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Fabrication And Characterization Of $Mg_xZn_{1-x}O$/Si Solar Cell By Using Chemical Spray Pyrolysis Method

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***Abstract*—In this work, $Mg_{0.05}Zn_{0.95}O$/Si heterojunction thin film solar cell has been fabricated by using chemical spray pyrolysis. The $Mg_{0.05}Zn_{0.95}O$ thin film was deposited on glass substrate at 350ºC to study the optical, structural and topographical properties were investigated. X-Ray diffraction (XRD) measurements relieve that the ($Mg_{0.05}Zn_{0.95}O$) thin film has polycrystalline, hexagonal structure. Output parameter of solar cell reveal that the efficiency of ($Mg_{0.05}Zn_{0.95}O$/Si) solar cell is (η=52%).**

***Keywords*—ZnO, chemical spray , Refractive index, photovoltaic field, Absorption Constant**

1-Introduction

Zinc Oxide ZnO- based alloys (including MgZnO, CdZnO, MnZnO) are promising semiconducting materials, therefore the attention in ZnO and ZnO-based alloys have been increased and become very wide in research fields[1,2]. ZnO is a wide band gap semiconductor, belongs to II-VI semiconductor group. It crystallizes in two main forms, hexagonal wurtzite and cubic zinc blende, and crystallizes in the cubic rocket salt structure under high pressure about 10 GPa. The lattice parameters of ZnO are a = 3.249Å and c = 5.206 Å, and the ratio of lattice parameter c/a is 1.602 which is slightly less than the value of 1.633 for an ideal (hcp) structure. ZnO has direct bandgap energy of 3.2 eV and 3.3eV at room temperature; this value of band gap is the reason of colorless of ZnO and it's transparent which is ranging between T=65%-85% in the range of λ= 400-800nm. There is also an abrupt edge at λ=380nm from the absorption spectrum. ZnO has a large exciton binding energy (~60meV) at room temperature[3,4]. It has been demonstrated that the band gap of $Mg_xZn_{1-x}O$ increases from 3.3eV to 3.99 when Mg concentration is increased to X=0.33. Theoretically the band gap energy of MgZnO films is tunable from 3.3 eV to 7.8eV by artificially controlling Mg content in the alloy[5]. Due to good promise application in photovoltaic field , this is an attempt to fabricate $Mg_xZn_{1-x}O$/Si(111) solar cell by chemical spray pyrolysis method . Many of researchers tried to use ZnO alloys to fabricate photovoltaic device ; Z. Duan in 2012 had been deposited $Mg_xZn_{1-x}O$ on FTO substrate by (MOCVD) method to fabricate solar cell with efficiency (η=0.71%)[3]. In 2010, S. Yodyingyong and others tried to benefit from ZnO nanowires (NW) and ZnO nanoparticles (NP) hybrid photoanodes for dye- sensitized solar cell, the results showed that ZnO (NW) recorded (η=0.94-1.58)%[6].

2-Theoretical principle

1-2 Absorption Coefficient (α) : This constant depends on the energy of incident photon (hν) and the properties of semiconductor (including the energy band gap and the type of electronic transitions). The value of this constant refers to the ability of film's material to absorb the energy of incident radiation beam, this value can be calculated by using the equation below[7].

$$\alpha = 2.303\frac{A}{t} \dots\dots\dots\dots\dots\dots\dots\dots 1$$

α: absorption coefficient

A: the absorbance,

t: thickness of thin film

2-2Refractive index (n_o):

Refractive index is the ratio between speed of light in the space to its speed in the medium. It's calculated by the equation below[8].

$$n_o = \left[\frac{4R}{(1-R)^2} - K^2\right]^{1/2} - \left[\frac{1+R}{1-R}\right] \dots\dots (2)$$

n_o :refractive index, R: reflectance of film, K: extinction coefficient The behavior of refractive index depends on the various preparing conditions and on the preparing method, its value depends on the material type, the crystalline structure, and the roughness of film's surface.

