Study the effect of thickness and reflectivity on (n-ZnSe / p-MASnI3 / p-CuSCN) solar cell properties using SCAPS-1D

Tariq A. Mohammed , Ayed N. Saleh
Department of physics, Collage of Education for pure Science, Tikrit University, Tikrit , Iraq
DOI: http://dx.doi.org/10.25130/tjps.24.2019.134

ABSTRACT

The effect of the absorption layer (MASnI3) within the range (200nm-900nm) was studied with the thickness of each layer HTM and ETM (10nm) for each. After completion of the study we found that the best thickness of the absorption plate is at (400nm), note that the cells used in the program is not perfect it contain defects, to be closer to the practical reality, after completing this study in the framework of this study was added a filter mirrors (95% mirro) from the library of the program (Scaps) and that the studied solar cells (n-ZnSe / p-MASnI3 / p-CuSCN) Reflectivity (R) ranged between 0.11-0.99 and the best reflective range at 0.99 was (η) 20.98 filler (FF) 68.55% short circuit current (Jsc) 34.040 mА/cm2 and volt circuit (Voc) 0.894 V. The default illumination spectrum has been set to the AM1.5 global standard.

1- introduction

The Earth receives an great amount of solar energy. The sun provides enough energy per minute to supply the energy needs of the world for a full year, and one day provides more energy than population consumption. In fact, the amount of solar radiation that strikes the earth over a period of three days is equivalent to Energy is stored in all fossil energy sources. Solar energy is a free source. The first solar cell has been in operation for more than 30 years and the solar cell has been extended in terms of efficiency. The biggest efficiency leaps have come with the emergence of transistors and semiconductor technology. There are many advantages of solar PV if it is one of the sources the world's most promising renewable energy [1]. A solar cell is a device that converts photovoltaic energy into an electric current, and can convert light into electrical energy using sunlight or any other industrial light. The development of low-cost, easy-to-use, high-efficiency, long-term solar cells (solar cells) has continued. Solar cells are a type of semiconductor that contains a biophysical compound, often organic or inorganic Lead-based halide material is often used as an energetic layer to collect energy. Pyrophosphate materials such as methylammonium lead halides and cesium lead halide are inexpensive to produce and simple to manufacture. The efficiency of solar cells for devices using these materials increased from 3.8% in 2009 to 22.7% in late 2018 due to internal cell substitutions. [2] The perovskite compound was known for many years but the first solar cell based on perovskite was manufactured in 2009 Before the researcher Miyasaka and her group. The structure of this cell was based on sensitive dye cells and gave energy conversion efficiency of 3.8% using the perovskite layer and the TiO2 layer as a collector of electrons, as well as using a liquid part of the cell, so the cell was only briefly stable. Researcher Park and his group developed this cell in 2011 using the same principle and also get the efficiency of conversion of energy 6.5% [3]. Later in 2012, researcher Henry Snaith and researcher Mike Lee of Oxford University demonstrated that perovskite were constant if they were in contact with a rigid carrier of gaps and there was no need to use the TiO2 layer to transport the electrons. It was found that the efficiency level had risen to more than 10%. In 2013, both sensitive and flat cells were subjected to several improvements. Burschka and her group [5] demonstrated that the repositioning technique for sensitive dyes had
increased efficiency to 10%. At the same time, Olga and her group [5] demonstrated that a flat cell by thermal evaporation could be made with an efficiency of 12% to 15% in both the pin and nip models, respectively. [6] Organic matter and the bottom layers of the layers of the electrodes at the top of the perovskite layer. In 2014, using the re-positioning of the layers, 19.3% efficiency was achieved by Yang Yang [7] in a flat cell model with a thin membrane. In December 2015, the efficiency of 21.0% was recorded by some researchers, in 2016 efficiency was reached 22.1%, and finally in 2018 the efficiency of 23.3% was registered at the Chinese Academy of Sciences.

- The aim of study:

1-The main objective of the research is to obtain high efficiency, which is the solar cell (n-ZnSe / p-MASnI3 / p-CuSCN) using the computer simulation method of solar cells

2. Simulation method

Is a one-dimensional program that simulates solar cells, developed in the Department of Electronic and Information Systems at the University of Gent / Belgium. The program is available free of charge to researchers and runs on Windows systems, where it takes 50MB of hard drive.

