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Preface

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Preface

The first edition of international symposium on physics and applications, 1st ISPA, was held from December 17 to 18, 2020 on Department of Physics, Institut Teknologi Sepuluh Nopember (ITS). The event was organized by Department of Physics, Faculty of Sciences and data analytic, ITS. The symposium is supported by Airlangga University, State University of Surabaya and National University of Singapore. However, due to the COVID-19 pandemic, The 1st ISPA 2020 was conducted virtually on December 17 to 18, 2020 in Surabaya, Indonesia through the Zoom Meeting platform.

In the symposium, we invite 6 keynote speakers and 6 invited speakers from Thailand, Malaysia, Taiwan, Japan, Bangladesh and Indonesia. The symposium has received significant interest amongst the community with 72 papers for oral presentations that have selected from 98 applicants received. The All papers are included addressing the research topics of the conference including theoretical physics, laser and optoelectronics, instrumentation and acoustics, earth sciences (geophysics), bio and medical Physics, and physics of materials.

We are grateful to A. Rubiyanto, S. Pratapa, A. Rusydi, Madlazim, and M. Yasin, who served as members of the Advisory Committee and actively contributed to accomplish a well-balanced scientific program. To our great pleasure, also a considerable number of graduate students lively participated. The keynote and invited speakers and also the participants who going to be presented papers: Thank you once more!

We hope during the symposium that we can develop research collaboration for supporting and increasing the quality of research in the physical sciences, in Indonesia.

The Editors,

Prof. Darminto
Dr. Lila Yuwana
Dr. Sungkono

1st International Symposium on Physics and Applications

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The 1st international Symposium on Physics and Applications, 1st ISPA or ISPA 2020, was held from December 17 to 18, 2020 on Department of Physics, Institut Teknologi Sepuluh Nopember (ITS). The event was organized by the Department of Physics, Faculty of Sciences and Data Analytics, ITS. Considering the covid-19 pandemic and the travel restriction, ISPA 2020 was conducted via Zoom Meeting. In addition, the symposium is supported by Airlangga University, State University of Surabaya, and National University of Singapore. This Proceedings issue compiles oral presentations that were submitted by the authors after rigorously reviewed by a special committee designated by the Journal of Physics Conference Series (JPCS) editor for ISPA.

Hopefully, we can develop research collaboration for supporting and increasing the quality of research in the physical sciences and its applications. We are grateful to the organizing and editorial committee that have actively contributed to accomplish a well-balanced scientific program. We also thank to graduate students lively participated, the keynote and invited speakers and also the participants who are going to be the presenter in ISPA 2020. The organizing and editorial committee, keynote and invited speakers are listed below.

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Keynote Speakers

No	Name	University/Institute/Organization
1	Bobby Eka Gunara	Institut Teknologi Bandung, Indonesia
2	Shammim Ahsan	Khulna University, Bangladesh

3	Hidetaka Arimura	Kyushu University, Japan
4	Kuo-Fong Ma	National Central University, Taiwan
5	Tosawat Seetawan	Sakon Nakhon Rajabhat University, Thailand
6	Muhammad Mahyiddin Ramli	Universiti Malaysia Perlis, Malaysia

Invited Speakers

No	**Name**	**University/Institute/Organization**
1	Hiroaki Yamanaka	Tokyo Institute of Technology, Japan
2	Suryani Dyah Astuti	Airlangga University, Indonesia
3	Hery Suyanto	Udayana University, Indonesia
4	Kuwat Triyana	Gajahmada University, Indonesia
5	Suasmoro	Institut Teknologi Sepuluh Nopember, Indonesia
6	Agus Purwanto	Institut Teknologi Sepuluh Nopember, Indonesia

In the symposium, we invited 6 keynote speakers and 6 invited speakers from Thailand, Malaysia, Taiwan, Japan, Bangladesh, and Indonesia. The symposium has successfully obtained positive responses from researchers by collecting significant and qualified 72 papers for oral presentations that have selected from 98 abstracts received. The presenters and participants are shown in **Figure 1**. The all papers are included addressing the research topics of the conference including theoretical physics, laser and optoelectronics, instrumentation and acoustics, earth sciences (geophysics), bio and medical physics, and material physics.