2-3 Extinction Coefficient (k_o):

Extinction coefficient refers to the quantity of absorbed energy of the film, in other word it is the quantity of absorbed incident photon energy by the electrons of the film material. That means it enacts the exhibit attenuation in electromagnetic wave inside the matter. Extinction coefficient calculated by equation below[9].

$$k_o = \frac{\alpha\lambda}{4\pi} \dots\dots (3)$$

k_o: extinction coefficient, α: absorption coefficient, λ: wavelength

3- Experimental procedure

3 – 1 <u>Preparation Of Solution</u>

Many steps took part in the process of fabricating the nanostructured $Mg_xZn_{1-x}O$ thin film, as below:

0.6585 gm of Zinc acetate dehydrate $Zn(CH_3COO)_2 \cdot 2H_2O$ supported by (Sinopharm chemical reagent company, Shanghi, China. With purity %99.99) was weighted by an electrical balance (supported by Radwag company, Poland, model AS 220/C/2) and dissolved in 100 ml of deionised water to get a molarity of (0.03 M). This solution putted on a magnetic starrier for 15 min. In the same way, 0.6421 mg of magnesium acetate tetra hydrate (supported by BDH chemical Ltd poole, England. With assay 98 to 102 percent) dissolved in 100 ml of deionised water and put on the magnetic starrier to obtain a clear solution. Then the two solutions were mixed with desired Mg concentration (x = 0.05) and the resultant solution kept in flask until the using time.

<u>3-2preparation of substrates</u>

The glass substrates should be cleaned carefully and perfectly before the employment, first they had washed by washing powder for a minute and then cleaned by water flow till remove all washing powder, second they put in flask fill with ethanol and put them in ultrasonic cleaner (supported by MCU company, China , model 3560) for 10 minutes and the power selected was 30 watts. After that the glass slides were taken to another flask filled with de ionic water and pick up them for drying, then they were kept for using in spray pyrolysis system. . And the silicon substrates have to cleaned carefully by using flask filled with suitable quantity of acetone, then they had put in the ultrasonic cleaner for 10 minutes, then they had picked up and dried by clean and soft weft

3-3 The spraying process

By running the Chemical spray coating equipment which supported by (Holmarc, HO-TH-04, India), this process took place in 10 minutes; with 2 minute duration for each spry process, the parameters of flux rate, pressure, substrate heat degree, distance between nozzle and substrate, speed of nozzle, and the area of nozzle movement as in table (1).

Table(1): the preparation conditions of spraying

Parameter	Alue
Substrate temperature	350-5ºC
Vertical distance	15cm
Move	100x70 mm
Speed	200, 10 mm/sec
Flow rate	5ml/min
Duration	2minute

4- Results and discussion

Fig(1),(2) explain the change of absorption coefficient with the change of incident photon's energy that hit the ZnO and $Mg_xZn_{1-x}O$ films respectively as a function of variable value of (x). Also it can be noticed from fig (1),(2) that the value of α was increased with the increasing of photon's energy. All fabricated films have high values of absorption coefficient $\alpha > 10^4$ cm^{-1}. This result due to probability of happening a direct electronic transitions, and this agree with [10].

