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REGULAR ARTICLE

Fabrication of CdSe/Si Thin Films Solar Cell by CBD

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Silicon *p*-type semiconductor is used to be as absorber layer in solar cell. In this work, the influence of CdSe thicknesses (0.1, 0.5, 1, 1.5, 2, 2.5, 3 nm) on the electrical parameters and the conversion efficiency of CdSe/Si solar cell fabricated by chemical bath deposition have been investigated before and after annealing at 873 K in one hour. It has been found that the short-circuit current density, open-circuit voltage and conversion efficiency increased as CdSe thicknesses increased. The maximum value of efficiency reached approximately 5.31% at 3 nm of CdSe thickness. After annealing, conversion efficiency was improved and it was 8.74%. Additionally, the characteristics of current density voltage solar cell investigated in the dark. The structure of CdSe/Si heterojunction solar cell was crystallized in hexagonal from XRD measurements. It has been found that the intensity for all peaks a decrease after annealing process at a temperature 873 K.

Keywords: Thin films, Solar cells, CdSe heterojunction, Nanostructures.

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1. INTRODUCTION

CdSe thin film which is an attractive material for energy conversion and it's a direct band gap (~ 1.7-2.2 eV) with interesting for electronic and opto-electronic features such as sensors, transistors and solar cells [1].

It has been used in heterojunction fabrications due to its photosensitive and nanocrystalline features [2]. Si heterojunction solar cells have a low temperature coefficient, high open voltage and small band gap energy (1.1- 1.6 eV) [3-5].

CdSe/Si heterojunction solar cells supply several benefits over conventional and traditional Si-homojunction solar cells. Low resistivity of CdSe films are necessary to reduce the series resistance of cells and reduce conduction band-Fermi level energy gap [6-7]. Most transparent n-type semiconductor films such as In_2O_3 [8], CdS [9], ZnO [10-13] and SnO_2 [14], it is used as a window layers that may be deposited on positive type semiconductors for obtaining different heterojunction-types. One of them, CdSe nanostructure which is known to have a window layer with a perfect energy gap is allowed to pass sunlight in this type of device [2]. Thus, solar cells *n*-CdSe/p-Si have been considered as alternatives for solar cells with low cost and high efficiency. It is necessary to realize a level of high energy by using a photovoltaic layer with low thickness in order to decrease fabricating costs and hesitancy due to Cd toxicity[15-16]. Several technologies have been used for deposition of heterojunction *n*-CdSe/*p*-Si such as thermal evaporation, electrochemical deposition, sputtering [17] and chemical bath deposition technique [18-21]. The aim of this paper is to find out the electrical characteristics of CdSe fabricated solar cells and the effects of CdSe thicknesses on the conversion efficiency of solar cell before and after annealing temperature. we present the results on structural properties of CdSe/*p*-Si solar cell before and after annealed at 873 K for 60 min.

2. EXPERIMENTAL DETAILS

The preparation process was achieved with cleaning the substrates. First the single substrate with orientation (111) was cut into slides of certain dimensions. It has been immersed in a methanol solution for 3 min. to ensure that organic materials are removed and then cleaned with hydrofluoric acid HF:H_2O diluted to 10% to remove the silicon dioxide layer. Finally they were rinsed with distilled water and placed in acetone solution until dry before they were placed into the deposition bath.

We used chemical bath deposition method to deposit CdSe films on Si substrates. Reflex system was used to synthesis sodium selenosulphite (Na_2SeSO_3) which is a mixture of (0.5M) from Na_2SO_3 and Se metal. Then they were added in a distilled water 10 ml and heated for (2-4 h). Ammonia solution with focus

(1 ml) was added to the cadmium chloride $CdCl_2$ which it is dissolved in quantity 10 ml distilled water. Si substrates were kept in the bath (20-24h) at room temperature. CdSe/Si solar cell was deposited by CBD with (0.1, 0.5, 1, 1.5, 2, 2.5, 3 nm) thicknesses. Then the samples annealed by thermal evaporation technique at 600 °C for 1 hour in vacuum (10^{-6} torr). X-ray diffraction patterns and SEM were measured for CdSe/Si heterojunction solar cell at various thicknesses for CdSe films before and after annealed process.

