

## Radiation effects on the Electrical Properties of $CdS_xCdSe_{1-x}$ Films

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### ABSTRACT

*The samples of n-type  $CdS_xCdSe_{1-x}$  ( with  $x = 0, 0.4, 0.5$  ) were prepared by thermal evaporation technique in vacuum of  $0.00133 Pa$  . Alloying CdSe with CdS allows the increase of thermal conductivity of the crystal ( for CdS the thermal conductivity is a factor of 4 larger than CdSe ) , which is favorable parameter to increase the band gap of the host material , which for excited state absorption. The structural and electrical properties of CdS /CdSe interface region of (200 , 400 , 600 nm) thick solar cell has been studied in conjunction with photovoltaic (PV) performances with a focus on the influence of temperature treatment at ( 300 – 425 °C ) . These results suggest that the  $CdS_xCdSe_{1-x}$  layer adjacent to the CdS /CdSe interface plays a crucial role in the increase of open circuit voltage ( $V_{oc}$ ), because of a decrease in the nonradioactive recombination rate and near the CdS /CdSe interface and an increase in the built-in electric field . The cells were exposed to 200 M Rad  $\gamma$ -doses . The cell performance parameters were measured and discussed before and after irradiation .*

**Keyword:** Heterojunction, Gamma ray, Electrical properties , Coating system.

### INTRODUCTION

Heterojunction is a junction formed between two materials with different band gap . A CdSe/CdS solar cell involves a heterojunction formed between these two materials . Sunlight is allowed to pass through the CdS layer (band gap = 2.4 eV)<sup>[1,2]</sup> . In such a device the CdS is referred to as the window layer . Cadmium selenide has a nearly optimum band gap for the irradiation spectrum of sun light<sup>[3]</sup> , thus the CdSe/CdS thin film solar cell is promising candidate as a highly efficient and low-cost solar cell<sup>[2]</sup> . However , to reduce the production cost and user hesitation due to toxicity of Cd , it is required to achieve a sufficient high energy conversion efficiency , using the PV active layer with a decreased thickness . On the other hand the PV performance of thickness solar cells are improved by the annealing temperature profile as well as the effect of  $\gamma$ -radiation<sup>[4,5]</sup> .

A Si/c-Si heterojunction solar cells offer the advantages of amorphous thin films technology such low temperature processes , large area deposition and simple processing . The low processes costs and high efficiency are reason for a deeper investigation . As a result the short-circuit current ( $J_{sc}$ ) has been found decrease as Resistivity decrease<sup>[6,7,9]</sup> . An alternate explanation for the decreases of the life time with Resistivity is that the doping is playing an indirect role in the recombination activity within an operating cell , making a defect . Such defects could be extended (such defects dislocations or precipitates that are introduced during crystal growth or device processing . Defects of this type are expected to give rise to distribution of energy levels within the band gap . Becomes the Fermi-level is set by the concentration of the

doping impurity<sup>[11,12]</sup>, low Resistivity material is sensitive to a larger fraction of these defects levels than is high-resistivity material is expected to have a smaller life time than high resistivity material<sup>[8]</sup>. The position of the Fermi-level is changed by changing the doping concentration. The position of the Fermi-level in the band gap can also be changed by temperature. The temperature moves the Fermi-level closes to mid gap. Where high energy radiation falls on a semiconductor device, energy is deposited in the semiconductor via two mechanisms atomic displacement and ionization. which cause a damage of semiconductor lattice and degradation of the all performing. The clarification of the striation, composition, electrical properties and thermal stability of chemical deposited  $CdS_x Se_{1-x}$  thin films is important to investigated<sup>[7,8]</sup>.