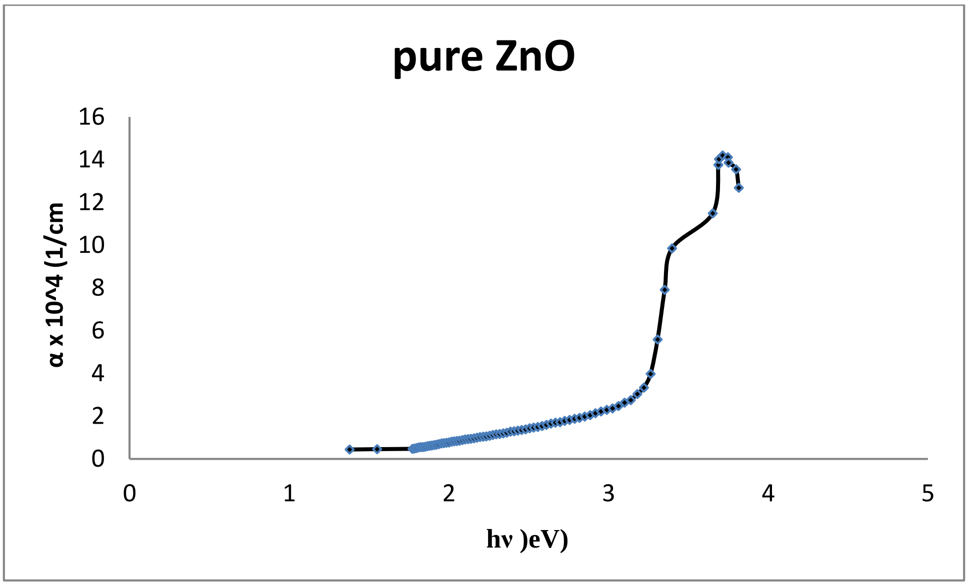

Fig.1: the relation between absorption coefficient (α) with energy of incident photon on ZnO

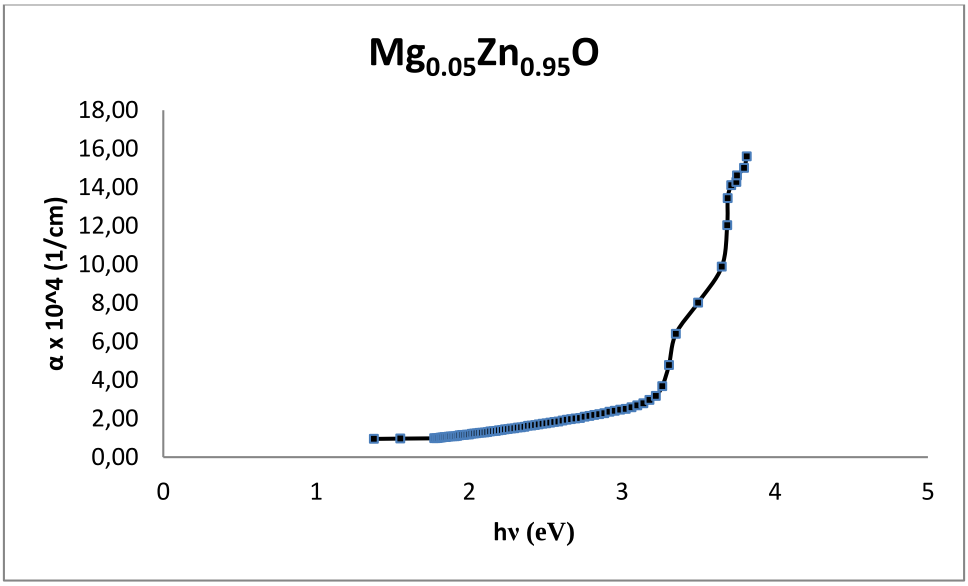

Fig.2: the relation between absorption coefficient (α) with energy of incident photon on $Mg_{0.05}Zn_{0.95}O$ thin film

The results as shown in fig(3),(4) declare that the ZnO nanostructured film doping by(x=0.05) of Mg has an increasing in the value of energy band gap from 3.30eV to 3.65eV, this mean the $Mg_xZn_{1-x}O$ is a tunable band gap for each needing application

