuInTe_2$) compound. XRD data supported that the formation of tetragonal structure. Optical properties reveal that band gap values range from 0.9-1.4 eV.

**Key words:** Copper indium ditelluride, thin films, solar cell, semiconductor, properties

## INTRODUCTION

The sizes of thin films were measured in nano and micron meter. Generally, thin films were deposited onto soda lime glass (Kunihiko *et al*., 2007; Lugo *et al*., 2017; Hossain *et al*., 2017; Olgar *et al*., 2017), indium tin oxide glass (Anuar *et al*., 2010; Ho *et al*., 2013; Anuar *et al*., 2007; Haron *et al*., 2011; Sabah *et al*., 2017), stainless steel (Fatas *et al*., 1987; Cuevas *et al*., 2016; Sun *et al*., 2016; Pujari *et al*., 2016; Dhaygude *et al*., 2017) and microscope glass slide (Ho *et al*., 2012; Shaji *et al*., 2017; Ho, 2014). Now a days, many researchers focus this field (Fajinmi and Adelabu; Zadam; Najamudin) due to thin films were used as optical mass memories, solar cells, hologram recording, solar selecting coatings, sensor devices, laser devices, photo-luminescent and electro-luminescent devices.

Here, the preparation and characterization of $CuInTe_2$ ternary compounds will be discussed. Furthermore, general properties of films such as optical, morphological structural and compositional will be investigated using various tools.

**Literature review:** X-Ray Diffraction technique (XRD) was used in order to study the structure of films. The XRD patterns show that the formation of tetragonal structure as compared to Joint Committee on Powder Diffraction Standards (JCPDS) data. There are numerous deposition methods were used to produce $CuInTe_2$ thin films including vertical Bridgman technique and vacuum evaporation method as reported by Mobarak and Shaban (2014), Roy *et al*. (2003), Ananthan and Kasiviswanathan (2009), Kazmerski and Juang (1998) and Boustani *et al*. (1997). The influence of heat treatment on electro deposited $CuInTe_2$ films was studied by Manorama *et al*. (2016). They found that amorphous structure in as-deposited films. However, the intensities of peaks and average crystallite sizes were increased for the films treated (80°C) under 5, 30 and 60 min, respectively as shown in XRD patterns. Lakhe and Chaure (2014) have reported the influence of deposition potential on the films. Deposition was carried out in the presence of reference electrode, working electrode and counter electrode. The films prepared at various deposition potentials such as 600, -650, -700 and 750 mV versus Ag/AgCl show amorphous structure. However, $CuInTe_2$ peaks such as (112), (220)/(204), (312)/(116) could be seen in annealed films (400°C for 1520 min). Dixit *et al*. (2013) have investigated the influence of stirring process on films. The obtained XRD data show that better crystallization for the films prepared under stirring conditions. Also, these films are more oriented in (112) direction if compared to those prepared under without stirring conditions.

## MATERIALS AND METHODS

The influence of temperature (200-260°C for at least 6 h) on $CuInTe_2$ films was studied by Kim *et al*. (2012). They choose solvothermal deposition technique due to minimal investment and simple method. The films indicate big lumps at temperature of 200°C according to SEM analysis. However, the average grain sizes were increased (from 500 nm to 2 μm) as the temperature was increased from 220-260°C. Chemical spray pyrolysis technique was used to prepare $CuInTe_2$ films as proposed by Tembhurkar (2016). The morphology of films was studied using Scanning Electron Micros copy (SEM). The larger grain could be seen in annealed films if compared to as deposited films. Also, SEM analysis indicate that good compound formation. Prabukanthan *et al*. (2007) have prepared $CuInTe_2$ thin films using chemical vapor transport method in the presence of iodine (as the transporting agent). The surface roughness values were measured using Atomic

Force Microscopy (AFM) technique. These values are 9.3 nm (as-deposited films) and 61.2 nm (films irradiated with a fluence of $1\times10^{13}$ ions/cm$^2$), respectively.

Transmission electron microscope technique has been used in order to study the morphology of films. The effect of laser fluence and the speed of the laser scan on the films was investigated by Galindo *et al.* (1989). Overall results reflect that obtained films are homogeneous and do not contain any secondary phases. Zedan and El-Menyawy (2016) have prepared $CuInTe_2$ films using flash evaporation technique. They conclude that illuminated films show better crystallinity conditions and larger sizes if compared to as-deposited films. Also, as- deposited films show the presence of small particles with well distribution of grains on the surface of substrate.

## RESULTS AND DISCUSSION

Energy dispersive X-ray analysis could be employed to determine the composition of thin films prepared under various deposition methods. For example, films with stoichiometry close to 1:1:2 of $CuInTe_2$ have been successfully grown by using chemical vapor transport method as reported by Prabukanthan and Dhanasekaran (2008). On the other hand, the films prepared using electro deposition method show close to ideal stoichiometry as suggested by Lakhe and Chaure (2014) and Patil *et al.* (2012).

