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I-V Characteristics Calculation Using SCAPS-1D Program

SCAPS-1D Programı Kullanılarak I-V Karakteristiklerinin Hesaplanması

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Özet

Bu çalışmada, güneş pili modellemesi için en yaygın kullanılan simülasyon yazılımlarından birini sunuyoruz. SCAPS-1D programının kullanımı bu çalışmada adım adım anlatılmıştır. İlk adımda, heteroeklem güneş pillerini sunduk ve fotovoltaik etkiyi açıkladık. SCAPS programının işleyişini açıklamak için, bu programın kısa bir tarihçesiyle başladık ve ardından farklı özelliklerinin genel bir tanımıyla devam ettik. Bu programı çalıştırmak ve bir güneş pilinin I-V özelliklerini elde etmek için gereken tüm bu adımları önceden tanımlanmış bir örnek aracılığıyla netleştirdik. Sonunda, CdS/CIGS heteroeklemli güneş pili üzerindeki V_{oc} ve J_{sc} üzerindeki optik bant aralığı değişiminin örnek bir çalışmasını yaptık.

Anahtar kelimeler: SCAPS_1D, Güneş Hücresi, İnce Filmler, CIGS

Abstract

In this work, we present one of the mostly used simulation software for solar cells modelling. The usage of SCAPS-1D program has been explained in this work step by step. At the first step, we have presented the heterojunction solar cells and explain the photovoltaic effect. To elucidate SCAPS program operation, we have started by a brief history of this program and then continued with a general definition of its different properties. By the mean of a predefined example, we have clarified all the stages needed to operate this program and to obtain I-V characteristics of a solar cell. At the end, we have made an example study of optical band gap variation on the V_{oc} and J_{sc} on CdS/CIGS heterojunction solar cell.

Keywords: SCAPS_1D, Solar Cells, Thin Films, CIGS

1. Introduction

The direct conversion of incident light photons energy into electric energy by a p-n semiconductor junction device has been known as the photovoltaic (PV) effect. When Chapin *et al.*[1] has presented the silicon solar cells with a 6% conversion rate in 1954, it was considered as the initiation of a new era of PVs. This phenomenon had already been known for over a century. In that concept, solar cells have been quickly considered as a very effective way of continuously powering remote location devices, especially for the space industry. Of course, this application of photovoltaic spread rapidly to other uses that exist in our daily life. The structure, properties and operation principles of solar cells have been thoroughly studied worldwide and reported in literature [2]. When photon energy is larger than or matches the energy bandgap of semiconductor in use, they can be absorbed by the material. The gained energy as a result of absorption of photon excites electron from the valance band to the conduction band where it can freely move leaving behind a hole (absence of electron). When the generation of the electron- hole pair is in the depletion region (the contact area in the p-n junction of solar cell), the existing field in this area will separate them where they can be collected at the exterior (left and wright) contacts.

Even though the concept of the solar cells is simple, but its construction and development consume lots of time and energy. In order to overcome this problem, some groups have started developing various programmes and worked on modelling of these solar cells. The complexity level of the programs changes from one to another and it mostly depends on the introduced output data. The most common used programs in the recent years are COMSOL [3], SILVACO ATLAS [4], AMPS [5], wxAMPS [6], and SCAPS [7-12]. Among these software SCAPS program is considered to be very easy for beginners with very vast range of output and input data [7]. In this article, we have intended to introduce this program and give a brief explanation on its multiple functions.

2. Heterojunction Solar Cells

In order to understand SCAPS program better, we will start by introducing what is a solar cell first and then what are its different electric parameters?

An n-type window layer, a p-type absorber layer and a junction between them make up a conventional window-absorber p-n type junction solar cell as present in Fig.1. In a homojunction device, these areas are made of the same material, but in a heterojunction device, they are made of two distinct materials.

The junction between p- and n-type regions is considered as the most essential part of any solar cell. In this region, the charge separation of holes and electrons is taken place by absorption of energetic photons at the charge depletion region. Hence, it plays a big influence in determining device performance. When performance of a solar cells is studied, four different parameters are observed;efficiency (η), the short circuit current (J_{sc}), fill factor (FF) and the open circuit voltage (V_{oc}).