(2-1) Characteristics that describe solar cell performance:

The main factors used to describe the performance of solar cells are the maximum power of pmax, the short circuit current of Jsc, and the open-loop voltage of the Voc, and Fill factor FF. These factors are determined by the bright J-V property curve. The conversion efficiency η is determined by these factors. Here are some explanations and brief versions of these factors for the simple n-p link:

(2-1a) Short circuit current density Jsc:

The short circuit Jsc current is the maximum current generated by the solar cell when the solar cell ends are in contact with one another (ie, short circuit). The solution can be obtained Jsc from the net current density J-V Solar system and from the following equation [8][9]:

\[ J(V) = J_{sc} - J_{dark}(V) \]  

Where: Jdark the density of the dark stream is given by the following equation:

\[ J_{dark}(V) = J_0 \left( e^{\frac{qV}{k_BT}} - 1 \right) \]  

Under solar lighting, solar cell behavior is described using the ideal diode equation (12-2) and an additional source of current Jsc due to illumination, thus giving the equation of the bright solar cell by compensating equation (2) in equation (1):

\[ J(V) = J_{sc} - J_0 \left( e^{\frac{qV}{k_BT}} - 1 \right) \]  

Similarly, the short circuit current is given by the following equation:

\[ J_{sc}(V) = J(V) + J_0 \left( e^{\frac{qV}{k_BT}} - 1 \right) \]  

Since v is the voltage across the junction, T is the absolute temperature. J0 The density of the saturation current is during darkness.

(2-1b) Voltage Open Circuit:

Voc is the voltage in which no current flows through the outer circle when the solar cell ends are not connected to each other. This is the maximum voltage that the solar cell can provide. Depends Voc on the optical current density Jph of the simple p-n connection, and is given by the following equation [9]:

\[ V_{oc} = \frac{k_BT}{q} \ln \left( \frac{J_{ph}}{J_0} + 1 \right) \]  

It is obtained from equation (5) by adjusting the net current J(V) to zero. This results in a compensation effect between the dark current and the photovoltaic current:

\[ V = V_{oc} \text{ and } J_{sc} = J_{ph} \text{, } J(V) = 0 \]

(2-1c) Fill factor FF:

The fill factor is the ratio between the maximum capacity Pmax = Jmp x Vmp generated by a solar cell and the output Voc and Jsc describes the FF "squared" J-V curve

\[ FF = \frac{J_{mp} \times V_{mp}}{V_{oc} \times J_{sc}} = \frac{P_{max}}{P_{in}} \]  

Jmp and Vmp is the maximum voltage point and the current density can not be generated by the solar cell.

(2-1d) Conversion efficiency η:

Conversion efficiency is described as the ratio between the maximum capacity generated by the solar cell and the ability to fall on it. This is given by the following equation:

\[ \eta = \frac{P_{max}}{P_{in}} = \frac{J_{sc} \times V_{oc}}{P_{in} \times FF} \]  

Radiation and value P_in The 1000 W/m² of the 1.5AM spectrum has become a standard for measuring the conversion efficiency of solar cells. Where the radiation capacity P_in is a measure of falling power as a function of the space of the solar cell.

(1-2-1e) Quantum Efficiency QE:

Quantitative efficiency is defined as the percentage between the number of electrons generated to the number of photons absorbed per unit wavelength falling on the surface of the device, expressed in the following mathematical relationship:

\[ Q_E = \frac{(I_{ph} / q)}{(P_{in} / h\nu)} \]  

*Where as:

*Iph/q Number of carriers generated.

*(P_in/hν) The number of photons dropped

Quantitative efficiency can be calculated in terms of promoter length and response.

\[ Q_E = \frac{hc}{\lambda^2} \]  

Where: h constant and equal to1.24 thus simplifying the equation and written as follows:

\[ Q_E = 1.24 \frac{hc}{\lambda} \]  

Whereas:

R: Response in units (A / W)

λ: wave length units in (nm)
If the number of electrons generated (9) is equal to the number of absorbed photons, naturally the reflected light will be reflected at the semi-conductor surface and not all that remains absorbed within the depletion zone so that the amount of efficiency can be increased by reducing the reflectivity of its surface As well as increase the survival time of the carriers by reducing the structural defects and increase the life span and increase absorption within the depletion zone, and the main key, which plays a prominent role in quantitative efficiency is the absorption coefficient, which depends on the cycle on the wavelength [10,11].

Table (1) The parameters of the solar cell used in the SCAPS-1D program

| Parameter                  | symbol (unit) | ZnSe | CuSCN | MASnI3 |
|----------------------------|---------------|------|-------|--------|
| Bandgap                    | Eg (eV)       | 2.9  | 3.6   | 1.3    |
| Electron affinity          | Z (eV)        | 4.1  | 1.7   | 4.2    |
| Dielectric permittivity    | e/c            | 10   | 5.1   | 10     |
| CB effective density of states | Nc (cm⁻³)   | 1.6E+18 | 2.6E+19 | 1.0E+15 |
| VB effective density of states | Nv (cm⁻³)   | 1.1E+19 | 2.6E+20 | 1.0E+18 |
| Electron thermal velocity  | νe(cm/s)      | 1.0E-7 | 1.0E-7 | 1.0E-7 |
| Hole thermal velocity      | νh(cm/s)      | 1.0E-7 | 1.0E-7 | 1.0E-7 |
| Electron mobility          | μe(cm²/V.s)   | 1.60E+2 | 25   | 1.60E+0 |
| Hole mobility              | μh(cm²/V.s)   | 2.50E+1 | 25   | 1.60E-6 |
| Coefficient absorption     | σ(cm⁻¹ cm²/V²) | 1E-6 | 1E-6 | 1E-6 |

