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A Numerical Study Of P-Cuo/N-Azo/ Thin Film Solar Cells Metal Oxide Based Scaps 1-D

Zulfadli Pelawi[1], H. Alam[2]
[1,2]Department of Electrical Engineering, Universitas Islam Sumatera Utara, Medan, North Sumatera Indonesia
E-Mail: zulfadlipelawi@gmail.com

Keywords

Thin film Solar Cells, Metal Oxide semiconductor, AZO, Window Layer, SCAPS-1D.

Abstract. In this paper described a photovoltaic characteristics of thin film heterojunction solar cells comprising p-CuO/n-AZO were conducted numerically using a solar cell capacitance simulator (SCAPS-1D). The solar cells device performance p-CuO/n-AZO metal oxide based was investigated, in terms of different n-AZO parameters such as the thickness and carrier concentration. The simulation results indicate that the highest efficiency attain to 9 %, by setting n-AZO thickness and carrier concentration of 50 nm, and 5.0x1018 cm-3 respectively. According to the results obtained, we conclude that the presented thin film solar cell device simulation model using SCAPS 1-D tools could be a part of the solar cell classes with potential promise for photovoltaic applications

1. INTRODUCTION

Among the renewable energy sources, solar energy is attractive, sustainable, and promising to develop further. Hence, solar photovoltaic (PV) energy is considered a clean, environment-friendly, and secure source of electricity. For decades, the second-generation solar energy known as thin film solar cell (TFSC) is active research has been executed to discover new effective materials that utilize as an absorber or main layer (p-type), contact layer, and window layer (n-type). In solar cell structures, the window layer usually consists of three part layers; transparent layers with different electrical/optical properties, the front contact, and the buffer layer. Generally, those materials made from metal oxide based, and the materials are should be transparent and may fit into the band structure of solar cells. All-oxide-based semiconductor materials are promising candidates for the future of sustainable energy production, such as copper oxide-based materials (CuO/Cu_2O) and zinc oxide (ZnO). Li et al. reported, commercialized and emerging thin-film photovoltaic (TFPV) technology uses metal oxides as transparent electrodes, and buffers /window layers. Here, a good property or material that determines whether the oxide transparent and whether it is possible to allow light to reach the absorbing layer is that the difference between its energy levels for electrons, known or called its band gap, is much greater than the energy in the light with the energy used to produce current and finally produce electricity [9].Those semiconductor oxides include a wide variety of electronic properties, low cost, and have a longer lifespan in terms of stability and non-toxicity. As can be seen, window layer solar cells have been experimented with, and the results show that the intrinsic Zinc oxide (ZnO) and aluminum dope zinc oxide (AZO) commonly have been used in thin-film solar cells as the window layer.

The n-type aluminum dope zinc oxide (n-AZO) has been used in photovoltaic cells and particularly as a window layer in various thin-film solar cell applications due to its transparency in the area visible wavelength and the band-gap reach of 3.3 eV. It should be noted, that the window layer material with the low band gap there is no possibility to generate any photocurrent, and it is due to poor response to the shortwave solar spectrum. In addition, usually, the window layer in solar cell devices should be well optimized to reach low absorption and electrical resistivity and, as reported in the previous study. Hence, those properties make this metal oxide AZO suitable for semitransparent based solar cells and other types of solar cells. Additionally, AZO is a stable compound, and this material known that it will not react with the other materials.

A Numerical simulations of solar cells using Solar Cell Capacitance Program (SCAPS-1D) have been reported by Burgelman et al. in 1996. Based on the previous report, Minemoto et al. have successfully demonstrated the ability of SCAPS-1D to numerically simulate the performance of perovskite solar cells. In addition, among the salient features of SCAPS-1D, which render it appropriate for this study is its ability to simulate cell structure with various complex defect configurations such as bulk or interface, charge type (no charge, monovalent, divalent or amphoteric, and energetic distribution. Another research group reported, which has succcesfully simulated n-TiO2/p-CuO and n-TiO2/p-Cu2O heterojunction solar cells and analyzed the effects of layer thickness and defect density in buffer and absorber thin films on cell performance. In another report, they also presented the numerical study of J–V curves for n-TiO2/p-Cu2O solar cells and confirmed the potential use of the n-TiO2/p-Cu2O structure on the numerical simulations.

The aims of this study is to investigate the effect of the varied parameters such as the thickness and the carrier concentration of n-AZO window layer toward of the performance of p-CuO/n-AZO simulated model. It should be note, the illumination was set from the top of cell in order to obtain the good efficiency of the performance cell.