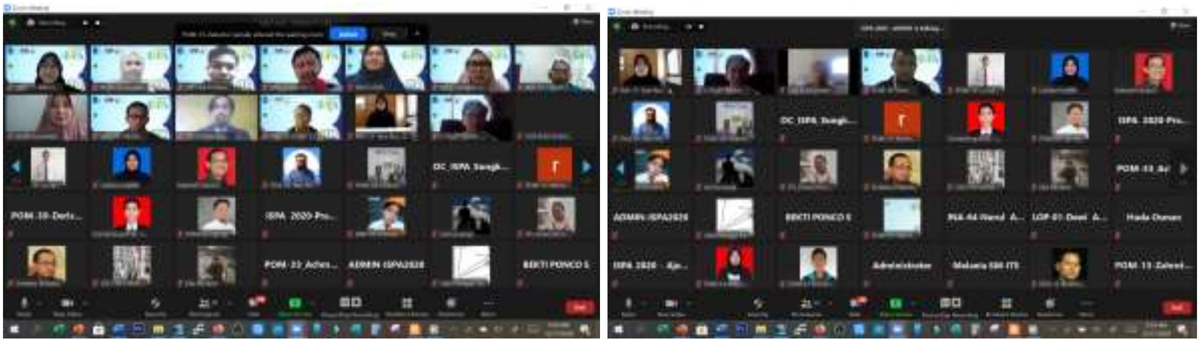

Figure 1. The participants of ISPA 2020.

The symposium is arranged for two days, the first day consisted of 3 keynote speakers, 3 invited speakers and 34 participants. As the first keynote speaker in plenary session, Dr. Muhammad M. Ramli from University Malaysia Perlis (UniMAP) - Malaysia, gave an excellent presentation on "Reduced-Graphene Oxide for Various Electronic Applications" (**Figure 2**). Keynote speakers present in plenary rooms (all participants the symposium) consecutively. Each keynote speaker will deliver their respective topic in the 30-40 minutes. Then the discussion (question and answer) between keynote speaker and audiences will be conducted in 10-20 minutes.

Figure 2. Keynote presentation from Dr. Muhammad M. Ramli

The second speech in plenary session was delivered by Prof. Kuo-Fong Ma from National Central University – Taiwan, with title of speech is "Earthquake: Knowns and Unknowns" (**Figure 3**).

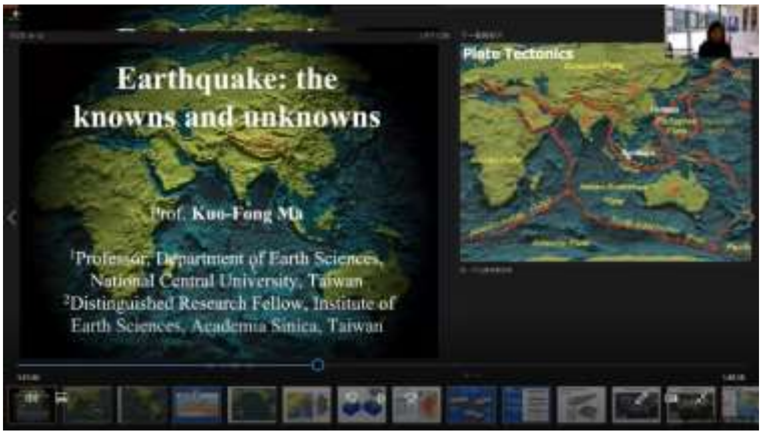

Figure 3. Keynote presentation from Prof. Kuo-Fong Ma

The third speech in plenary session was delivered by Prof. Shamim Ahsan from Khulna University – Bangladesh, with the title of speech is “Prospects of CO_2 Laser Polishing Technique” (**Figure 4**).

Figure 4. Keynote presentation from Prof. Shamim Ahsan

After the keynote speaker session, 3 invited speaker and 34 oral presentations were divided into 3 rooms based on work topics. Furthermore, invited speakers present their topic after plenary seasons in 25-30 minutes and discuss with participant in 10-15 minutes. Invited speaker rooms are parallel. In the parallel rooms, participants present their papers after invited speaker in 10-15 minutes and following discussions with others in 5 minutes. Following is the list of invited speakers:

1. Prof. Kuwat Triyana from Gajah Mada University - Indonesia with the title of speech is “Functionalized Quartz Crystal Microbalance with Polyvinyl Acetate/Citric Acid Nanofiber for Detecting Trimethyl Amine”.
2. Prof. Hiroaki Yamanaka from Tokyo Institute of Technology - Japan with the title of speech is “Exploration Geophysics for Earthquake Disaster Mitigation”
3. Prof. Suasmoro from Institut Teknologi Sepuluh Nopember - Indonesia with the title of speech is “Iron and Copper based BO6 octahedron of perovskite: Structure, Oxidation state, Electronic and Magnetic properties”

On the second day, this conference consisted of 3 keynote speakers, 3 invited speakers and 38 participants. The first speech in plenary session on second day was delivered by Prof. Hidetaka Arimura from Kyushu University - Japan, with the title of speech is "What is the medical physics from academic point of view?" (**Figure 5**).