* URL of SCAPS–1D program: https://users.elis.ugent.be/ELISgroups/solar/projects/scaps/SCAPSinstallatie.html

3. Effect of thickening on the absorption layer (Absorber layer)
The effect of the absorption layer (MASnI₃) within the range (200nm-900nm) was investigated with the thickness of the HTM layer and the ETM at 10nm. After completion of the study we found the best thickness of the absorption plate is (400nm) and Fig (1) shows the characteristic (I-V) of cell ZnSe / MASnI₃ / CuSCN, with increasing the thickness of the absorption layer the increases characteristic curve (I-V).

![Fig. 1: I-V characteristic of ZnSe/MASnI₃/CuSCN](image1)

The density of the short-circuit current (Jsc) increases by increasing the thickness of the P-MASnI₃ from 24.306 (mA/cm²) at 200 nm to 30.231 (mA/cm²) at 400 nm. It then drops to its value at 24.655 (mA/cm²) at a thickness of 900 (nm) and as in Fig (2). The reason for their rise is the ability of the material to absorb more photons and, in turn, to make the highest contribution to the generation of electron-gap pairs that lead to their elevation. The reason for their decrease is the result of the union of the surface that leads to the depletion of the electrons [12,13] as well as the voltage of the open circuit (Voc) at 0.892 V at 200 nm to 0.801 V at 900 nm as shown in Fig. (3) due to the parallel impedance leading to a decrease in the voltage of the open circuit [14,15].

![Fig. 2: Effect of thickness of the absorbent layer p-MASnI₃ on JSC](image2)

![Fig. 3: Effect of thickness of the absorbent layer p-MASnI₃ on Voc](image3)

As for the filling factor (FF), the height of the thickness of 200 (nm) and 70.27%, and then decrease at a thickness ranging from (nm) 400 - 900 and their value is 70.11%, 47.51% respectively as shown in Fig (4). The increase of the absorption thickness and therefore because the increase of the interface of the interface, which generates a constraint that works on the capture of electrons and reduces the current depletion environment that negatively affects the...
values of the filling factor and because of the high process of the union at the interface. The laws capture electrons and reduce the current and thus lead to the drop filling factor, The filling factor is affected by the increase of the resistivity respectively because the higher the thickness the greater the value of the capacitor. Respectively, which blame lead to a reduction of overfilling factor [16].

Fig. 4: The effect of thickness of the absorbent layer p-MASnI3 on FF

The efficiency of the cell (η) increases by increasing the thickness of the MASnI3 from 15.32% at 200 nm to 18.63% at 400 nm and then decreasing to 9.79% at 900 nm. As in Fig (5), the efficiency of the bottom decreases with the thickness if the thickness of the absorber absorbs the largest length of the spread of the transport of the ship is the possibility of exposure of the Union even before reaching the poles metal cannot avoid the process of restoring the Union is not only by reducing the thickness of its absorption, Fish will increase the rate of re-union, which reduces the efficiency of the family and that the decrease in thickness leads to a reduction of the rate Which was reintroduced by the Union, thus increasing the efficiency of the Chalets [17,18].

Quantitative efficiency (QE) was 93% at 200 nm to 97% at 400 nm and then decreased to 64% at 900 nm. This means that the quantity efficiency decreases with the increase of fish and as Fig (6) where quantitative efficiency (QE) does not stop at the distance of p-n from the surface because the semiconductor material with the large power gap was used as a window layer allowing the photons with less energy E_g1 to pass through them, the photons that were energy E_g1 and E_g2 In the retail p-n [19]. Photons with long wavelengths will absorb deeply into the absorption layer p-MASnI3 and thus the quantum efficiency of the electrons generated there will be large and dependent on propagation length, thus increasing the value of Voc and Jsc [20]. The decrease in the efficiency value at long wavelengths is due to the low absorption coefficient, which leads to a decrease in the rate of carrier generation and increase the re-union rate at the back surface of the cell, which leads to a decrease in the length of propagation of the carriers and thus decreases the number of electrons generated for each absorbed photon [20].