Lower efficiency (if compared to silicon based solar cell), rare elements (tellurium) and toxicity (tellurium) are some examples of disadvantage of $CuInTe_2$ films. However, researchers have found that tellurium could be used to replace selenium due to it has high vapor pressure.

Generally, copper indium ditelluride could be categorized in family $A^{I}$-$B^{III}$-$C^{VI}$ as suggested by Murali *et al.* (2012). There are many literature reviews and research papers have point out the use of $CuInTe_2$ films in solar cell applications (Nadenau *et al.*, 1995; Zhang *et al.*, 2013; Orts *et al.*, 2007; Arun *et al.*, 2005; Ali *et al.*, 2017; Assali *et al.*, 1999; Takahiro and Tokio, 2011). Because of many reasons such as band gap values are in the range of 0.9-1.4 eV (Muftah *et al.*, 2010; Chandran *et al.*, 2012; Rai *et al.*, 2017; Sugan *et al.*, 2014; Wasim *et al.*, 1984; Sridevi and Reddy, 1986; Mise and Nakada, 2010; Roy *et al.*, 2002; Ishizaki *et al.*, 2004), higher open circuit voltages, better temperature coefficients, higher absorption coefficient ($10^5$ cm$^{-1}$) and p-type polycrystalline (Lacruz *et al.*, 1984; Soud *et al.*, 1993; Masoud, 2015; Fitzgerald and Potrous, 1989).

## CONCLUSION

In this research, there are several deposition methods such as electrodeposition, solvothermal method, vacuum evaporation method and chemical spray pyrolysis method were used in order to prepare $CuInTe_2$ thin films. The experimental results show that tetragonal structure based on XRD data. These films display p-type electrical conductivity and the band gap values in the range of 0.9-1.4 eV.

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## REFERENCES

Ali, A., M. Mehdi and B. Farshad, 2017. Facile hydrothermal synthesis of $CuInTe_2$ quantum dots using reseda as a green capping agent for increasing the efficiency of dye sensitized solar cells. J. Mater. Sci. Mater. Electron., 28: 6366-6372.

Ananthan, M.R. and S. Kasiviswanathan, 2009. Growth and characterization of stepwise flash evaporated $CuInTe_2$ thin films. Sol. Energy Mater. Sol. Cells, 93: 188-192.

Anuar, K., T.W. Tee, A.H. Abdullah, N. Saravanan and H.S. Min, 2010. Deposition and characterization of Cu4SnS4 thin films by chemical bath deposition method. Macedonian J. Chem. Chem. Eng., 29: 97-103.

Anuar, K., W.T. Tan, M.S. Atan, K. Dzulkefly, S.M. Ho, H.M. Jelas and N. Saravanan, 2007. Cyclic voltammetry study of copper tin sulfide compounds. Pac. J. Sci. Technol., 8: 252-260.

Arun, V., T. Du and B.S. Kalpathy, 2005. Characterization of Copper Indium ditelluride/electrolyte interface utilizing electrochemical impedance spectroscopy. Appl. Surf. Sci., 242: 168-176.

Assali, K.E., M. Boustani, T. Bekkay, A. Khiara and A. Outzourhit *et al.*, 1999. Initial results of $CdS/CuInTe_2$ heterojunction formed by flash evaporation. Sol. Energy Mater. Sol. Cells, 59: 349-353.

Boustani, M., K.E. Assali, T. Bekkay and A. Khiara, 1997. Structural and optical properties of $CuInTe_2$ films prepared by thermal vacuum evaporation from a single source. Sol. Energy Mater. Sol. Cells, 45: 369-376.

Chandran, V., S. Srinivas and K.R. Murali, 2012. Pulse electrodeposited $CuInTe_2$ films. ECS. Trans., 41: 93-98.

Cuevas, A., R. Romero, E.A. Dalchiele, J.R. Ramos and F. Martin *et al*., 2016. Spectrally selective CuS solar absorber coatings on stainless steel and Aluminium. Surf. Interface Anal., 48: 649-653.

Dhaygude, H.D., P.P. Chikode, S.K. Shinde, N.S. Shinde and V.J. Fulari, 2017. Evaluation of the holographic parameters by electrosynthesized CdxZn1-xS(X=0.3) thin films using double exposure digital holographic interferometry technique. Opt. Laser Technol., 88: 194-197.

Dixit, P., D. Kavita, K.S. Ashok, T. Vikas and R. Poolla, 2013. Electrochemical growth and studies of indium rich $CuInTe_2$ thin films. Intl. J. Mater. Sci. Appl., 3: 1-5.