Figure 5. Keynote presentation from Prof. Hidetaka Arimura

The second speech in plenary session on second day was delivered by Prof. Bobby Eka Gunara from Institut Teknologi Bandung – Indonesia, with title of speech is "Higher Dimensional Static Black Holes" (**Figure 6**).

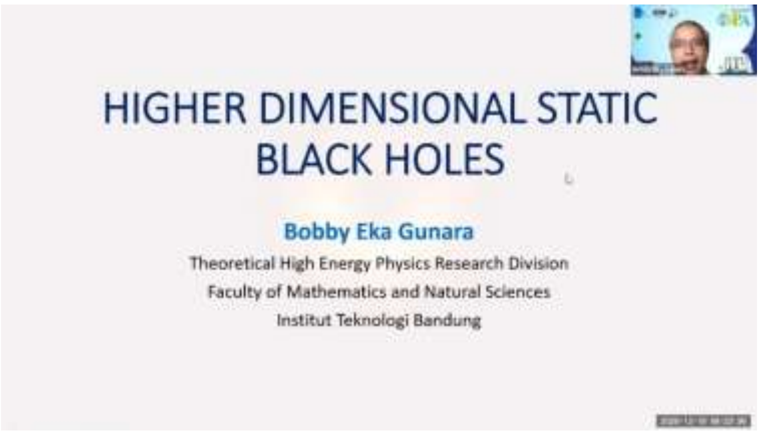

Figure 6. Keynote presentation from Prof. Bobby Eka Gunara

As the last keynote speaker in plenary session on second day, Prof. T Seetawan from Sakon Nakhon Rajabaht University – Thailand, gave a presentation on "Advantage of Flexible Thermoelectric Module for Small Generator."

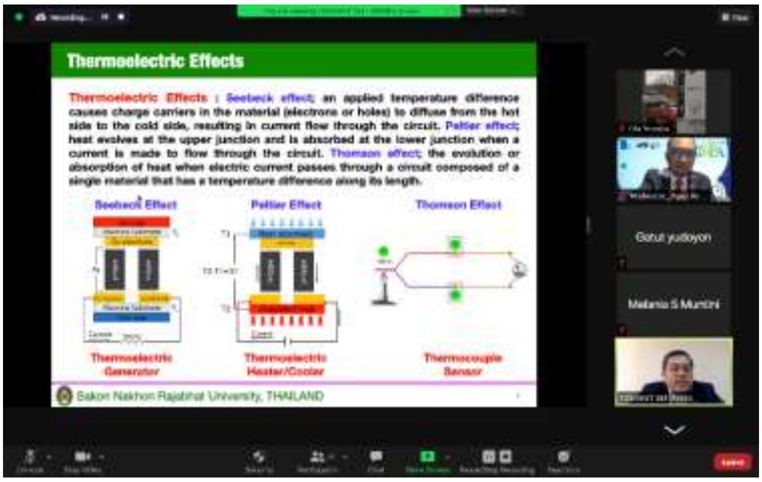

Figure 7. Keynote presentation from Prof. T Seetawan

After the keynote speaker session, 3 invited speaker and 38 oral presentations were divided into 3 rooms based on work topics. This is the list of invited speakers:

1. Prof. Suryani Dyah Astuti from Universitas Airlangga - Indonesia with the title of speech is “The Role of Organic Photosensitizer in Antimicrobial Photodynamic Inactivation (PDI)”.
2. Prof. Hery Suyanto from Udayana University - Indonesia with the title of speech is “Organic Materials Utilization for Biomarker and Forensic Needs by Using Laser-Induced Breakdown Spectroscopy (LIBS) Method”
3. Prof. Agus Purwanto from Institut Teknologi Sepuluh Nopember - Indonesia with the title of speech is “Relation between Channel and Measurement Matrices for Successful Quantum Teleportation.”

Here are several photos of oral presentation activities of the participants.

