# Influence of addition (Mn) on enhance efficiency of ($CuInTe_2$) photovoltaic cell

Mohammed Hamid[1], Suha. A. Fadaam[2] , Laheeb. A . Mohammed[3] , Bushra H. Hussein[4]

[1,3,4]Dept. of physics/ College of Education For Pure Science (Ibn Al-Haitham) / University of Baghdad
[2] Ministry of Education, Directorate General for Education ,Baghdad AL-Rusafa, Baghdad , Iraq

**Article info**

*Received:*
4 September 2018

*Received in revised form:*
20 October 2018

*Accepted:*
20 October 2018

## Abstract

The optical , crystal structure and electrical properties has been studied for thin film ($CuInTe_2$) , where equipped by thermal evaporation and study influence of doped Mn on this properties . The Characteristics the crystalline structure of all thin films at room temperature was the random composition . But when adding Mn as an impurity element show that polycrystalline composition for this thin films towards to (112) . Measured energy gap from optical properties has been increased by adding Mn in thin films. The test efficiency of solar cell using solar simulator with 1.5 AM , (1000 mW cm) for all thin films prepared , where was the cell factors gained from I-V characteristics are $V_{oc}$ , $I_{sc}$ , FF and η for cell..

## 1. Introduction

The ternary compound material $CuInTe_2$, it has distinguish characteristic as chalcopyrite I-III-$VI_2$ compound [1]. The material I-III-$VI_2$ studied extensively because it is very important for potential application in solar cell [2-5] . The ZnO/CdS/$CuInSe_2$ thin film with polycrystalline structure and have great solar energy efficiency over than 14% [6] .

Can be configured compounds for example $CuInX_2$ (X=Te ,Se,S), when deposit $CuInTe_2$ it found the conductivity in both p- and n- type [7-9] . $CuInTe_2$ have a high absorption value reach to $\alpha = (10^4 - 10^5)\, cm^{-1}$ , and have a direction band gap between (0.92-1.02) eV which falls in the optimum extent for conversion of solar cell [10]. The band gap $CuInTe_2$ can be adjusted might by substitution of the trilogy material such as Mn for In atom. Add Mn impurities have impact on stability structure of material ,a disordered defect-related zinc-blende phase with a structural formula of $Cu_{2(1-z)}Mn_zIn_2Te_4$ is found in $MnIn_2Te_4$ – $CuInTe_2$ diagram however, by eutectoid reaction they can be separated into two tetragonal phases of CuInTe2 and MnIn2Te4 [11]. In this study CuIn(1-0.05)Mn(0.05)Te2 has been planned with their structural and optical properties been systemically studied in order to develop the efficiency solar cell properties of Cu In Te2 semiconductors.

*Corresponding author. E-mail: athanasios.papathanasiou@nu.edu.kz


### Experimental Procedure

The powder $CuInTe_2$ used in the investigates were prepared by mix-up the elements constituent from copper , Indium and tellurium in percentages weigh of fixed.

The mixture is placed in tube of quartz that empty it from air , and put the tube in oven in a horizontal position at a temperature of 900 °C , the maintain at the temperature for mixture a interval 24 h after that cooled to room temperature( RT) . The prepared of thin films by evaporation vacuum for powder $CuInTe_2$ under vacuum $10^{-5}$ Torr onto glass and silicon substrate .The thickness of thin films $CuInTe_2$ was measured by interference microscope , through this were thickness of the films was (450±10) nm .

### Results and discussion

The figure (1) displays X-Ray diffraction $CuInTe_2$ thin films without adding , where shows that all films have amorphous structure , because the procuress of deposition at room temperature on the substrates, this process of deposition relatively cold to the temperature of materials ($CuInTe_2$) , as if process of rapid cooling , which earn the films this random structure . The X-ray diffraction-XRD show in figure (2) for $CuInTe_2$ thin films with adding 5% Mn . where the shape shows that the films possess a polycrystalline structure with two peaks referred to toward (112) and (220) .

The image of AFM used to study of surface topography and as well as give us statistical information on the grain size and surface roughness of the prepared films . The figure (3) shows the image of AFM for

$CuInTe_2$ (pure or without adding) and $CuInTe_2$ ( impurity by 5%Mn or adding 5% Mn ) ,

Where observe from of the shape all the films possess a homogenous structure and there are no any empty location in the crystalline structure of all films the prepared .