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3. RESULTS AND DISCUSSION

Figure 1 shows that the dark current density voltage curve of the solar cell which investigated in forward and reverse directions. As a result the current value is higher in forward direction compared to the reverse direction. This is attributed to the generation of trap centers which increases the possibility of recombination process occurring, which drift the carriers at a very low level [22].

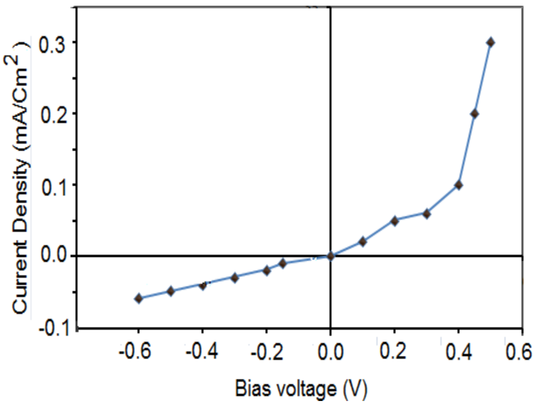

Fig. 1 – *J-V* curve in dark

Through illumination the generation of excitons as well as their dissociation to free charge carriers, light absorption through CdSe/Si layer creates free electrons and holes (excitons) were pushed toward the electrodes over an interphase potential barrier [16]. Internal defects will be reduced which will reduce optical carrier recombination and lead to increase conversion efficiency [22].

Fill factor and efficiency have been determined by the equation [24]

$$FF = \left[\frac{I_m V_m}{I_{sc} V_{oc}}\right] \times 100\% \tag{1}$$

Where I_m , V_m the current density and voltage at maximum.

$$\eta = \left[\frac{I_{sc} V_{oc} FF}{P_{hv}}\right] \times 100\% \tag{2}$$

Fig. 2 shows the *I-V* curves under the light illumination of the solar cell at different CdSe thicknesses and the Table 1 was presented the parameters of CdSe/Si solar cells at (0.1, 0.5, 1, 1.5, 2, 2.5, 3 nm) which are represented the critical factors affecting cell performance. Short circuit current density and open-circuit voltage depend on the solar cell thickness which they are widely observed as the thickness of the samples increased. This is due to the low propagation length and the probability of collecting the generated electrons near the back side of the solar cell is low. It was attributed to the high internal area reflection, it is difficult to reduce the total generation by thinning the thickness. The generation takes place near intersection and this will increase the probability of combination [25]. Increasing the thickness of the layer led to increase the efficiency and the highest efficiency was obtained approximately (5.31 %) at a thickness 3 nm.

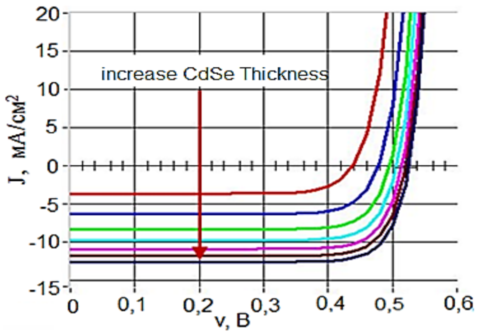

Fig. 2 – Current density- voltage characteristics in an illumination

Table 1 – CdSe/Si solar cell practical result in light

Thickness, nm	V_{oc}, Volt	J_{sc}, μA/cm²	*FF* %	*η* %
0.1	0.44	3.64	76.44	1.22
0.5	0.48	6.32	78.43	2.37
1	0.50	8.34	79.26	3.27
1.5	0.51	9.77	79.74	3.94
2	0.51	10.88	79.96	4.47
2.5	0.52	11.85	80.15	4.93
3	0.53	12.58	80.35	5.31

The results which represents the effects of annealing temperatures 873 K on the parameters of the solar cell by increasing CdSe thicknesses were tabulated in Table 2 and shown in Fig. 3. We observed that the best range of CdSe thickness is 3 nm because the efficiency of the conversion was improved and it was become 8.74 % after annealing. This is due to the change in the structure of heterojunction solar cell and the development in the interface layer between *p*-Si and *n*-CdSe.