Fatas, E., P. Herrasti, J.A. Medina and F. Arjona, 1987. Electrodeposition and characterization of CdS thin films on stainless steel and tin oxide substrates. Electrochim. Acta, 32: 139-148.

Fitzgerald, A.G. and S.M. Potrous, 1989. A micro beam analysis study of some heterojunctions formed with $CuInTe_2$. Sol. Energy Mater., 19: 141-155.

Galindo, H., F. Hanus, M.C. Joliet, A.B. Vincent and L.D. Laude, 1989. Laser induced synthesis of $CuInTe_2$. Proceedings of the International Conference on Optical Science and Engineering, April 16-19, 1989, SPIE, Bellingham, Washington, pp: 77-80.

Ho, S.M., 2014. Atomic force microscopy investigation of the surface morphology of Ni3Pb2S2 thin films. Eur. J. Scient. Res., 125: 475-480.

Ho, S.M., K. Anuar and W.T. Tan, 2013. Thickness dependent characteristics of chemically deposited tin sulphide films. Universal J. Chem., 1: 170-174.

Ho, S.M., N. Saravanan, K. Anuar and W.T. Tan, 2012. Temperature dependent surface topography analysis of SnSe thin films using atomic force microscopy. Asian J. Res. Chem., 5: 291-294.

Hossain, M.S., H. Kabir, M.M. Rahman, K. Hasan and M.S. Bashar *et al*., 2017. Understanding the shrinkage of optical absorption edges of nanostructured Cd-Zn sulphide films for photothermal applications. Applied Surface Sci., 392: 854-862.

Ishizaki, T., N. Saito and A. Fuwa, 2004. Electrodeposition of $CuInTe_2$ film from an acidic solution. Surf. Coat. Technol., 182: 156-160.

Kazmerski, L.L. and Y.J. Juang, 1998. Vacuum deposited $CuInTe_2$ thin films: Growth, structural and electrical properties. J. Vac. Sci. Technol., 14: 769-776.

Kim, C., D.H. Kim, Y.S. Son, H. Kim, J.Y. Bae and Y.S. Han, 2012. Solvothermal synthesis and characterization of a $CuInTe_2$ absorber for thin-film photovoltaics. Mater. Res. Bull., 47: 4054-4058.

Kunihiko, T., M. Noriko and U. Hisao, 2007. Preparation of Cu2ZnSnS4 thin films by sulfurizing sol gel deposited precursors. Sol. Energy Mater. Sol. Cells, 91: 1199-1201.

Lacruz, A., C. Rincon, G. Perez and S.M. Wasim, 1984. Electrical and optical properties of $CuInTe_2$ grown from near stoichiometric compositions. Prog. Cryst. Growth Charact., 10: 283-287.

Lakhe, M. and N.B. Chaure, 2014. Characterization of electrochemically deposited $CuInTe_2$ thin films for solar cell applications. Sol. Energy Mater. Sol. Cells, 123: 122-129.

Lugo, S., Y. Sanchez, M. Espindola, F. Oliva and V. Roca *et al*., 2017. Cationic compositional optimization of CuIn(S1-ySey)2 ultra-thin layers obtained by chemical bath deposition. Appl. Surf. Sci., 404: 57-62.

Manorama, L., S.K. Mahapatra and N.B. Chaure, 2016. Development of $CuInTe_2$ thin film solar cells by electrochemical route with low temperature (80°C) heat treatment procedure. Mater. Sci. Eng. B., 204: 20-26.

Masoud, D., 2015. Effect of negative and positive field on p-type $CuInTe_2$ films having excess Copper and Indium. Intl. J. Adv. Comput. Technol., 4: 143-146.

Mise, T. and T. Nakada, 2010. Low temperature growth and properties of Cu-In-Te based thin films for narrow bandgap solar cells. Thin Solid Films, 518: 5604-5609.

Mobarak, M. and H.T. Shaban, 2014. Characterization of $CuInTe_2$ crystals. Mater. Chem. Phys., 147: 439-442.

Muftah, G.E.A., A.P. Samantilleke, P.D. Warren, S.N. Heavens and I.M. Dharmadasa, 2010. Electrochemical deposition of $CuInTe_2$ layers for applications in thin film solar cells. J. Mater. Sci. Mater. Electron., 21: 373-379.

Murali, K.R., C. Vinothini and K. Srinivasan, 2012. Characteristics of pulse plated Copper Indium telluride films. Mater. Sci. Semicond. Process., 15: 194-198.

Nadenau, V., T. Walter and H.W. Schock, 1995. Growth of $CuInTe_2$ polycrystalline thin films. J. Cryst. Growth, 146: 251-255.