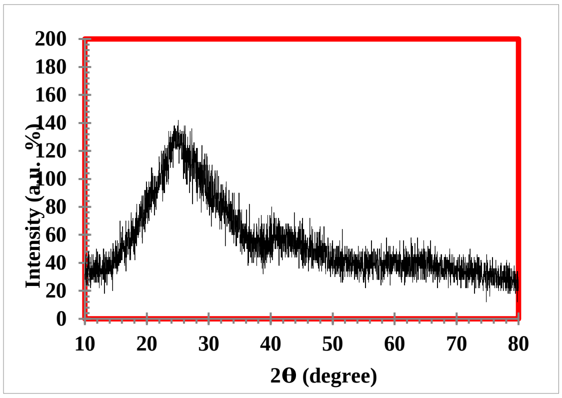


**Fig (1) . X-ray diffraction for $CuInTe_2$ thin films**

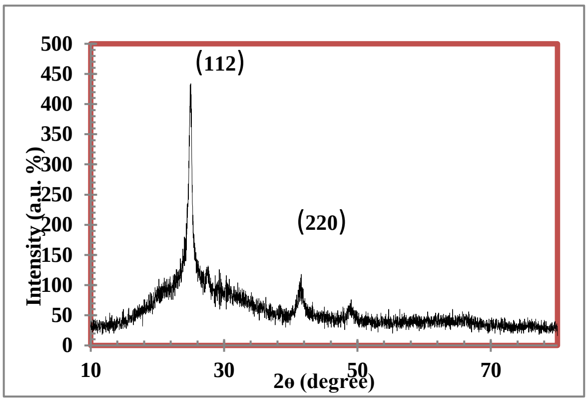


**Fig (2) . X-ray diffraction $CuInTe_2$ by adding 5%Mn**

The table (1) shows grain size , root mean square and roughness for all films prepared , and shows there correspond between result AFM and XRD relative to the increase in gain size and surface regularity (transition from random to polycrystalline ).

**Table (1) : Grain size , Root mean square and Roughness for all thin films**

| Sample | Grain size (nm) | Root mean square (nm) | Roughness (nm) |
|---|---|---|---|
| **$CuInTe_2$ (pure)** | **93.07** | **1.74** | **0.04** |
| **$CuInTe_2$ (5%Mn)** | **91.63** | **3.20** | **0.06** |

The optical properties of the $CuInTe_2$ thin films was measured by UV-1800 spectrophotometer in the rang 300-1100 nm . The figure (4) shows the transmission as function for wavelength. Figure shows there is increase in transmission with increasing wavelength (the high values of permeability in the infrared region) ie (the possibility of using these films as a window in the electromagnetic spectrum ). And shows figure also shows low in transmission at short wavelengths (visible region) , this is appropriate in solar cell application.