### FABRICATION METHOD

The Samples were prepared by thermal evaporation technique in vacuum of 0.00133 Pa ( $=10^{-5}$  Torr). Coating system Edward E306 operated at  $5 \times 10^{-5}$  Torr. (E306 Edward). The samples thickness were 200 nm, 400 nm and 600 nm, and the deposition rate was kept constant at 3 nm/sec during the deposition process. The substrate temperature was also held constant at about 300K. The purpose of preparation is to characterize the ageing behavior of CdSe thin films grown by thermal evaporation in vacuum under ambient conditions with respect to various parameters, such as film thickness, molar fraction, ambient gas to obtain stability i.e. films which do not show drift in film resistance with time. The dark electrical resistivity of the obtained CdSe thin films was measured as a function of temperature in the temperature range from 300K up to 425K in order to obtain the thermal activation energy of the free charge carriers.

$CdSe_x Se_{1-x}$  Thin films with ( $x = 0, 0.4, 0.5$ ) were deposited by a molybdenum boat in vacuum of about 0.00133 Pa. The source to substrate distance was 13 cm and the rate of deposition was 8 Å/sec. The film thickness was determined using thickness monitor (Edward306).

### EXPERIMENTAL RESULTS AND DISCUSSION

#### *1- Ageing studies on $CdS_x Se_{1-x}$ thin films under ambient conditions:*

The resistance R of nine CdSe thin films of different thickness (200 nm, 400 nm and 600 nm thickness). CdSe was measured in vacuum, in Argon and in Air atmospheres. The variation of the resistance with time are illustrated in Fig.(1-a,b,c) for the thickness 200 nm, 400 nm and 600 nm respectively: curve a (in vacuum), curve b (in Argon) and curve c (in Air)<sup>[13]</sup>. As shown, Oxygen in air has pronounced effects on the film resistance, because when CdSe films are exposed to air Oxygen molecules become physically adsorbed on the film surface. The physics orbbed oxygen captures free electrons from the conduction band and becomes chemically adsorbed in the film. The formation of depletion region shows down the chemisorptions rate<sup>[14]</sup>. Once the electrical potential established between the desorbed oxygen and the ionized donors stops further electrons coming to the surface, the oxygen chemisorbed in the film comes to a halt. The oxygen chemisorptions is a manifested as the increase in film resistance with time<sup>[18]</sup>.

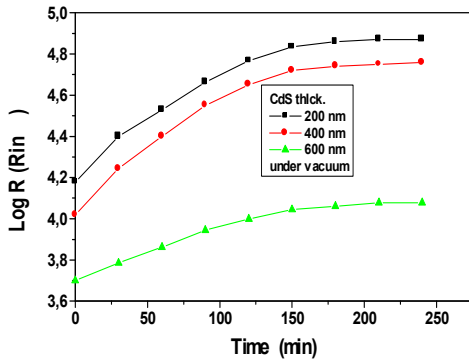


Fig (1,a) :The variation in the film resistance of CdS thin film

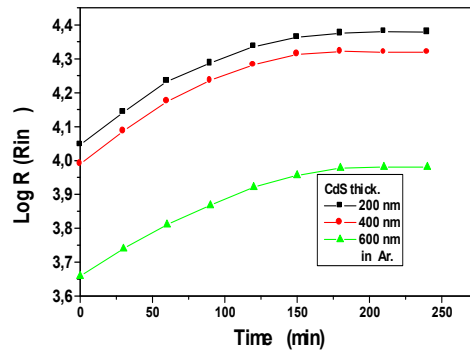


Fig (1,b) :The variation in the film resistance of CdS thin film 200 , 400 and 600 nm thick. under Ar.

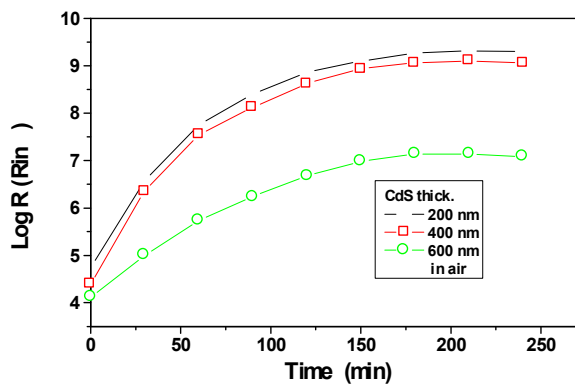


Fig (1,c) :The variation in the film resistance of CdS thin film 200 , 400 and 600 nm thick. in air