Figure 8. Several oral presentation activities

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Peer review declaration

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Peer review declaration

All papers published in this volume of Journal of Physics: Conference Series have been peer reviewed through processes administered by the Editors. Reviews were conducted by expert referees to the professional and scientific standards expected of a proceedings journal published by IOP Publishing.

- **Type of peer review:** Double-blind
- **Conference submission management system:** https://event.its.ac.id/ispa/
- **Number of submissions received:** 98
- **Number of submissions sent for review:** 73
- **Number of submissions accepted:**70
- **Acceptance Rate (Number of Submissions Accepted / Number of Submissions Received X 100):** 95.89%
- **Average number of reviews per paper:** 2
- **Total number of reviewers involved:** 42
- **Any additional info on review process:** All papers had undergone plagiarism check and double-blind review by two reviewers. Based on the plagiarisms check and reviewer comments, revised manuscript were submitted by authors for final publication.
- **Contact person for queries:**
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  Affiliation: Department of Physics, Faculty of Science and Data Analytic
  Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia
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Simulation of Hydrogenated Amorphous Silicon-based Solar Cell: Investigation of *J-V* Characteristic in Optimum Thickness

Simulation of Hydrogenated Amorphous Silicon-based Solar Cell: Investigation of *J-V* Characteristic in Optimum Thickness

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Abstract. One of the factors that influence the current density-voltage (*J-V*) characteristics of solar cells is the thickness of the constituent material's layers. Thus, when the solar cell is constructed using p/i/n junctions type, each layer thickness will contribute to the resulting electrical characteristics. In this research, a simulation of solar cell's electric current density calculation based on amorphous hydrogenated silicon has been carried out. The simulation is conducted to determine the numerical solution of the two-dimensional semiconductor equation, which is the distribution of the number of electron charge carriers and holes in the simulated solar cell device. It was started by determining the optimum thickness producing the best performance from each layer. Material performance indicators are seen based on the *Jsc* and *Voc* values. The p layer thickness in the p/i/n junction was simulated with the variation (70-220)Å/5500Å/300Å. The active layer was manufactured with variations of 150Å/(4500-7500)Å/300Å. Finally, we have also simulated the *J-V* characteristic of a solar cell by thickness variation for the n layer in the p/i/n junction is 150Å/5500Å/(100-350)Å. The results obtained from each simulation process are then re-simulated in each layer's optimum thickness combination. Through a series of simulated processes of each layer, the best results were obtained when solar cells based on hydrogenated amorphous silicon were made at a thickness of 190Å/7500Å/150Å, with *Jsc* and *Voc* of 5.33 A⁄m and 0.65 V, respectively.

1. Introduction

Over the period of time, the photovoltaic research has been improved to raise the better performance of high-efficiency solar cells. The design, material properties, and fabrication technology become the main factors determining the performance of solar cells. Numerical modeling and simulation in the solar cell have been the best approach to finding an optimized structure with well fitted parameters.The proposed physical structures, geometry on cell performance, and fitting of modeling output to experimental results could be observed and tested by numerical simulation.

Hydrogenated amorphous silicon (a-Si:H) has been known as a good candidate for optoelectronic material applied to solar cells. Besides its high optical absorption coefficient [1], a-Si:H material has a bandgap that can be tuned from 1.6 to 1.8 eV. This energy lies in band gap energy (1.7 eV), at which high solar energy conversion efficiencies are expected [1]. Compared to other structures, hydrogenated amorphous silicon material has low-temperature deposition capability. Therefore, material fabrication has a low manufacturing cost.

In previous research, the process of optimizing the thickness of the p-layer, intrinsic layer and n-layer on a-Si: H based solar cell device was carried out by Siddique et al [2]. Each thickness variation is compared with each other for best performance using the wx-AMPS simulator. The optimum thickness of p-layer, i-layer and n-layer were 20 nm, 830 nm and 30 nm, respectively, with the highest efficiency being 17.7483% [2].

In this work, we will study the characteristics of the maximum thickness of solar cells based on amorphous silicon material using the Femlab simulator. This software is good enough at describing the phenomenon of the transport of electric charge carriers in semiconductor materials. The electrical parameters of an amorphous silicon hydrogenated solar cell are investigated theoretically using a two dimensional model. By using a two-dimensional geometric model, one can see how the uniform distribution of the concentration of the charge carrier is calculated at a certain thickness. In another study, two-dimensional modeling of solar cells based on perovskite nanoroad for dark case study has achieved a good match between analytical and numerical finite element model [3]. The model describes the simple p-i-n junction structure. The purpose of the work is to show how solar cell electrical parameters, in the form of *J-V* characteristics, are related to the optimum thickness of the device layers. Here, the short circuit current density, and the open-circuit voltage, are calculated considering each layer's optimum thickness respectively. The last calculation should be done to simulate the final J-V characteristic by combining the three optimum thicknesses, from the optimization process of p-layer, i-layer and n-layer.