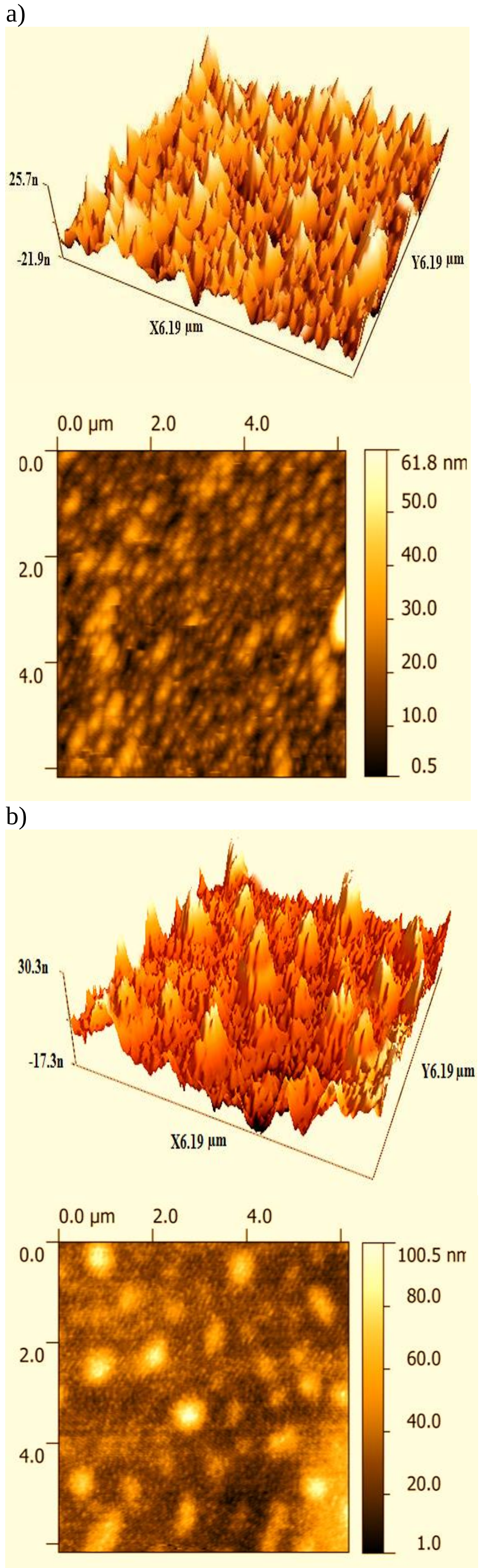


**Fig (3) : 3D and 2D AFM of thin films (a) $CuInTe_2$ pure (b) $CuInTe_2$ (5%Mn)**

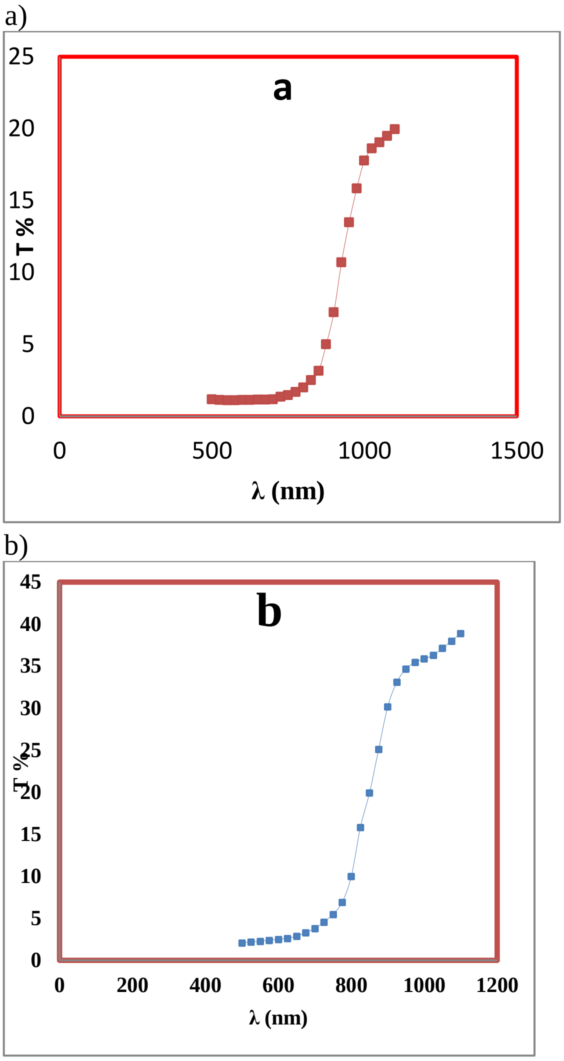


Fig (4) The transmission of thin films (a) CuInTe$_2$ pure (b) CuInTe$_2$ (5%Mn) as a function of wave length

Absorption coefficient determined, by thickness (t) that given through equation [12] .

$$\alpha=2.303 ((A)/t) \quad (1)$$

Where the (α) is a significant to the ability of materials absorption of light , and which is a function for photon energy and energy gap .[13]

The energy gab ( $E_g$) can be calculate from equation [14]

$$\alpha h\nu = B\left(h\nu - E_g\right)^n \quad (2)$$

Where ( α is absorption coefficient ) ,( B is constants) , ( n is constant take value (2 , 3, 2/3 ,3/2 ) depending on the transition type . The plot of $(\alpha h\upsilon)^2$ versus photon energy shows in Figure (5),

The energy gap specify through of stability of line on axis (Y=photon energy )a t (αhυ=0) .Influence addition (Mn) on (CuInTe$_2$) cause increase in energy gap from(1.1) eV for CuInTe$_2$ to (1.45)eV for CuIn$_{(1-0.05)}$Mn$_{(0.05)}$Te$_2$. This increase is due to the improved influence the stretching force in Te (In ,Mn) bound. This study is an important candidate to study the photovoltaic cell because it has a matches of solar cell spectra [15,16] .