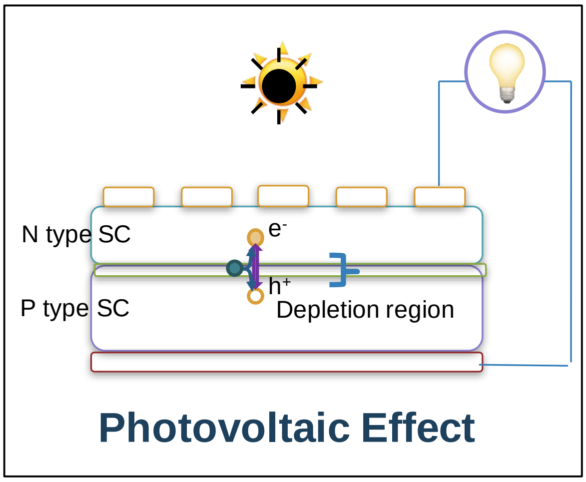

Figure 1: A schematic image of a pn junction solar cell.

3. SCAPS-1D definition

The first version of SCAPS-1D program was developed in 1998 by Marc Burgelman group at the university of Gent, Department of Electronics, and Information Systems (ELIS), Belgium. After that more than 50 versions has been developed until late this year (SCAPS 3.3.10) [13, 14]. This software is freely available with an easy working interface where the user can manipulate the different solar cells input parameters such as the thicknesses of different layers, the doping concentration, some electric properties such as mobility and dielectric effect, the doping distribution and concentration, the contacts different properties, etc. On the other hand, the usual calculated outputs using this program are I-V, C-V, C-f, QE. In order to use SCAPS-1D software correctly, some important steps must be taken into consideration. The example presented in this explanation section is taken from the SCAPS-1D package.

3.1. Opening and Loading

On the Desktop or on the file manager open the program or the scaps3310.exe file. The opened window is SCAPS Action Panel (Fig.2), on the left, click on the "Set problem" button and then choose "load" on the lower right of the Solar Cell Definition Panel. From the previously defined solar cells, we will choose "example CIGS.def" file and load it (Fig.3).

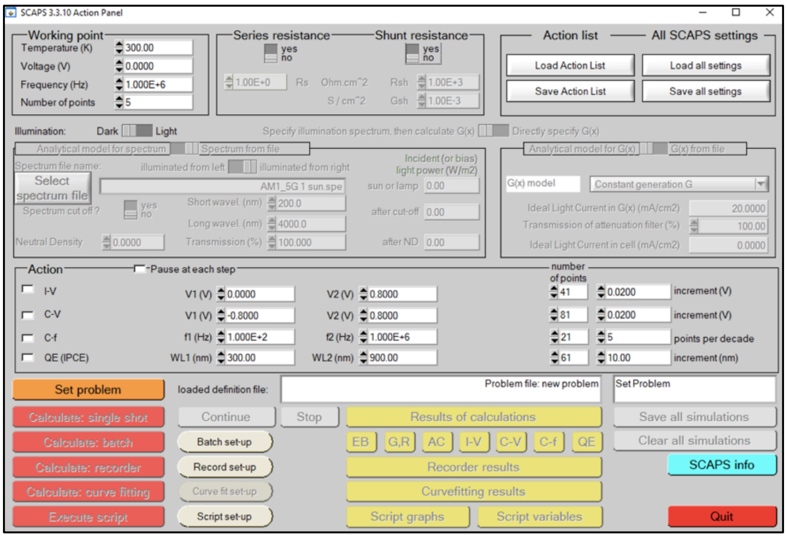

Figure 2: Action Panel in SCAPS program.

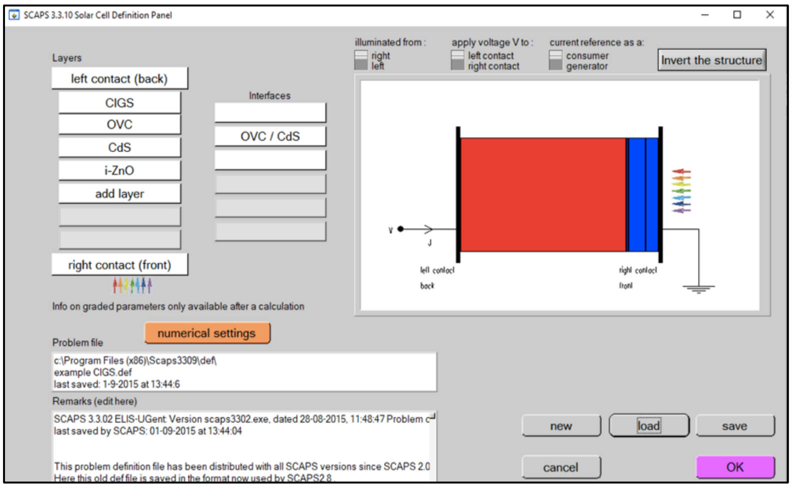

Figure 3: Solar Cell Definition Panel in SCAPS program.