2. Methods

All simulation procedures for calculating the concentration of free charge carriers use Femlab. The results obtained from the previous step are used to calculate the electric current density and create a J-V curve, using Matlab 5.1. The geometry of a-Si:H-based solar cell p-i-n junction is modeled in a two-dimensional structure. Figure 1 shows a simple model of a device with an initial thickness of the p/i/n junction of 150 Å/5500Å/300 Å, respectively, which were performed experimentally by Usman [4]. The variation in thickness of each layer was simulated, with the other two layers thickness were made constant. The p-layer was simulated at a thickness variation of (70-220) Å, while for the i-layer, it was varied at the (4500-7500) Å interval. For the n layer, the thickness simulated is in the range (100-350) Å.

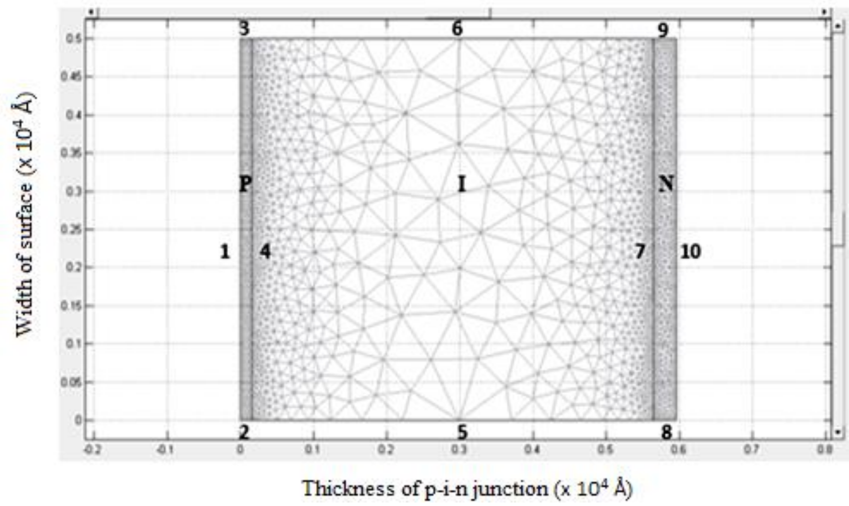

Figure 1. The two-dimensional geometry of the solar cell device is based on the a-Si: H material for the p / i / n junction structure with an initial thickness of 150 Å / 5500 Å / 300 Å. The variation in thickness of each layer was simulated, with the thickness of the other two layers being constant.

Figure 1 is a model of a solar cell device when observed from the side of the device. The incident photon, with a simulated power of 34 mW, hits the left side of the device and undergoes energy absorption depending on the material's absorption coefficient. The x-axis represents the thickness of the p-i-n layer, while the y-axis represents the device's surface width that receives light energy.

Tabel 1. Input Parameter

Parameter	Number	Referenc e
electron charge (q)	1.602 x 10^{-19} C	[5]
Temperature (T)	300 K	[5]
Boltzman constant (k)	1.38 x 10^{-23} J/K	[5]
Vacuum permittivity (ϵ_0)	8.85 x 10^{-14} F/cm	[6]
Intrinsic concentration (n_i)	1.46 x 10^{10} cm^{-2}	[5]
Relative permittivity of silicon (ϵ_r)	11 F/cm	[5]
Photon flux (F)	$10^{17}cm^{-2}s^{-1}$	[5]
Transmission factor (P)	0.71 S/cm	[5]
Electron mobility (μ_n)	40 cm^2/Vs	[6]
Hole mobility (μ_p)	5 cm^2/Vs	[5]
Electron diffusivity (D_n)	40 cm^2/s	[6]
Hole diffusivity (D_p)	5 cm^2/s	[6]
Energy gap of p-layer (Eg_p)	2.00 eV	[7]
Energy gap of i-layer (Eg_i)	1.6 eV	[5]
Energy gap of n-layer (Eg_n)	1.65 eV	[5]
Ratio between ionized and neutral charge (c)	100	[5]
Donor energy(E_D)	0.088 eV	[5]
Acceptor energy(E_A)	0.053 eV	[5]
Minimum energy of conduction band (E_{mc})	0,65	[5]
Concentration of ionized donor (N_D)	10^{17} cm^{-3}	[5]
Concentration of ionized acceptor(N_A)	10^{17} cm^{-3}	[5]
Absorption coefficient (α)	9.2 x 10^4 cm^{-1}	