2. METHOD

The Solar Cell Capacitance Simulator or SCAPS is one of the modeling tools in a PV system and generally known as a free software as introduced by Burgelman et al. The modeling tools that was used in this work is SCAPS-1D version 3.3.08. Furthermore, the heterojunction solar cell of i-ZnO/p-CuO was simulated under standard illumination (AM 1.5 G, 100 mW/cm^2, 300K), and the schematic/structure of p-CuO/n-ZnO heterojunction solar cell devices was presented as described in fig.1and Fig.2. The main functionality of SCAPS is to solve the one-dimensional semiconductor equations. In the bulk of the layers, these equations

$$\frac{\partial}{\partial x} = \varepsilon_0 \varepsilon \frac{\partial \Psi}{\partial x} = \frac{d^2\Psi(x)}{dx^2} - q\,(p - n + N_{D-}\, N_A + \frac{\rho def}{q}) \qquad (1)$$

Where Ψ(x) is electrostatic potential, p and n are respectively electron hole density; and ε_0 and ε are vacuum and and relative permittivity respectively. Meanwhile, N_D and N_A are respectively charged impurities of donor and acceptor, ρ here as respectively electron/ hole distribution.

The numerical simulation was prepared using SCAPS software in purpose to find out the electrical characteristics (AC and DC) of heterojunction solar cells. We found that the solution generated for our issue simulation case. The software feature tools have a dark and light current, and the illumination results along with several other features. The design model proposed in this section consists of some layers and they are; Al/P-CuO/n-AZO/TiO2/ITO, as shows in Figure 1.

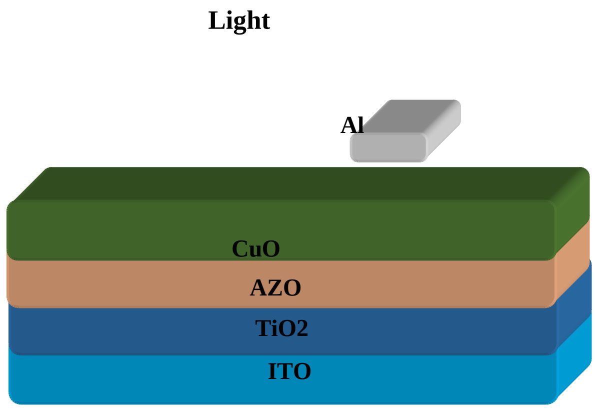

Figure 1. Semi-transparent TFSC CuO based device structure.

The output of a photovoltaic device is highly dependent on parameters such as the concentration of charge carriers, the thickness of the photovoltaic cell, the optical and electrical properties. The parameters required in the SCAPS-1D simulation for PV devices is as provided in Table 1.

Table 1. Parameters forTiO2, Cu2O, and CuO

Parameters	n-TiO2	n-AZO	p-CuO
Thickness (nm)	300	50-300	350
bandgap (eV)	3.20	3.300	1.5
electron affinity (eV)	4.2	4.450	4.070
dielectric permittivity (relative)	10	9	18.100
CB effective density of states ($1/cm^3$)	2.0x1017	2.2x1018	2.2x1019
VB effective density of states ($1/cm^{3)}$	6.0x1017	1.8x1019	5.5x1020
electron thermal velocity (cm/s)	100	1.0x107	1.0x107
hole thermal velocity (cm/s)	250	1.0x107	1.0x107
electron mobility (cm^2/Vs)	10	1.0x102	1.0x102
hole mobility (cm^2/Vs)	0	2.5x101	1.0x10-1
shallow uniform donor density N_D ($1/cm^3$)	1017	1.0x1018	0
shallow uniform acceptor density N_A ($1/cm^3$)	0	1	1.0x1016

3. RESULTS AND DISCUSSION

An According to relevant theories, the thickness of a window layer (n-AZO) mainly be influenced by its conductivity, which means when the conductivity of the window/buffer layer higher, the penetration of the depletion region towards the side of the absorber then causes the efficiency of the cell were increase as represented in 2D contour plots of J-V characteristic (Voc, Jsc, FF and η) of thin-film heterojunction of p-CuO/n-ZnO solar cells structure from our simulation model.

Here, we noticed that the short-circuit current density (Jsc) is bigger than 12 mA/cm2 for the thinner window layer, and it was maintained up to 14 mA/cm2 at thinner thickness. In this case, as can be seen from the results J-V characteristic solar cell performances are dependent on the thickness and carrier concentration (doping) parameter. From Fig. 2, the contour plots show the short circuit current density (Jsc) was increased when the thickness of the window layer was set at a lower thickness followed by the improvement of the J-V characteristic such efficiency (η), Voc, Jsc, and FF of the cell device.

We assume that the improvement of those parameters is owing to a better collection of the photogenerated electrons, which influenced the enhanced efficiency.