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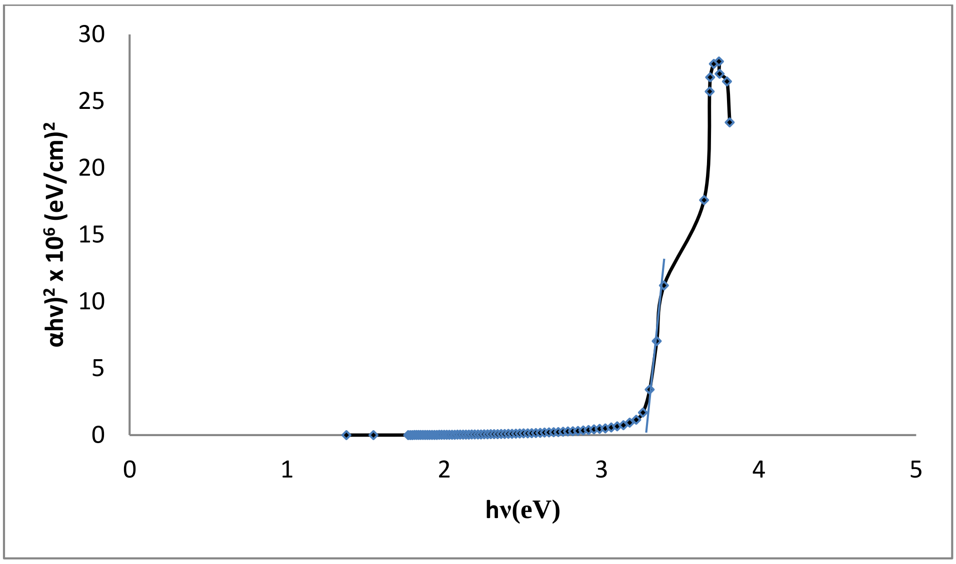

Fig.3: $(\alpha h\nu)^2$ x10^6(eV/cm$)^2$ variation with photon energy for of pure ZnO

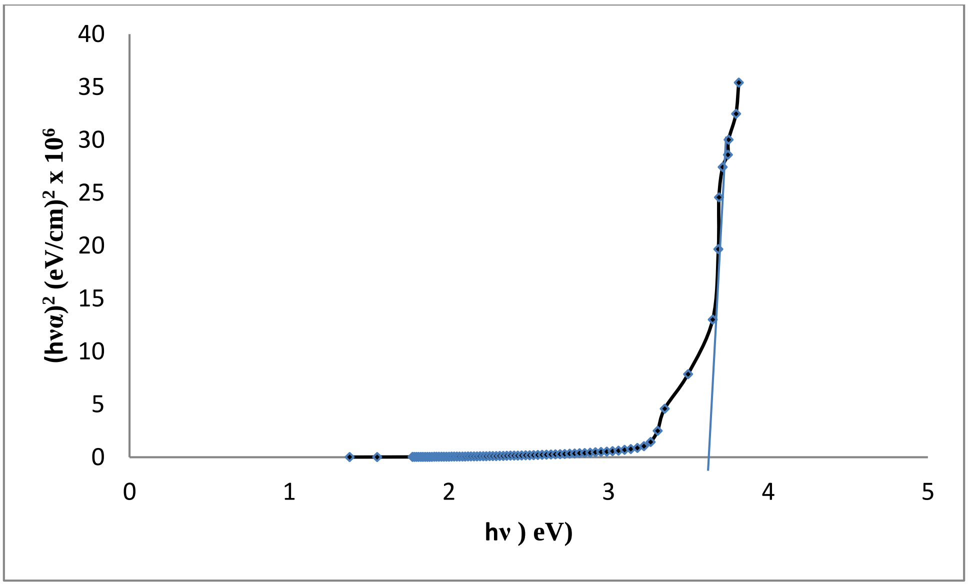

Fig.4: $(\alpha h\nu)^2$ x10^6(eV/cm$)^2$ variation with photon energy for $Mg_{0.05}Zn_{0.95}O$

2-4 Extinction Coefficient (k_o)

The value of this coefficient is calculated from (α) by using equation (3) in the range of 300-900 nm. It's important to notice the dependence of (k_o) on(α), and they have direct proportion fig (5), (6) therefore there is increasing in values of extinction coefficient by increasing of photon's energy, this increasing starts slowly and then became very quickly, but it stays in high average.

