# بهبود بازدهی سلول خورشیدی کادمیوم تلوراید با لایه بافر اکسید روی

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**چکیده- در این مقاله، یک ساختار جدید از سلول خورشیدی با بازده زیاد ارائه گردیده است . سلول خورشیدی پیشنهادی در مقایسه با انواع متداول آن دارای یک لایه بافر (ZnO) اضافه است.همچنین با تغییر ناخالصی و ضخامت لایه ها بازدهی به طور مؤثری افزایش یافته است. در حالی که ساختار معمول سلول خورشیدی دارای بازده ۲۰/۲۵٪است ، به کمک این ساختار پیشنهادی می توان به بازده حدود ۷۳٪ رسید.**

کلید واژه- سلول خورشیدی، ZnO ، بازده، لایه بافر

# Improving the Efficiency of CdTe thin film Solar Cell with ZnO Buffer layer

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Abstract- In this work, a new structure for Solar Cells is proposed which can improve their Efficiency greatly. In comparison to the original solar cells, the proposed structure makes use of a ZnO layer (called Buffer layer). It is possible to improve Efficiency with changing thicknesses and doping levels of layers. While the original structure has the maximum Efficiency of 20.25%, the new structure can achieve the Efficiency of 73%.

Keywords*:* Baffer layer, Solar cells, ZnO, Efficiency.

## 1. Introduction

Nowadays, due to population increase and subsequently decrease of fossil fuel resources such as oil and gas, the researchers are looking for alternative energy sources. One of the most popular power sources is solar energy. The main reasons for this popularity are its easy availability and renewable characteristics. Technically, the solar cell converts the solar energy to the electricity. According to the required voltage or current, the solar cells are arranged in the parallel or series scheme which make the solar panel.

Originally, the structure of CdTe solar cell consists of glass substrate, Transparent Oxide Conductor layer (TCO), Window layer, Absorbent layer and Back contact [1]. In recent years, many attempts have been made to reach a more optimal structure with higher efficiency. A significant solution to enhance the efficiency of a solar cell is adjusting the structural parameters such as layer thickness and doping levels. In[2], Thin-films are employed to improve the cost structures of photovoltaic by reducing the use of the expensive silicon wafers. In Reference [3,4] explains the details of the deposition of uniform arrays of CdTe/CdS heterostructures that is suitable for solar cells by close-spaced sublimation and chemical bath deposition techniques.

By changing the photovoltaics parameters of the solar cells, their performances can be changed effectively. In the opinion of basic physics of semiconductors, maximum efficiency can be achieved with optimization of the cell parameters. In this regard, this paper suggests an optimal structure for solar cells. The proposed structure makes use of a buffer layer to increase the efficiency. Also, the thickness and doping of the other layers are adjusted precisely. The practical results show the satisfying and high performance of the proposed structure in comparison to the conventional structures. Also, the simulations are implemented in the WXAMPS software.

In this paper, first, the thin film solar cell is introduced. Then, by studying the effects of buffer layer and changing doping and thicknesses of layers, the optimization of the performance of solar cells have been investigated.

## 2. The proposed CdTe solar cell structure

In this section, the structure of thin film solar cells is described.According to Equation1, the conversion efficiency of solar cell is equal to the proportion of generated maximum output electrical power to the total power of incident light beam as follows:

$$\eta \cong \frac{V_m \times I_m}{p_{in}} \cong \frac{V_{oc} \times I_{sc} \times FF}{p_{in}} \quad (1)$$

Where $\eta$ is efficiency; $V_m$ and $I_m$ are the voltage and current of maximum output; $P_{in}$ is the input light power, $V_{oc}$ is the open circuit voltage; $I_{sc}$ is the short circuit current and FF is the Fill Factor.

According to Figure 1, Eq.1 is ploted. The shaded area shows the maximum power output $P_m(I_m V_m)$ that the quantities $I_m$ and $V_m$ correspond to the current and voltage in the maximum state. By choosing a load correctly, close to 80% of the Product $I_{sc}V_{oc}$ can be achieved. The short-circuit current($I_{sc}$) is equal to the photocurrent derived.[6]

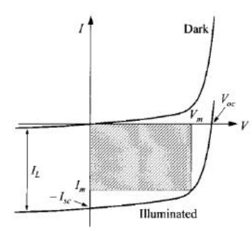



Fig1.Voltage-Current characteristics of p-n under fluorescent and dark

Figure2 shows the proposed structure of CdTe thin film solar cells.In this figure, the tin oxide layer is the transparent connection that is responsible for collecting current from the front of solar cells. This layer is deposited on a glass substrate.Cadmium Sulfide (CdS) layer (also called Window layer) acts as a window that can prevent lights that have more energy than the band gap. Also, Cadmium Telluride (CdTe) layer is used as an absorbent layer.