Fig.(2) represents the influence of the film thickness on ageing . It shows the plot of the normalized  $(R/R_0)$  against the time (t) in minutes , where  $R_0$  is the initial resistance of the film : curve a ( for CdSe film 200 nm thick.) , and curve b ( for CdSe film 400 nm thick.) , and curve c ( for CdSe film 600 nm thick.) . From the fig.(2) its evident that ageing decreased with the increase in film thickness . The film thickness influences the oxygen adsorption on the film surface due to the large surface .<sup>[14,15]</sup>

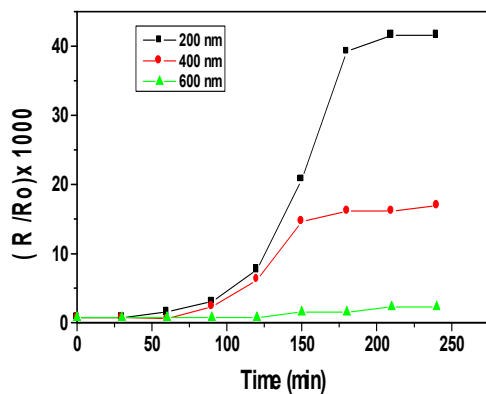


Fig (2) :The influence of the film thickness on ageing for CdSe thin film curve (a) 200nm for , (b) for 400nm and (c) for CdSe 600nm

The same procedure was repeated for the three samples with thickness (200 , 400 , 600 nm ) but with the other proposed compositions ( CdS<sub>0.4</sub> Se<sub>0.6</sub>) and (CdS<sub>0.5</sub> Se<sub>0.5</sub>)solid so lotions , in thin film form . As shown in Figs (3,a,b,c) and (4,a,b,c) , the variation of the film resistance (k) with time has the same solution behavior, since oxygen in air has pronounced effects on the film resistance in both aforementioned compositions<sup>[15]</sup>.

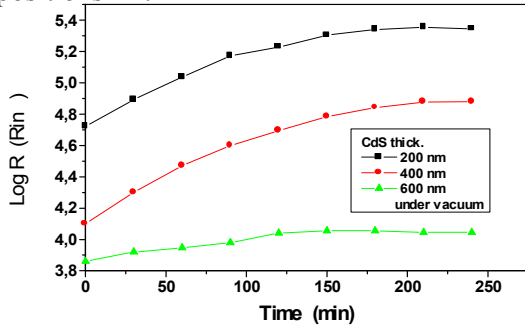


Fig (3,a): The variation in the film resistance of CdS 0.4 Se0.6 solid solution 200 , 400 and 600 nm thick under vacuum

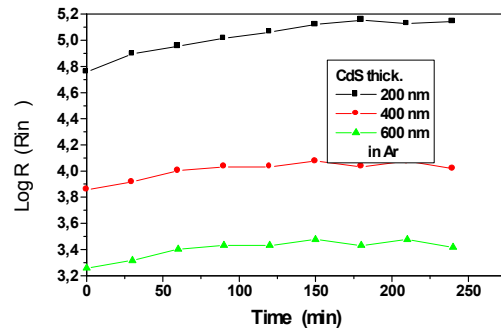


Fig (3,b): The variation in the film resistance of CdS 0.4 Se0.6 solid solution 200 , 400 and 600 nm thick under vacuum

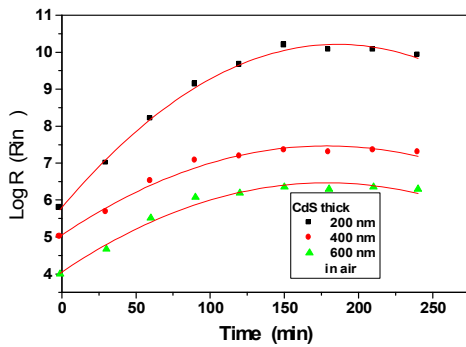


Fig (3,c): The variation in the film resistance of CdS 0.4 Se0.6 solid solution 200 , 400 and 600 nm thick under vacuum