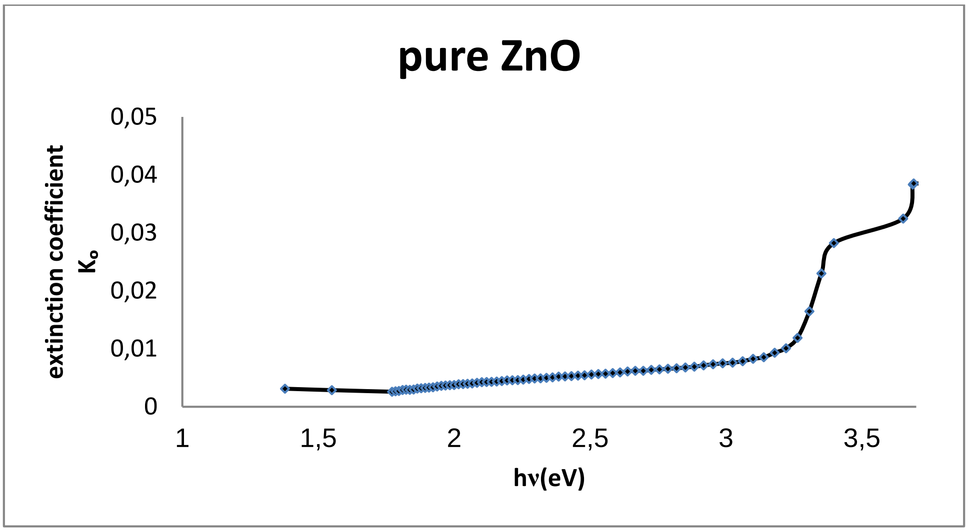

Fig.5: The relation between extinction coefficient and photon energy of pure ZnO thin film

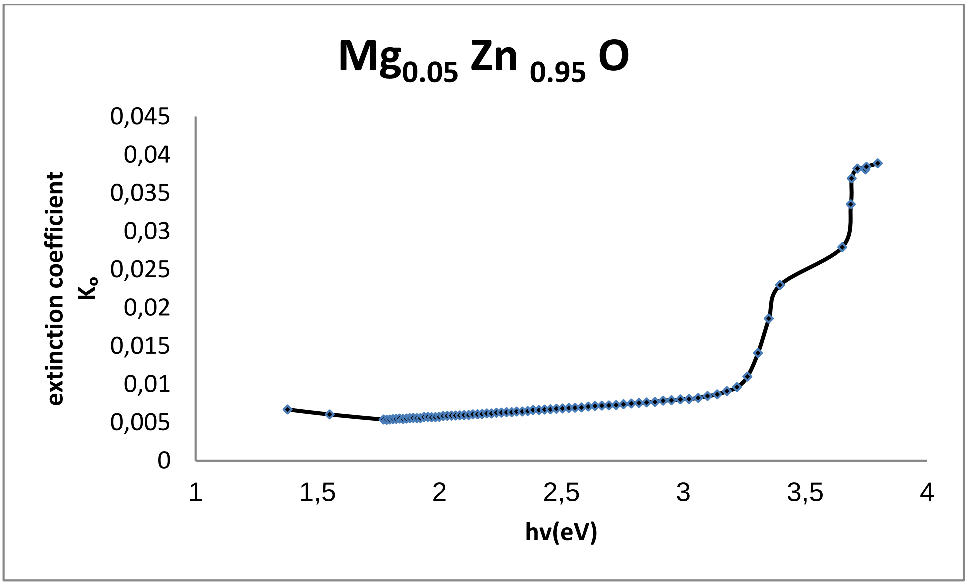

Fig.6: the relation between extinction coefficient and photon energy of$Mg_{0.05}Zn_{0.95}O$ thin film

3-4Refractive index n_o

The value of refractive index of prepared films was calculated from eq.(2) in the range of (300-900)nm, therefor the refractive index is considered as a function for the reflectivity ®[11]. Fig: (7), (8) shows the variation of refractive indices as a function for photon's energy.

The values ranging (n_o =1.3-2.59) Table (2) depends on the energy of incident photon; they are increasing with the increase of photon's energy till they reach the maximum value in the levels that meet the optical energy gap. After that values would decrease due to increase in direct electronic transitions in these levels.