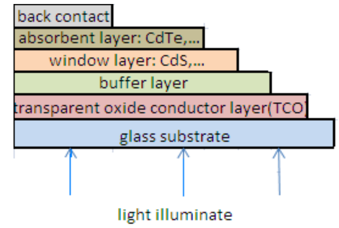



Fig. 2. The initial proposal for the structure of a thin film solar cell

*2.1. Front contact*

In the simulation of front layer, due to its location, some properties such as high transparency, conductivity and having a band gap close to the CdS layer are significant. At present, the main material that is used as front electrodes for making CdTe solar cell is $SnO_x$. The main deficiency of this material is its low conductivity. Indium tin oxide is formed by adding indium to $SnO_x$. According to the literature, [($SnO_x$:F(FTO))] material is obtained by adding fluorine to tin oxide. Another material that is used as a front contact in the manufacture of solar cell is Zinc Oxide (ZnO). In order to maintain a high voltage, often the intrinsic $SnO_x$ thin layer is combined between TCO and CdS window layer to avoid the possible deviation caused by pin holes in the CdS. In order to reduce the loss of photon absorption at wavelengths less than 500nm, the intrinsic TCO (high resistance) and a thinner CdS layer are employed in the structure.[5]

*2.2. Window layer in the CdTe solar cell*

Due to the limitation of doping ability and the high absorption coefficient of CdTe, using the homojunction equipment with high efficiency is not very attractive as a window layer. Therefore, heterogeneous structure of n-CdS and p-CdTe is used to reach high efficiency [5]. CdS material with band gaps of 2.42ev can absorb photons with wavelengths less than 510nm [6].

*2.3. Absorbent layer in the CdTe solar cell*

In this layer, CdTe material with a band gap of 1.4ev can absorb photons with wavelengths less than 810nm [3].

*2.4. Buffer layer*

Adding Buffer layer between TCO and CdS can improve solar cell performance. This event roots in some significant issues:

- If the resistivity of the Buffer layer is roughly consistent with CdS, it will reduce the possibility of local band formation between the TCO/CdTe. This connection occurs when CdS layer is thinner. By reducing CdS layer, the open circuit voltage $V_{oc}$will remain constant that can generate a higher short-circuit current density($J_{sc}$).
- If Buffer layer is used, the removal process[1]of the CdTe layer will be reduced. This will greatly reduce the shunt resistance problems.
- Buffer layer help to relieve the pressure between the layers and thus improve the adhesion.

According to the above discussion, the use of buffer layer will improve the structure performance of solar cell [5].

## 3. Experimental details

3.1. *Assumptions*

To do this work, we use a program that is suitable for simulating and analyzing of one-Dimensional Microelectronic and Photonic Device structures. To achieve this goal, at first, the input data(e.g., band gap, affinity, doping, mobility gap state defect distributions in the bulk and at interfaces, etc), should be fed to the software.[7-8].

In this work, the bias voltage range of 0-0.7-1 V in darkness and light are selected. Also the working temperature is 400 $^0$c. The I-V characteristics of this solar cell are defined under 1.5 AM illumination (normalized at 100 mw/cm$^2$). Also, the four layers of SnO2 as the front contact, ZnO as a buffer layer, CdS as the window layer and CdTe as the absorbent layer on a glass substrate are used. After 3000 simulations,the thicknesses of the four layers that used here,are obtained experimentally. Baffer layer thickness must be such that a tradeoff between the possibility of local band formation between the TCO/CdTe and the transfering of electrons from TCO to Window layer can being achieved. Profile used for these 4 layers can be seen in the table 1.