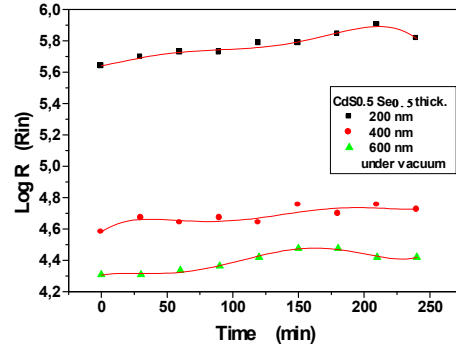


Fig.(4,a):The variation in the film resistance of CdS0.5 Se0.5 solid solution differnt thick. under vacuum

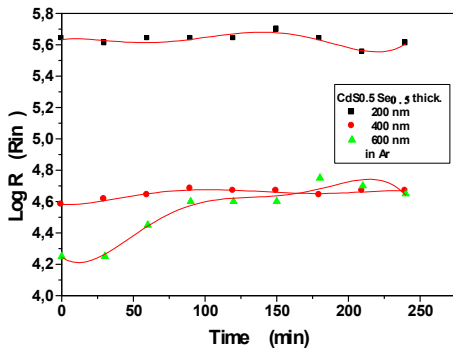


Fig.(4,b):The variation in the film resistance of CdS0.5 Se0.5 solid solution differnt thick in Ar

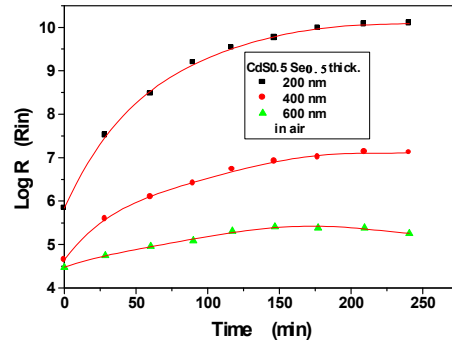


Fig.(4,c):The variation in the film resistance of CdS0.5 Se0.5 solid solution differnt thick. in air

As observed before , for the first composition in Fig.(2) which representing (R/R<sub>0</sub>) against the time (t) , the other compositions have the same behavior , Figs (5) and (6) shows the film thickness influence the oxygen adsorption on the film surface . This also attributed to the large surface to volume ratio of thinner films . Since acceptor-type adsorbed molecules , localize near the conduction electrons , the adsorption power ( the sensitivity of the semiconductors to a given type of gas ) can be determined as the relation <sup>[13,17]</sup>.

$$B = (G_o - G_a)/G_a$$

Where ( $G_o$ ) is the conductance before chemisorptions of the gas , and ( $G_a$ ) is the conductance after complete chemisorptions since ,  $G_o = 1/R_o$  and  $G_a = 1/R_a$  , then

$$B = (R_a - R_o)/R_o$$

By using this equation , the adsorption power has been calculated for the thin film , used with different composition as seen in table (1) .

**Table(1) : The absorption power B for  $CdS_xSe_{1-x}$  thin films .**

Film Thickness (nm) Composition	Values of B		
	200 nm	400 nm	600 nm
Cd Se	69182	17375	1380
Cd $S_{0.4}Se_{0.6}$	58488	15846	435

As observed in this table, B for each composition decreases with increasing the film thickness . The results are in harm only with the obtained results , and in a good agreement with data obtained by Samonta [13,17] . As also observed , B decreases with increasing the molar fraction (x) . As a result in fact , the electrical behavior of the proposed thin films , under different compositions , as the thickness of the samples increase , the resistivity decrease , which means that the conductivity of the this films increases .