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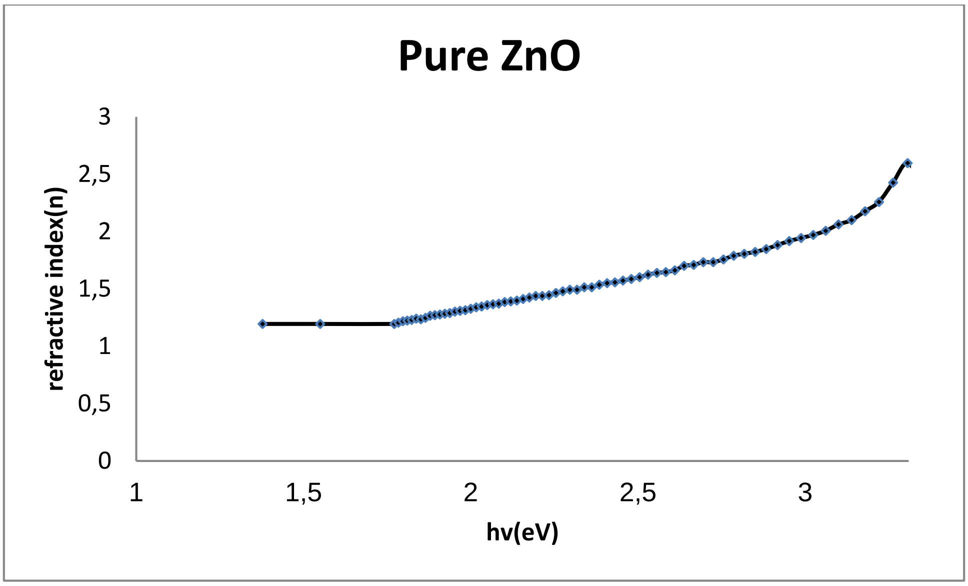

Fig.7: Variation of refractive index with photo energy of pure ZnO

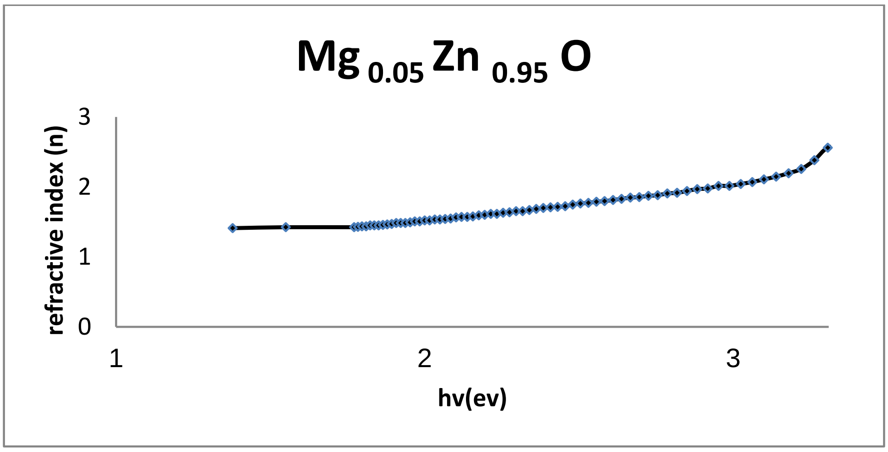

Fig.8: Variation refractive index with photon energy of Mg_x Zn_{1-x} O alloy

Table(2): variation of some optical constants of nanostructured ZnO film by dopping with 0.05 Mg

(x)	Eg(eV)	A	n_o	K_o
0	3.30	$1.42*10^5$	2.59	0.0385
0.05	3.65	$1.55*10^5$	2.561	0.0388

4-4 Topographical& structural properties

Fig (9) declares the AFM picture of $Mg_{0.05}Zn_{0.95}O$ nanostructure thin film, the diameter average is 93.05 nm Table (3), Fig (10) declares the $Mg_{0.05}Zn_{0.95}O$ alloy XRD pattern, the grain size particle has been calculated by using Debye- scherrer equation : $D=0.9\lambda/\beta\cos\theta$[11]. Table (4) summarized the structural properties of $Mg_{0.05}Zn_{0.95}O$.