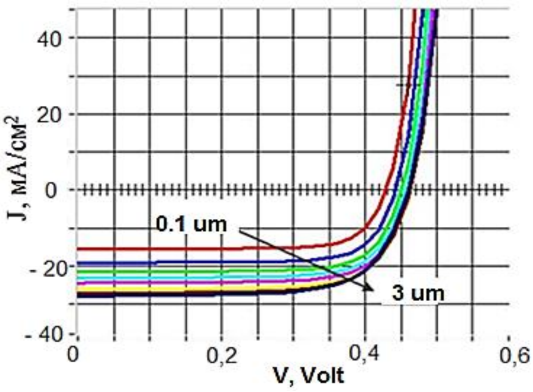

Fig. 3 – *J-V* curve for solar cell after annealing at 873 K

Table 2 – CdSe/Si solar cell at annealing temperature 873 K

Thickness, nm	V_{oc}, Volt	J_{sc}, μA/cm²	*FF* %	*η* %
0.1	0.43	16.64	63.75	4.56
0.5	0.44	19.32	64.66	5.49
1	0.45	22.34	65.66	6.60
1.5	0.45	25.77	65.87	7.63
2	0.45	26.88	66.26	8.01
2.5	0.46	27.78	66.47	8.49
3	0.46	28.58	66.53	8.74

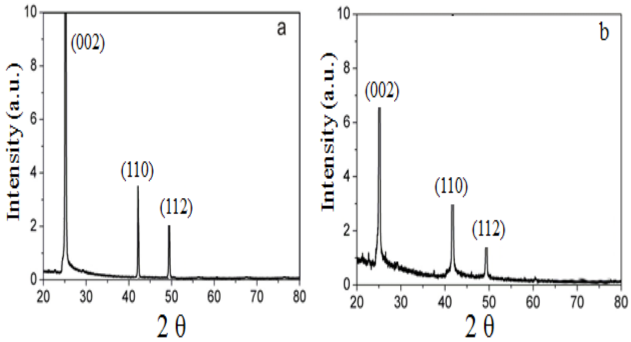

Fig. 4 – XRD of (a) CdSe/Si cell before annealing (b) at annealing 873 K

XRD pattern was shown in Fig. 4 (a, b) of CdSe/Si thin film. From the Figure we notice the appearance of three sharp peaks with a polycrystalline hexagonal structure. The intense peak at 2θ = 25.2° was corresponding to (002) plane of hexagonal structure and two intensity peaks at 42.5° and 49.9° were corresponding to (110) , (112) planes respectively before and after annealing in agreement with standard database [26]. In Fig. 4b we notice that the peak intensity of (002) decreased after annealing compared with the intensity of the peak itself in Fig. 4a. Also the intensity of another two peaks (110) and (112) were decreased at annealing temperature 873 K. The reason for this is believed to be the decrease in crystalline defects as well as the change in cell structure after annealing.

CONCLUSIONS

We have investigated the effect of various CdSe thicknesses for fabrication CdSe/*p*-Si heterojunction by CBD on the electrical parameters solar cell before and after annealing at 873 K. The best efficiency of CdSe/Si solar cell was around 5.31 % by increasing the CdSe thickness at 3 nm and it was improved to be 8.74 % after annealing at the same thickness and at a temperature of 873 K. From XRD pattern, the intense peak was (002) which crystallized in hexagonal structure and decreased after annealing. In addition to the intensity of two peaks (110) and (112),which also decreases for the annealed cell at 873 K and with a time of one hour.

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Виготовлення тонкоплівкових сонячних батарей на основі CdSe/Si методом CBD

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Кремнієвий напівпровідник *p*-типу використовується як поглинаючий шар в сонячних елементах. У цій роботі було досліджено вплив товщини CdSe (0,1, 0,5, 1, 1,5, 2, 2,5, 3 нм) на електричні параметри та ефективність перетворення сонячних елементів CdSe/Si, виготовлених методом хімічного осадження у ванні, до та після відпалу при 873 К протягом однієї години. Було виявлено, що щільність струму короткого замикання, напруга холостого ходу та ефективність перетворення збільшуються зі збільшенням товщини CdSe. Максимальне значення ефективності досягало приблизно 5,31% при товщині CdSe 3 нм. Після відпалу ефективність перетворення була покращена і склала 8,74%. Додатково досліджені характеристики щільності струму напруги сонячної батареї в темряві. Було виявлено, що інтенсивність для всіх піків зменшується після процесу відпалу при температурі 873 К.

Ключові слова: Тонкі плівки, Сонячні елементи, Гетероперехід CdSe, Наноструктури.