3.2. Definition of Solar Cell

In our case, the different layers are already defined in a conventional p-n heterojunction solar cell. Thus, we will clarify the different chosen parameters of p-type CIGS absorber layer as an example by clicking on the layer button (Fig.4).

On the right of the “Layer Properties Panel”, we can fill out the different electric properties of the layer such as the optical band gap, the dielectric permittivity, the electron affinity, electron/hole mobility and the thickness as well. Down to the right, the absorption of the material can be set from a model or from the previously available files in the absorption library of the program. The defect on the left side of this panel is divided into three different types: Auger and radiative recombination which present band to band transition, also the SRH (Shockley-Read-Hall) recombination. In this model, they set only the SRH recombination by introducing a neutral, single, and uniform defect level with a defect density of 10*E18. After setting all the various properties of a layer, we can save the changing by clicking on “Accept” button. On both sides (up and down) of the structure on the right, we can also change the properties of the back and front contacts and also define a specific defect density at the interfaces between the different layers.

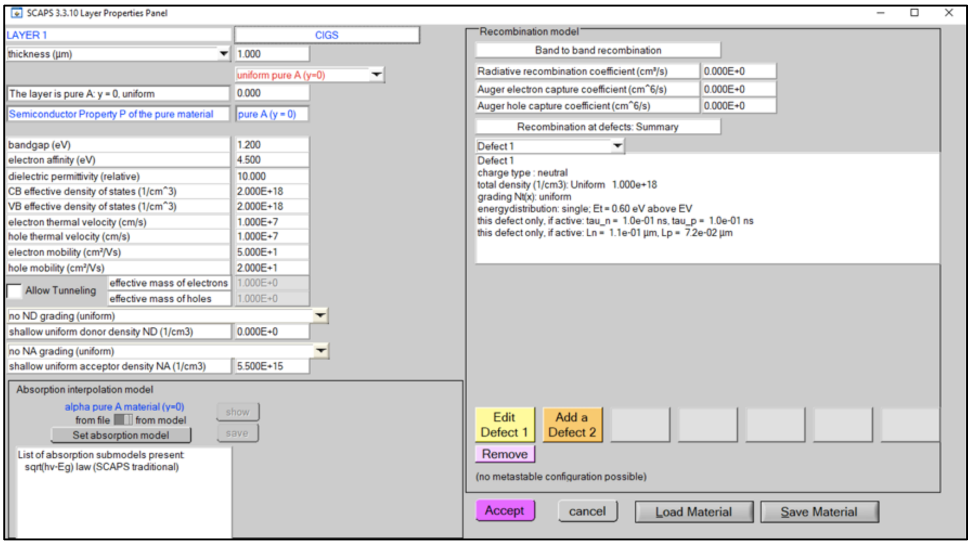

Figure 4: Layer Properties Panel in SCAPS program.

3.3. Operating of the program

After completing the simulation model of the solar cell, it is time to start testing the program by clicking on “OK” button that will take us back to the Action Panel.
At the upper left of the “Action panel”, we can define the working points that will be constant during the calculation process such as the temperature, the voltage, and the frequency. During the illumination mode, different types of spectrums can be defined according to the solar cell type and the wanted wavelength range that the solar cell will be working under.

In our case, we want to calculate I-V characteristics of the predefined solar cell so we will choose I-V checkbox. When the calculation ends, we can see the results by clicking the I-button on the right to open the I-V Panel as present in Fig.05. The I-V graph and the I-V characteristics like V_{oc} and J_{sc} can be seen at the interface, and we can also save them by clicking on “Save” button.

To study the effect of a certain properties like the thickness on the V_{oc} we can change this property using the “Bach set-up” Button (Fig.2) and then applying on “calculate Bach” button.