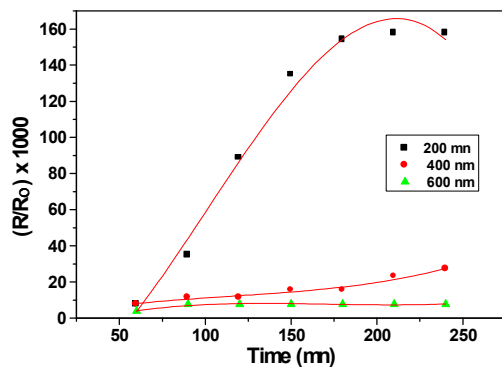


Fig.(5):  $R/R_o$  against time for CdSe Se solid solution as a function of film thickness

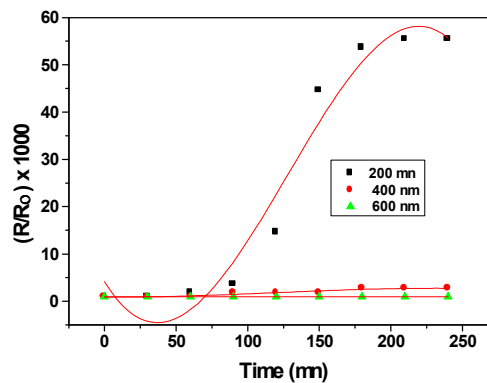


Fig.(6):  $R/R_o$  against time for CdSe Se solid solution as a function of film thickness

## 2- Temperature dependence of $CdS_xS_{1-x}$ film dark electric Resistivity :

The dark electrical Resistivity ( $\rho$ ) of three  $CdS_xS_{1-x}$  films (200 , 400 , 600 nm thick.) with ( $x = 0 , 0.4 , 0.5$  ) was measured in temperature range ( 300 – 425K ) . As shown in Figs (7 , 8 , 9 ) which illustrate ( $\log \rho$ ) as a function of ( $1/T$ ) for the different compositions for every thickness (200 , 400 , 600 nm) . As a result each graphical representation yields two distinct linear parts indicating the existence of two levels , the corresponding activation energies for conduction free charge carriers  $\Delta E , \Delta E_2$  are given in table (2) .

**Table(2) :The activation energies  $\Delta E_1$  and  $\Delta E_2$  in case of  $CdS_x S_{1-x}$  thin films .**

T , nm	200 nm		400 nm		600 nm	
	$E_1$ eV	$E_2$ eV	$E_1$ eV	$E_2$ eV	$E_1$ eV	$E_2$ eV
CdSe	0.13	0.8	0.19	0.8	0.18	0.8
$CdSe_{0.4} Se_{0.6}$	0.136	0.85	0.136	0.85	0.139	0.85
$CdSe_{0.5} Se_{0.5}$	0.139	0.863	0.14	0.841	0.14	0.85

The value of 0.14 eV for shallow donor level is consistent with the trap depth of 0.12 eV described by Bube and Barto<sup>[20]</sup> for CdSe single crystal . In  $CdS_x S_{1-x}$  thin films it is in good agreement with 0.14 eV obtained by Wayna and Breitweiu<sup>[8]</sup> . and it can be predicated that this shallow donor level is formed due to Se Vacancies in fair agreement with 0.12 eV the activation energy for  $V_{se}$  in case of Cd Se or to Se an S vacancies in case of  $CdS_x S_{1-x}$  solid solution. However , the value  $\pm 0.83$  eV for the deep level is large compared with 0.31 eV obtained by Samanta et al<sup>[13,17]</sup> for the other donor level in case of air oxidized CdSe films , but in fair agreement with the value of 0.6 eV obtained by Wagner and Breitreiser<sup>[8]</sup> and 0.8 + 0.1 eV observed for high resistivity samples<sup>[9,10,11]</sup> . The predicted acceptor level from thermoelectric power ( Seebeck Coefficient S ) measurements may be attributed to oxygen up-take . However this level cannot be detected by dark electrical resistivity measurements as a function of temperature .