For the simulation to produce a short circuit current density (*Jsc*) that is close to the previous experiment conducted by Usman [5], the selective absorption coefficient of 9.2×10^5 cm^{-1}has been used in the simulation. The absorption coefficient defines the ability of the material to absorb the photon energy of the sun. Hydrogenated amorphous silicon materials have a reasonably large absorption coefficient (> 10^5 cm^{-1}) [1]. For simplicity, some parameters are applied without units after applying a scale factor to them.

Neuman boundary conditions are used for the solar cell layer's surface, which is not related to contact, while the other side applies the Dirichlet boundary condition [6]. The relationship between hole (p) and electron concentrations (n) and intrinsic concentration n_i at the quasi-Fermi level is defined

$$p = n_i e^{-\psi} v \quad (1)$$

$$n = n_i e^{\psi} u \quad (2)$$

The concentration distribution of charge carriers is obtained from the solution of the Continuity Equation and the Poisson's equation, which is applied to hydrogenated amorphous silicon materials [7]. The results obtained from the simulation are electric current density at various voltages. The optimum value of each thickness variation of p-layer, i-layer, and n-layer is taken from the highest short circuit current density *Jsc*. It can be inferred that the characteristics of deposited layers will affect the output performance of solar cells during the efficiency measurement [8]. The greater the number of *Jsc* and *Voc*, the better the solar cells' performance [9]. The optimum thickness combination of each layer is simulated again to find the *J-V* characteristics obtained.

3. Result and Discussion

3.1. Optimum Thickness Determination of each layer in p-i-n structure

The holes tend to move more slowly and are easily lost during the recombination process than electrons. This causes every photon that enters through the p layer to be easily absorbed by electrons and allows many photons to enter the active region. This causes the p layer known as the window layer, and holes are mostly generated in this layer [10]. The variation in thickness in the p-layer positively contributes significantly to the increase in the number of holes and the intensity of light transmitted. The *J-V* characteristics of the simulation results at various thicknesses are shown in Figure 2.

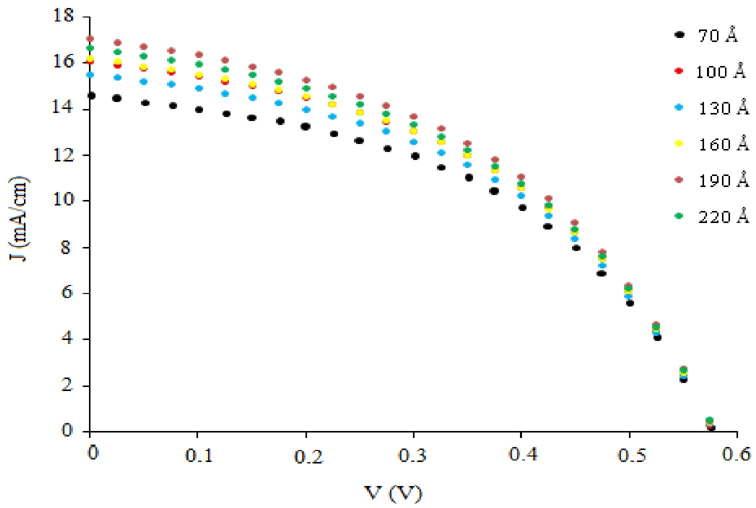

Figure 2. *J-V* Curve at thickness variation of p-layer, where the i and n layers adjust to5500Å and 300Å.

Increasing the thickness of the p-layer affects the amount of photons uptake. The thickness of the p-layer, which is very thin (70Å), makes the p-layer act as a depletion layer so that a diffusion potential is not formed [5]. Conversely, if the p-layer is too thick, it will reduce the function of the p-layer as a window layer so that photon energy begins to be absorbed by the p-layer [11]. Therefore, the p-layer thickness of 220Å causes *Jsc* to decrease. Excessive absorption of photon energy by the p-layer will result in reduced photon energy received by the i-layer. As a result, the load carrier formation process (generation process) is hampered so that the resulting *Jsc* decreases. In this work, no calculation of electric current density at a thickness of 150 Å. The electrical characteristics of the material at this thickness are assumed to have trend-following results between a thickness of 130 Å and 160 Å. According to the data presented in Figure 2, increases in *Jsc* occur regularly from a thickness of 130 Å to 190 Å. Based on the simulation, the p-layer thickness producing the highest *Jsc* was obtained at a thickness of 190 Å. The amounts of *Jsc* and *Voc* are 17.09 mA/cm and 0.575 V, respectively.