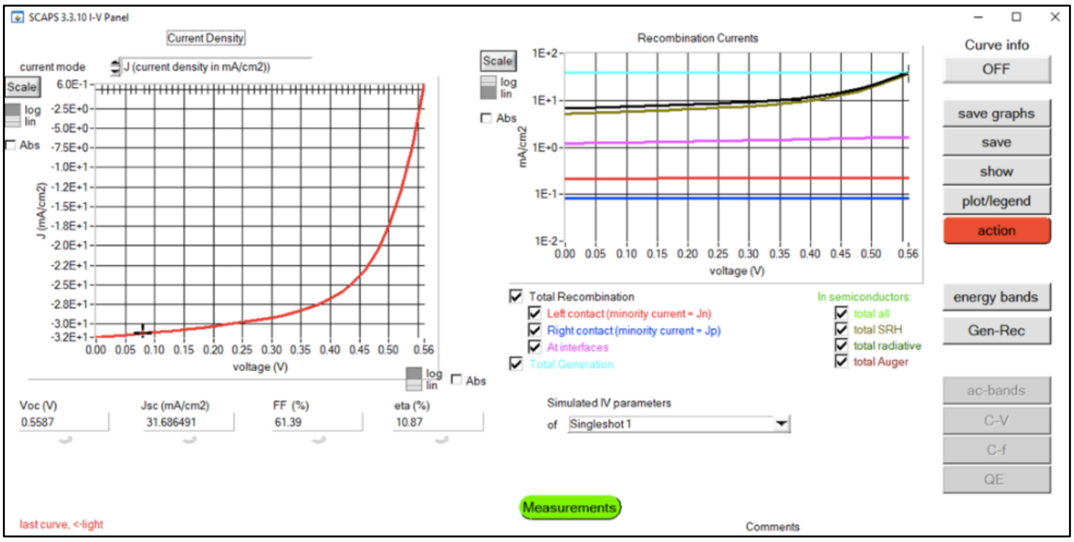

Figure 5: The I-V Panel in SCAPS program.

3.4. Example on the effect of absorber layer band gab variation

In this case, we will change the optical band gap values of the CIGS absorber layer from 0.9 eV to 1.6 eV and observe its effect on the V_{oc} and J_{sc} of the solar cell. In Fig. 6, the band gap increasing resulted in changing the values of V_{oc} from 0.3 eV to 0.9 eV. Thus, we can see that the program can detect the altering of the solar cells parameters and show its influence on the output data. Also in Fig.7, we can see that contrary to the V_{oc}, J_{sc} values decreased by augmenting the band gap where it reduces from 43.4 mA/cm^2 to 19mA/cm^2 , these observation are well explained in many article [15].

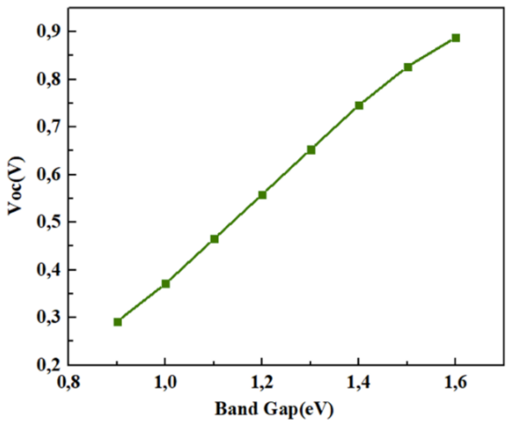

Figure 6: Simulated V_{oc} with increasing band gap values

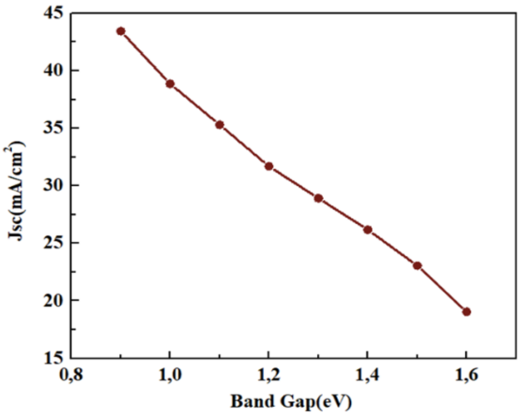

Figure 7: Simulated J_{sc} with increasing band gap values

4. Conclusion

In this article, we have given a brief introduction on the well-known SCAPS-1D simulation program used to simulate and predict the performance of the different solar cells. We have also provided explanations on the general use of this software. In addition, by using an existed model on the program library, we have described the general steps that must be followed to successfully obtain correct results on this program. At the end, we have presented an example study of the bag gap variation on the optoelectrical outputs of a solar cell.

5. References

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