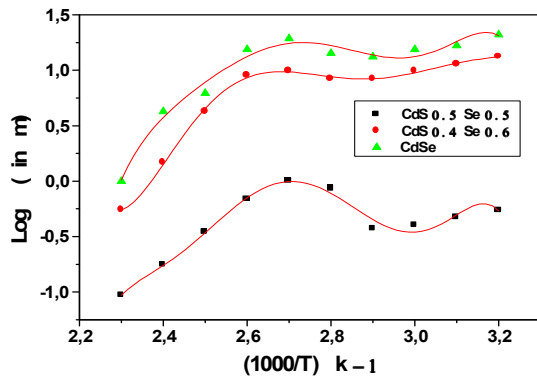


Fig.(7): Log as function of 1000/T for three coposition (x = 0.04 and 0.5 for thickness 200 nm)

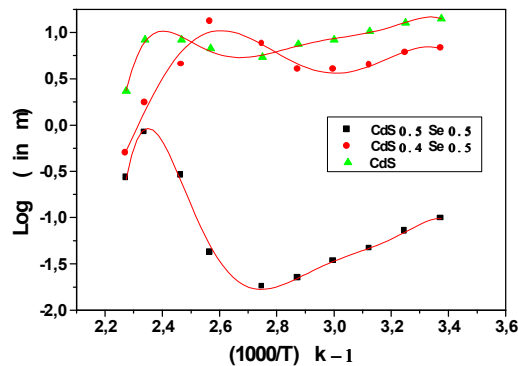


Fig.(8): Log as function of 1000/T for three coposition (x = 0.04 and 0.5 for thickness 400 nm)

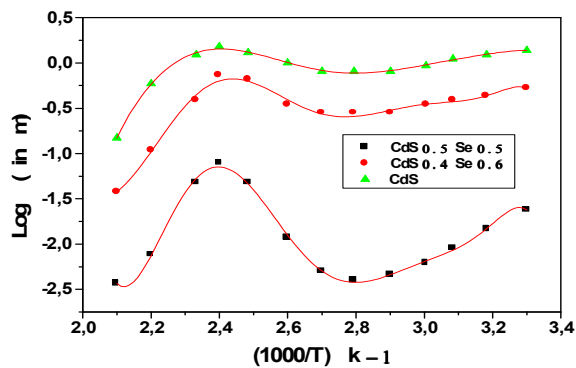


Fig.(9): Log as function of 1000/T for three coposition (x = 0.04 and 0.5 for thickness 600 nm)

### 3- The effect of $\gamma$ -radiation :

The ionization effect of  $\gamma$ -radiation can be produced at the surface or in the bulk . Surface effects will clearly be most important for thin films , where total ionizing dose can be high ( 200 M Rad ) but bulk damage will be caused by more penetration radiation . Briskman et al. <sup>[19,20]</sup> have suggested that the breakpoint for considering only surface damage comes for thickness less than  $\pm 20\mu\text{m}$  , and that in this case it is the energy flounce which is important . For thickness materials both surface and bulk effects have to be considered , becomes its our range of measurements . For measurements to be truly applicable conditions , the radiations have to be performed on tested materials in vacuum , Argon and in air . Let us describe the results regarding the influence of  $\gamma$ -radiation of the CdS-Se sample on the variation of the films resistance as a functions of time under different conditions . Fig(10) shows that , for the sample with thickness (200 nm), no significant changes in the resistance measurement observed in the different media ( vacuum , Argon , air ) after irradiation with  $\gamma$ -dose<sup>[20]</sup> . To further our understanding of these samples properties , several parameters were varied . Changing the thickness of the samples to be ( 400 nm )<sup>[21]</sup> , Fig.(11) the following observations has no effect in performance after irradiation , this results recommended by Fig.(12) for the samples with thickness ( 600 nm ) . As it can be seen , for whole samples with different thickness , the resistance no changed after irradiation .

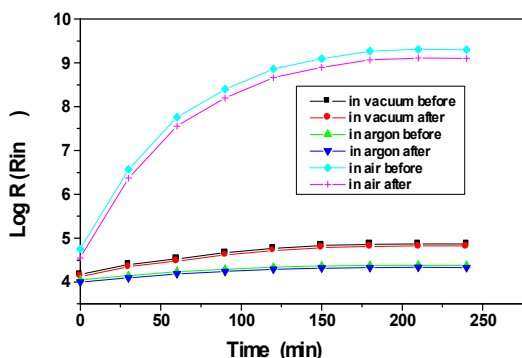


Fig (10) :The variation in the film resistance of CdS thin film 200 nmthick. before and after irradiation