The measurement of (I-V) for photovoltaic solar cell by utilization of equation [17]

$$I = I_s\left(\exp\left(\frac{qV}{\beta K_B T}\right) - 1\right) - I_L \quad (3)$$

$$\eta = \frac{P_m}{P_{in}} \times 100\% = \frac{I_m V_m}{P_{in}} \times 100\% \quad (4)$$

$$F.F = \frac{J_m V_m}{J_{sc} V_{oc}} \quad (5)$$

Where $\eta$ is (efficiencies of solar cell ) , F.F is (Fill factor ) .

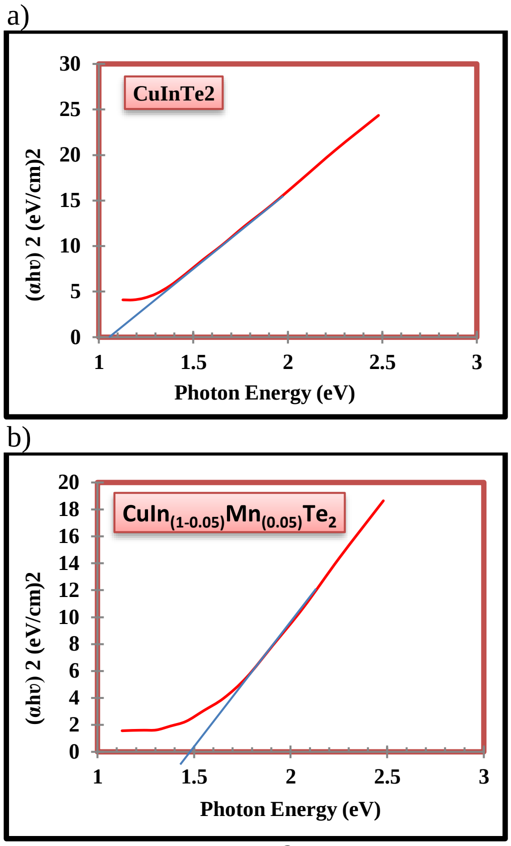


Fig (5). Plot of $(\alpha h\upsilon)^2$ as a function photon energy for thin films CuInTe$_2$ pure and CuInTe$_2$ (5%Mn)

Figure (6) shows characteristics of (I-V) for CuInTe$_2$ / Si and CuIn$_{(1-0.05)}$Mn$_{(0.05)}$Te$_2$ , where the figure shows an increase the value $V_{oc}$ , Thus increasing of value of solar cell efficiency with addition of Mn for CuInTe$_2$ this is consistent with surface roughness of with result Atomic force Microscope AFM .

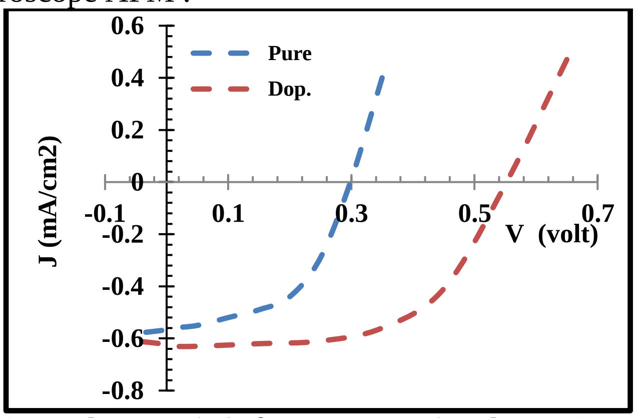


Fig (6) I-V characteristic for CuInTe / Si and CuIn(1-0.05)Mn(0.05)Te2 Solar cell under illumination