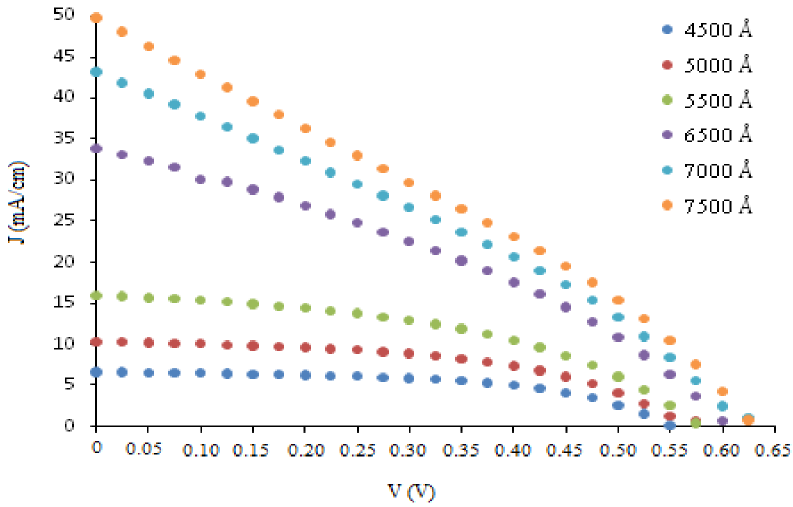

Figure 3. J-V Curveat thickness variation of i-layer, where the p and n layers adjust to 150Å and 300Å.

The i-layer is a depletion and active layer of solar cells that play an essential role in utilizing photon energy for the excitation process of charge carriers from the valence band to the conduction band. The variation in the thickness of the i-layer can affect the current-voltage density characteristics of solar cells because of its enormous contribution to creating a photocurrent generator. The simulation results are shown in Figure 3. An increase of i-layer thickness caused the more photon energy absorbed and also the multiplication of electron-hole generation [8]. In the thickness range of i-layer from 450 A to 7500 A, the depletion layer elongated, which increased the number of donor and acceptor ions.The increase in the ion diffusion path length can also make a longer lifetime and increase the drift current [12] .The figure shows the i-layer thickness's effect on the short circuit current density (*Jsc*) and the open-circuit voltage (*Voc*). The thin i-layer reduces the amount of absorbed photon energy, thus inhibiting the charge carrier generation process.This can be seen from the resulting small Jsc value.

In contrast, the highest *Jsc* and *Voc* values were 49.66mA⁄cm and 0.625 volts, respectively, obtained when the i-layer was thickest, which was 7500 Å. The generation process requires sufficient photon energy to run smoothly [4].Therefore, the optimum thickness will provide sufficient photon energy absorption to increase the charge carrier generation process rate.

The n-layer is referred to as the negative pole for solar cells [5].Thickness variations of the n layer were simulated to obtain the optimum thickness to produce the best *Jsc* and *Voc* values. The simulation results are shown in Figure 4. It shows that the n layer's variation can provide a significant change in the Jsc value. As the thickness of the n-layer continues to increase, the short circuit current density (*Jsc*) and the open-circuit voltage (*Voc*) decrease. The largest decrease in *Jsc* occurs when the thickness is increased from 300 Å to 350 Å, while the *Voc* value appears constant at 0.575 volts. This indicates that the increase in thickness is not sufficient for the n-layer. The simulation results obtained follow previous research conducted by Takahashi and Konagai with the highest Jsc results at a thin n-layer thickness of 90 Å [13]. In general, it can be said that the best *J-V* graph will be obtained when the n-layer thickness is thin enough. By making it very thin to this layer, a large fraction of the charge carrier created by the intrinsic part passes easier to reach the external contact, where it can then be utilized.