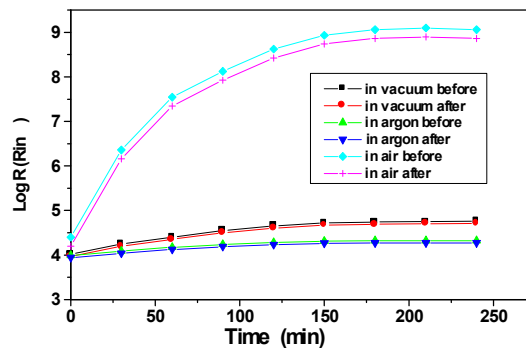


Fig (11) :The variation in the film resistance of CdS thin film 400 nmthick. before and after irradiation

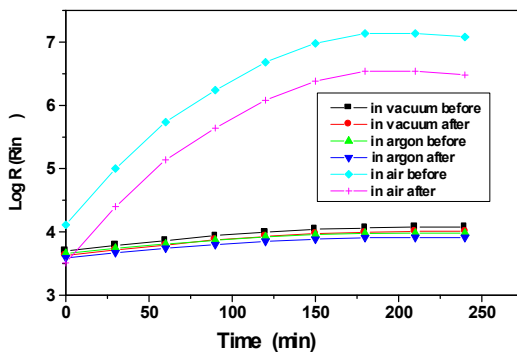


Fig (12) :The variation in the film resistance of CdS thin film 600 nmthick. before and after irradiation

An exception, as the thickness increase slight decrease in the resistance for the thickness one (600 nm). On the other hand, an important of this study is that, the most degradation due to  $\gamma$  irradiation of the all samples could be noticed with the (600 nm) thickness sample measured in air, which means conductivity increase due to increase the oxygen can contrition in air which increase the creations of traps which cause dislocation.

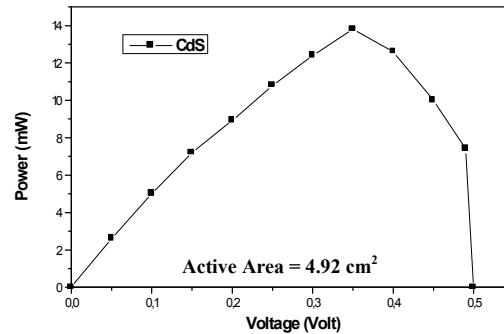
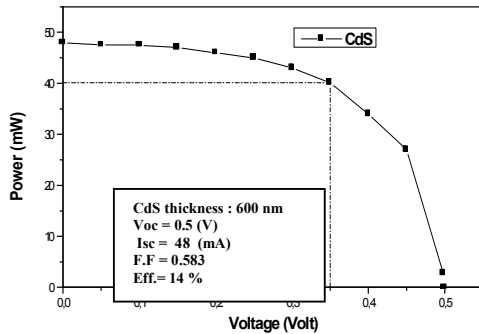


Fig.(13) : Solar cell output characteristics under the influence of full solar light intensity with 4.92 cm<sup>2</sup> area .

Fig.(14) : Output power characteristics for the fabricated cell with 4.92 cm<sup>2</sup> area under the sun levels (120000 Lux)

The efficiency and radiation resistance of fabricated solar cell are graded up. They are, then fabricated in the form  $CdS_x S_{1-x}$  heterojunction cells, with different composition and different thickness under the effect of temperature in different media. The improvement of (I-V) and (P-V) performances of the best fabricated solar cell of 600 nm thick were investigated in air, figs.(13), (14) shows that open-circuit Voltage of (0.5 V), a short-circuit current of (48 mA), a fill factor of (58.3 %) and conversion efficiency of (14 %), due to the increase of oxygen concentration in air.

## CONCOLUSION

The aim of study is fabrication photovoltaic solar cell with different composition to improve the conversion efficiency and fill factor, the performances of the best fabricated solar cell of 600 nm thick were investigated in air. This is due to maximum absorption of light and reduce the recombination of electro hole pair.

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