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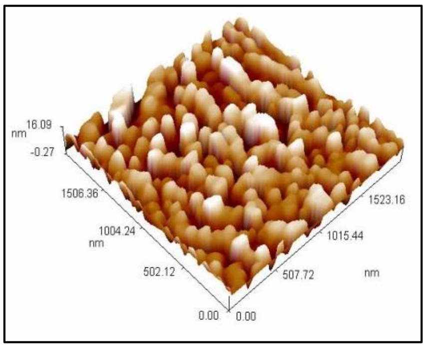


Fig(9): AFM picture of $Mg_{0.05}Zn_{0.95}O$

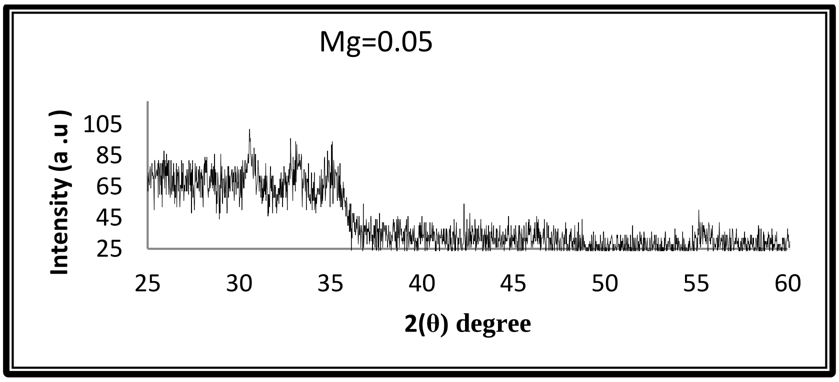


Fig.10: XRD pattern of $Mg_{0.05}Zn_{0.95}O$ alloy that prepared by chemical spry pyrolysis

Table. 3: The surface roughness analysis

Diameter Ave.	**93.05nm**
Roughness Ave	**13.3nm**
Root mean sequare	**15.4nm**

Table (4): lattice parameter of $Mg_{0.05}Zn_{0.95}O$ nanostructure thin film

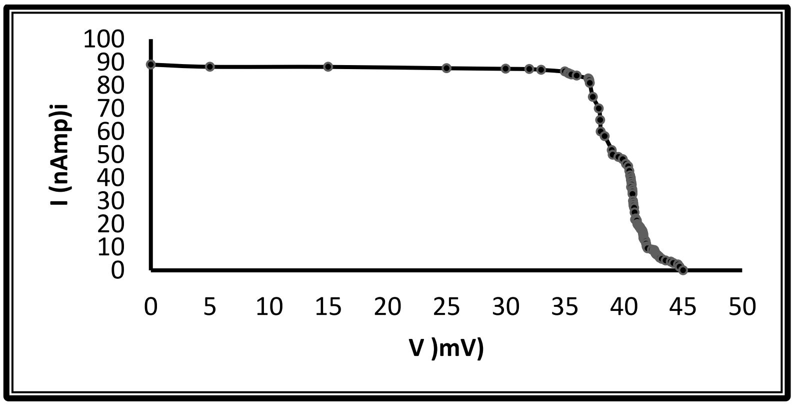
2θ	***34.197***
I/I_0	***80***
Grain size	***51***
$\sigma x10^{14}(line/m^2)$	***2.7***

5-4 Solar cell measurmet

Fig (11) declare the I-V curve of fabricated $Mg_{0.05}Zn_{0.95}O$ solar cell that had been recorded efficiency of η=(0.52%), this result due to the little value of roughness leads to increase the reflectance of the surface. Table (5) sumarized the output parameter of fabricated solar cell.

Table (5):Output parameter of solar cell

I_{max}	*83nA*
V_{max}	*37mV*
I_{sc}	*89nA*
V_{oc}	*45mV*
F.F	*0.76*
η%	*0.52*



Fig(11): I-V curve of $Mg_{0.05}Zn_{0.95}O$ solar cell

Conclusion

In conclusion, $Mg_xZn_{1-x}O$ thin films were deposited on glass substrates at 350ºC by Chemical Spray Pyrolysis method. The effect of Mg concentration on some optical properties was also studied. Also the structure properties of was studied. Then, $Mg_{0.05}Zn_{0.95}O$/Si nanostructure solar cell was fabricated with 0.52% efficiency

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