Fig (6) QE with wavelength at different thickness variation

4. Effect of inactivation on the cell (ZnSe / p-MASnI3 / p-CuSCN n)

In the framework of this study, a mirror filter (95% mirror) was added from the library of the program (SCAPS) and the best cell of the studied cell nucleus (n-ZnSe / p-MASnI3 / p-CuSCN) (0.11-0.99). The best range of reflectivity was 0.99 and the efficiency of the cell (η) was 20.89%, the (FF) 68.55% and the short circuit current (Jsc) 34.048 (mA / cm^2) and the open circuit volt (Voc) 0.894 V where the increase in reflectivity Increase the energy absorption as the electron-gap generation rate increases as shown in Fig(7).

Fig (7) (I-V) charactiristic of the n- ZnSe/p-MASnI3/p-CuSCN cell with different reflectivity

The density of the short circuit current (Jsc) increases with the increase of the reflectivity concentration of the ZnSe n- mA / cm^2 (33.115) for the reflective material of the reaction material 0.11 to 34.045 (mA / cm^2) at a reflective concentration of 0.99. As in Figure (8). The V-volt increases slightly from 0.890 V at concentration of 0.11 to 0.890 V at the concentration of 0.99 as shown in Fig(9). This is due to an increase in the concentration of the anxiety in the background layer increasing the electric field (MASnI3), leading to increased separation between the gap and electron carrier (Exton), which results in an increase in the performance of the solar cells and the high value of Jsc Voc, as well as on the basis of equations (5), (4).
As for the efficiency of quantity QE, Fig (12) shows that there is a slight decrease in the reflection rate of the spectroscopy on the efficiency values at the wavelengths due to the absorption of this application which reduces the rate of generation of electron-gap pairs. The value of the efficiency quantity. As long as the photogaloch longitudinal lengths will be absorbed deeply into the P-MASnI3 absorption layer, there will be a significant reduction in quantum efficiency at the length of the cutting waveguide and based on the amalgamation (10) [19].

5. Conclusions

The study of the ETM / MASnI3 / HTM solar cell through the effect of thickness as well as the cell reflection of the I-V curve and the quantitative efficiency curve (QE) on the cell showed that the use of software computer in the simulation process to facilitate the process of manufacturing solar systems and reduces:

1- We estimate that the thickness of the absorption layer (400 nm) will increase the properties of I-V and QE and the best cell obtained is ZnSe / MASnI3 / CuSCN. The efficiency value was 18.63% (Voc) 0.879 V, short circuit current (Jsc) 30.231 (mA / cm²).

2- The value (ZnSe / MASnI3 / CuSCN) showed that the increase in reflectivity increases the bending properties (I-V) and slightly reduces the quantitative efficiency (QE) and the best cell obtained is (ZnSe / MASnI3 / CuSCN), Where the efficiency value was 20.89%, the value of the open circuit voltage (Voc) 0.894 V, the short circuit current value (Jsc) 34.048 (mA / cm²) and the value of the fill factor (FF) 68.55%.

6. References

[1] Fang, H.; Li, X.; Song, S.; Xu, Y.; and Zhu, J. (2008). Fabrication of slantingly-aligned silicon nanowire arrays for solar cell applications. Nanotechnology, 19(25): 255703.

[2] Babayigit, A.; Boyen, H. G.; and Conings, B. (2018). Environment versus sustainable energy: The case of lead halide perovskite-based solar cells. MRS Energy and Sustainability, 5.

[3] Im, J. H.; Lee, C. R.; Lee, J. W.; Park, S. W.; and Park, N. G. (2011). 6.5% efficient perovskite quantum-dot-sensitized solar cell. Nanoscale, 3(10): 4088-4093.

[4] Lee, M. M.; Teuscher, J.; Miyasaka, T.; Murakami, T. N.; and Snaith, H. J. (2012). Efficient hybrid solar cells based on meso-superstructured...
دراسة تأثير سلك وانعكاسة على خصائص الخلية الشمسية CuSCN باستخدام SCAPS-1D
طارق لديب محمد، عابد نجم صالح
قسم الفيزياء، كلية التربية للعلوم الصرفة، جامعة تكريت، العراق

الملخص

تم دراسة تأثير طبقات الألومنيوم (MASnI3) ضمن مدى (200nm-900nm) على سلك وانعكاسة للخلايا الشمسية CuSCN باستخدام SCAPS-1D
وطبقات المواد الألفابيتية (HTM) للمواد النائمة (الغلاية) عند سلك (10nm) بلون الألومنيوم (ETM) على سلك وانعكاسة للخلايا الشمسية CuSCN بنظام من مكتبة البرنامج (Cap) للخلايا الشمسية (95%mirror) وانعكاسة النانوديناميكية. وتمثل هذه الدراسة (99%) ونسبة طبقات الألومنيوم (MASnI3) بعضها بين (0.11-0.99) وكانت كفاءة الطاقة (η) (89.65) وعامل الإضاءة (FF) على الوليام (0.894 V (Voc) ونسبة الطاقة (η) 0.894 V (Voc)