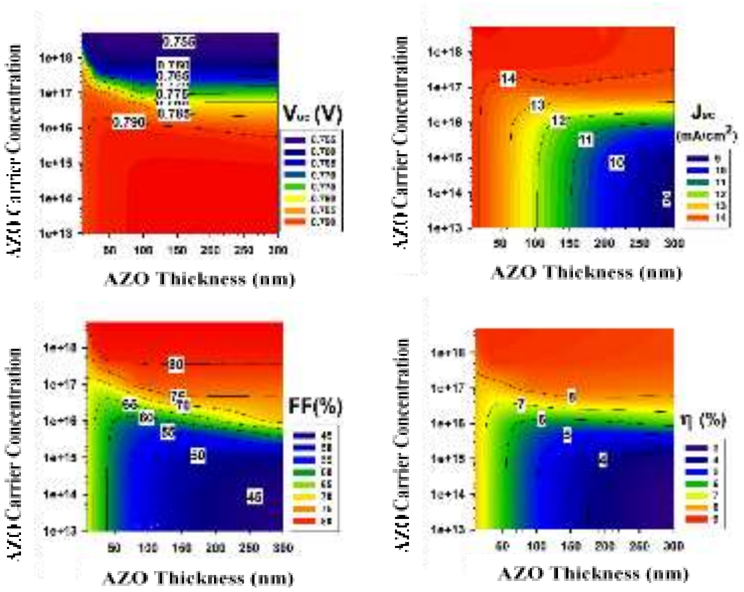

Figure.2. 2D contour plots of Thin-film heterojunction of p-CuO/n-AZO solar cell device

Furthermore, fig. 3. shows the performance of the thin film heterojunction of p-CuO/n-AZO solar cells by varying the carrier concentration of n-AZO window layer in the range area from $1x10^{18}$ cm^{-3} to $8x10^{18}$ cm^{-3} and It clearly shows that the higher doping concentration, the better the performance of a cell. Based on our investigation, in Fig.3. The characteristics solar cell parameters (Jsc, Voc, FF, and η) have been generated dependent on the doping/carrier concentration variation of the n-AZO layer.

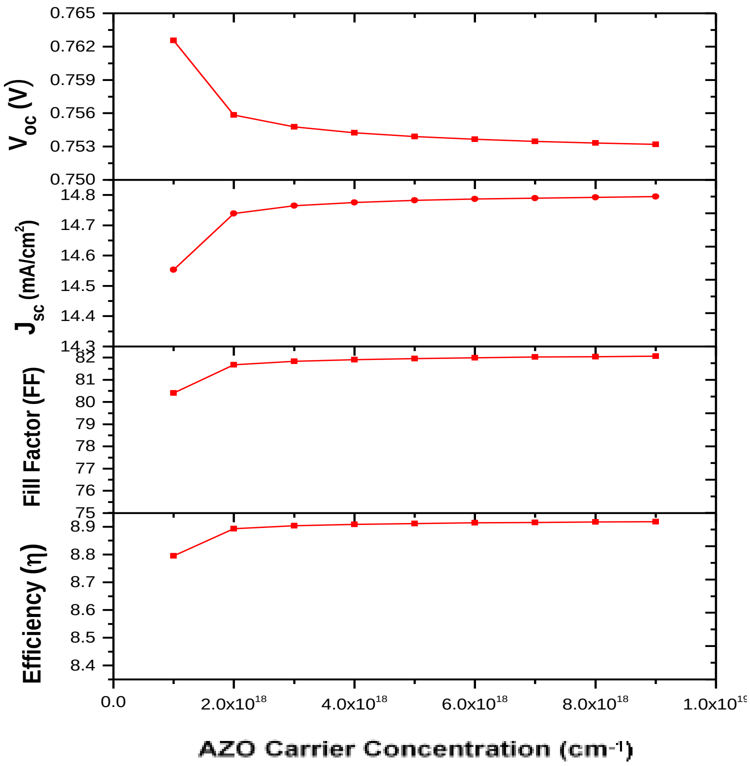

Figure3. The Plot Curve J-v Characteristic performance (Voc, Jsc, FF and η), of p-CuO/n-AZO solar cell device

However, unlike other parameters, we noticed that as the n-AZO level of doping concentration variation window layer was set lower the Voc values became higher as illustrated in Figure 3. These results show matched and supported theoretically, which the decrease in the reverse saturation current, Jo, results in the increase of open circuit voltage (Voc) value, and as explained by Shockley equation as expressed below;

$$V_{oc} = \frac{KT}{q} In \left(\frac{J_{ph}}{J_0} + 1\right) \qquad (2)$$

Where, T is defined as operating temperature, K is the Boltzmann constant, and q for the elementary charge, while J_{Ph} and J_0 are were described as the photo-generated current density and the saturation current density respectively.

4. CONCLUSIONS

The numerical study on metal oxide with different thickness and doping concentration of p-CuO/n-AZO thin-film heterojunction solar cell structure have been executed in this work. Our findings reveal that the best value for thickness and carrier concentration of the window layer in our presented model structure is 50 nm and 9x1018 cm-3 correspondingly, which is considered as the optimized parameter and corresponds to the cell efficiency result of 9%. We believe the optimimized n-AZO thickness and doping concentration values obtained in this work may be utilized for the fabrication process for the purpose can reducing the cost of the fabrication of TFSC by keeping the thickness thin for a whole layer in the structure of the device. Acknowledgments The SCAPS (3.3.07) simulation software used in this study was provided by Marc Burgelman, University of Gent, Belgium. We acknowledge the technical support given by Islamic University of North Sumatera (UISU) Medan, Indonesia.

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