Olgar, M.A., B.M. Basol, Y. Atasoy, M. Tomakin and G. Aygun *et al*., 2017. Effect of heat treating metallic constituents on the properties of $Cu_2ZnSnSe_4$ thin films formed by a two-stage process. Thin Solid Films, 624: 167-174.

Orts, J.L., R. Diaz, P. Herrasti, F. Rueda and E. Fatas, 2007. $CuInTe_2$ and In-rich telluride chalcopyrites thin films obtained by electrodeposition techniques. Sol. Energy Mater. Sol. Cells, 91: 621-628.

Patil, N.A., M. Lakhe and N.B. Chaure, 2012. Characterization of $CuInTe_2$ Thin Films Deposited by Electrochemical Technique. In: AIP Conference Proceedings, Mittal, R., A.K. Chauhan and R. Mukhopadhyay (Eds.). AIP, College Park, Maryland, pp: 1073-1074.

Prabukanthan, P. and R. Dhanasekaran, 2008. Growth of $CuInTe_2$ single crystals by iodine transport and their characterization. Mater. Res. Bull., 43: 1996-2004.

Prabukanthan, P., K. Asokan, D.K. Avasthi and R. Dhanasekaran, 2007. Effect of 80 MeV Au8+ ions irradiation on $CuInTe_2$ single crystals grown by CVT technique. Mater. Sci. Semicond. Process., 10: 252-257.

Pujari, R.B., A.C. Lokhande, J.H. Kim and C.D. Lokhande, 2016. Bath temperature controlled phase stability of hierarchical nanoflakes CoS2 thin films for supercapacitor application. RSC. Adv., 6: 40593-40601.

Rai, D.P., A. Shankar, P.S. Anup and T.P. Sinha, 2017. Electronic, optical and thermoelectric properties of bulk and surface (001) $CuInTe_2$: A first principles study. J. Alloys Compd., 699: 1003-1011.

Roy, S., B. Bhattacharjee, S.N. Kundu, S. Chaudhuri and A.K. Pal, 2003. Characterization of $CuInTe_2$ thin film synthesized by three source co-evaporation technique. Mater. Chem. Phys., 77: 365-376.

Roy, S., P. Guha, S. Chaudhuri and A. Pal, 2002. $CuInTe_2$ thin films synthesized by graphite box annealing of In/Cu/Te stacked elemental layers. Vac., 65: 27-38.

Sabah, F.A., N.M. Ahmed and Z. Hassan, 2017. Effects of concentration and substrate type on structure and conductivity of p-type CuS thin films grown by spray pyrolysis deposition. J. Electron. Mater., 46: 218-225.

Shaji, S., L.V. Garcia, S.L. Loredo, B. Krishnan and J.A. Martinez *et al*., 2017. Antimony sulfide thin films prepared by laser assisted chemical bath deposition. Appl. Surf. Sci., 393: 369-376.

Soud, A.M., H.A. Zayed and L.I. Soliman, 1993. Transport properties of CuInS2, CuInSe2 and $CuInTe_2$ thin films. Thin Solid Films, 229: 232-236.

Sridevi, D. and K.V. Reddy, 1986. Electrical conductivity and optical absorption in flash evaporated $CuInTe_2$ thin films. Thin Solid Films, 141: 157-164.

Sugan, S., K. Baskar and R. Dhanasekaran, 2014. Hydrothermal synthesis of chalcopyrite $CuInS_2$, $CuInSe_2$ and $CuInTe_2$ nanocubes and their characterization. Curr. Appl. Phys., 14: 1416-1420.

Sun, K., F. Liu, C. Yan, F. Zhou and J. Huang *et al*., 2016. Influence of sodium incorporation on kesterite Cu2ZnSnS4 solar cells fabricated on stainless steel substrates. Sol. Energy Mater. Sol. Cells, 157: 565-571.

Takahiro, M. and N. Tokio, 2011. Effect of tellurium deposition rate on the properties of Cu-In-Te based thin films and solar cells. J. Cryst. Growth, 314: 76-80.

Tembhurkar, Y.D., 2016. Annealing effect on structural and electrical properties of $CuInTe_2$ thin films. Intl. J. Sci. Res., 5: 504-506.

Wasim, S.M., A.L. Vielma and C. Rincon, 1984. Optical absorption study of $CuInTe_2$ crystals grown from near stoichiometric compositions. Solid State Commun., 51: 935-937.

Zedan, I.T. and E.M.E. Menyawy, 2016. Illumination induced changes on the optical functions and valence band splitting parameters of flash evaporated $CuInTe_2$ films. Opt. Intl. J. Light Electron Opt., 127: 1301-1306.

Zhang, X., K. Shen, Z. Jiao and X. Huang, 2013. A study of the electronic structures and optical properties of $CuXTe_2$ (x=Al, ga, In) ternary semiconductors. Comput. Theor. Chem., 1010: 67-72.