**Table (2) Voc, Jsc, Vmax , Jmax , F.F and η CuInTe / Si and CuIn(1-0.05)Mn(0.05)Te2 Solar cell under illumination**

| sample | $V_{oc}$ (Volt) | $J_{sc}$ ($mA/cm^2$) | $V_{max}$ (Volt) | $J_{max}$ ($mA/cm^2$) | F.F | η % |
|---|---|---|---|---|---|---|
| $CuInTe_2$ | 0.56 | 3 | 0.25 | 2.9 | 0.431 | 0.72 |
| CuIn (1-0.05)Mn (0.05)Te2 | 0.63 | 5.5 | 0.45 | 4.1 | 0.53 | 1.8 |

**Conclusion**

We conclude from this study can be deposition the thin film of ($CuInTe_2$) by vacuum evaporation, the addition of ( Mn ) as impurities , where the crystalline structure transformed from random to polycrystalline to orientation (112) when addition (Mn) **.** The optical properties showed that energy gap is suitable for solar sell application. The solar cell efficiency results showed when addition of (Mn) for $CuInTe_2$, there is increases in value of efficiency to (1.8%).

(1-5).

## References

[1] Shay. J.L and Werni ck J.H." Ternary Chalcopyrite Semiconductors, Growth, Electronic Properties and Applications"(New York: Pergamon), (1975).
[2] Mass.e G and Djessas K 1993 Phys. Status Solidi a 139 K45
[3] Rockett A, Abou-Elfotouh F, Albin D, Bode M, Ermer J, Klenk R, Lommasson T, RussellTWF, Tomlinson R D, Stolt J, Walter T and Peterson T M 1994 Thin Solid Films 237 1–11
[4] Tuttle J R, Contreras M A, Gillespie T J, Ramanathan K R, Tennant A L, Keane J, Gabor A M and Noufi R 1995 Prog. Photovolt. 3 235–8
[5] Tuttle J R, Contreras M A, Gabor A M, Ramanathan K R, Tennant A L, Albin D S, Keane J and Noufi R 1995 Prog. Photovolt. 3 383–91
[6] Mitchell K W, Eberspacher C, Ermer J H, PaulsKL and Pier D N 1990 IEEE. Trans. Electron. Devices 37 410
[7] Tell B, Shay J L and Kasper H M 1972 J. Appl. Phys. 43 2469
[8] Wasim S M and Albornoz J G 1988 Phys. Status Solidi a 110 575
[9] Chahboun N, El Assali K, Khiara A, AmezianeELand Bekkay T 1994 Solar Energy Mater. Solar Cells 32 213
[10] M. Lakhe, N. B. Chaure, "Characterization of electrochemically deposited CuInTe thin films for solar cell applications", Solar Energy Materials & Solar Cells, 123, 2014, 122–129. (doi.org/10.1016/j.solmat.2014.01.008)
[11] A. Rivero, M. Ouintero, M. Morocoima, and J. C. Woolley,J. Alloy & Compd. 224, 93–96 (1995).
[12] K. Yamada, N. Hoshino, T. Nakada, (2006)," Crystallographic and electrical properties of wide gap Ag(In1-x,Gax)Se2 thin films and solar cells", Science and Technology of Advanced Materials 7, 42–45.
[13] D. A.Neamen, (2003), semiconductors physics and Devices, Third edition , copyright©, McGraw Hill Compnies , Inc
[14] J.W. Lekse, A.M. Pischera, J.A. Aitken, (2007), Understanding solid-state microwave synthesis using the diamond-like semiconductor, AgInSe2, as a case stud, Mater. Res. Bull. 42.PP 395-403.
[15] Yongquan Guo, Shuai Li, Tai Wang, and Nana Xie , " Structure and magnetic properties of CuIn1-xTxTe2(T=Co,Mn)", AIP Advances 7, 085203; 10.1063/1.4991423, (2017).
[16] A. S. Meshram, Y. D.Tembhurkar and O. P.Chimankar ," Structural, Optical and electrical Properties of CuInTe2 Thin Films Prepared by Spray Pyrolysis",International Journal of Advance Research in Science and Engineering , Vol,No6,Issue No.09, (2017).
[17] B.D.Cullity, (1978), elements of X-Ray diffraction, 2nd edition, copyright © by Addison – Wesley Publishing company, Inc