Table1: Electrical properties of the layers

| **properties** | **$SnO_2$** | **ZnO** | **CdS** | **CdTe** |
|---|---|---|---|---|
| permittivity | 9 | 9 | 10 | 9.4 |
| $E_g$(ev) | 3.6 | 3.3 | 2.4 | 1.5 |
| Affinity(ev) | 4 | 4.4 | 4 | 3.9 |
| $N_c$(cm$^{-3}$) | 2.20E+18 | 2.20E+18 | 2.20E+18 | 8.00E+17 |
| $N_v$(cm$^{-3}$) | 1.80E+19 | 1.80E+19 | 1.80E+19 | 1.80E+19 |
| $\mu_n$(cm$^2$/v/s) | 100 | 10 | 100 | 320 |
| $\mu_p$(cm$^2$/v/s) | 25 | 2.5 | 25 | 40 |
| $N_d$(cm$^{-3}$) | 1.00E+17 | 1.00E+18 | 1.10E+18 | 0 |
| $N_a$(cm$^{-3}$) | 0 | 0 | 0 | 2.00E+14 |
| Thickness (um) | 1 | 0.01 | 0.12 | 6.33 |

*3.2. Simulation Results*

[1] opposite of the deposition process

In order to see the effect of using buffer layer on the solar cell, first this layer is not considered in the simulation. In this regard, the simulation isperformed by changing the thickness of the material used for solar cell and by using electrical specifications that were expressed in table 1. As it can be seen in figure3, the efficiency of the solar cell is about 20.25%, open circuit voltage is 0.6807V, short circuit current is 45.2894 mA/cm$^2$ and Fill Factor is 65.7213%.

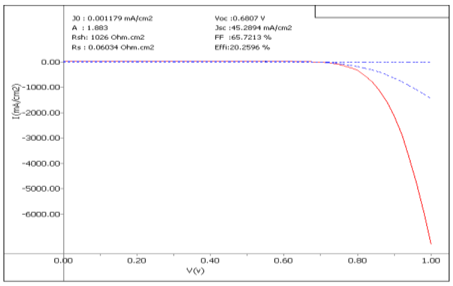



Fig. 3. I-V characteristics of CdS/CdTe solar cells without buffer layer

Now, the buffer layer is added to the structure. In this second case,Baffer layer improved electron's transport and eventually improve the Efficiency and Fill Factor and Current. These events happen because in this case the potential barrier of electrons is less than the case without Baffer layer. Here, the following results are achieved. The solar cell could achieve to 73.0750% efficiency, 0.6514V open circuit voltage, 161.9034 mA/cm$^2$ short circuit current and 69.2910 Fill Factor [figure 4]. As it is seen, the efficiency is improved about 53% more than first case.

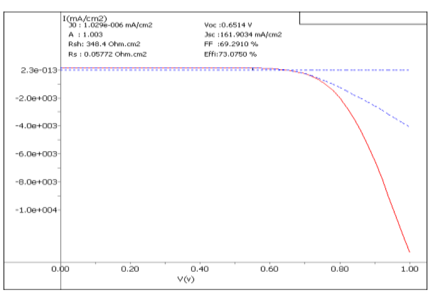


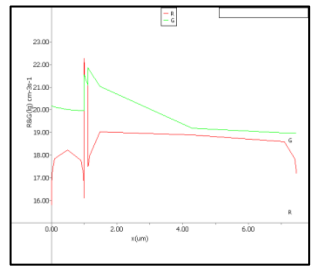

Fig. 4. I-V characteristics of CdS/CdTesolar cells with buffer layer

In the first case, the recombination of the carriers is not dependent on the thickness of the solar cell but in the second case, despite the recombination increases for the thicknesses less than 4μm, it decreases for the thicknesses more than 4μm.it 's reason is the reduction of the possibility of local band formation between the TCO/CdTe.

## 4. Conclusions

This paper proposed a new approach to improve the structure of the solar cell. In this regard, the efficiency of 73.75% was achieved by determining the optimal thickness for thin film solar cells with the ZnO buffer layer. In comparison to the case of neglecting ZnO buffer layer, the efficiency is increased 53%.

a)




b)

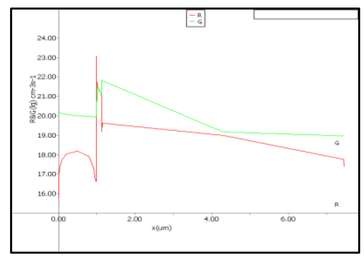



Fig. 5. R&G characteristics of CdS/CdTe solar cells a)without buffer layer, b) with Buffer layer

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