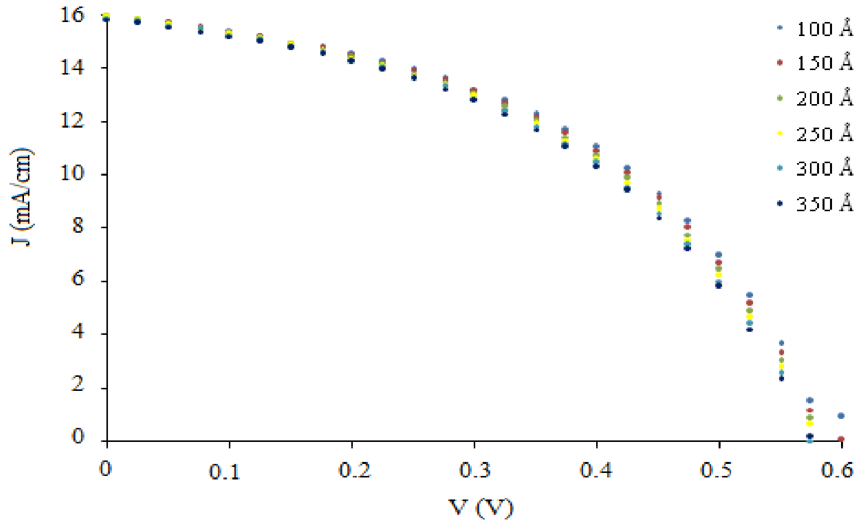

Figure 4. J-V Curveat thickness variation of n-layer, where the p and i layers adjust to150Å and 5500Å.

3.2. J-V Characteristic for Optimum Thickness

The optimum thickness of each layer on a-Si: H-based solar cell with a p-i-n structure is expected to be the best combination to increase *Jsc* and *Voc*. Simulations were carried out on the three optimum thicknesses of the layers, namely the combination of 190 Å / 7500 Å / 150Å. Figure 5 provides the results of calculating the electric current density at the voltage variations generated by the device.

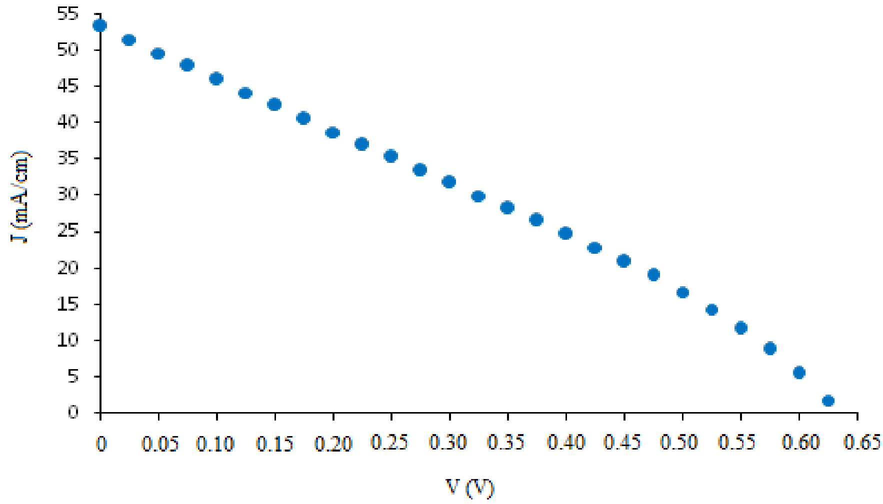

Figure 5. *J-V* Curve at an optimum thickness of each layer, which is adjusted to the variation of 190 Å/7500 Å/150 Å.

The short circuit current density *Jsc* and open-circuit voltage *Voc* obtained are 53.3 mA/cm and 0.65 V, respectively. This value is undoubtedly influenced by the choice of the impurity concentration in the simulation. The calculation of the defect condition that occurs due to the presence of dangling bonds in the bond structure contributes to the increase in the number of charge carriers to cause a shift in the Fermi energy level in the material.

What we have done here was merely having simulated the electrical characteristic of hydrogenated amorphous silicon, without modification in each junction or surface coating. The research purely wants to know more about the effect of each layer optimization process in the resulting electrical performance of solar cells. Therefore, the next consideration needs to be applied in order to know some possibilities related to the real experiment result.

4. Conclusion

The variation in thickness of each layer contributes to the J-V characteristics of solar cells based on amorphous hydrogenated silicon materials. The optimum thickness of the p layer is 190 Å with a *Jsc* of 17.09 mA/cm and a constant *Voc* of 0.575 V. The optimum thickness for the n layer is 150 Å, with *Jsc* and *Voc* are 15.98 mA/cm and 0.6 V, respectively. Significant changes were obtained when varying the thickness of the active layer, and the optimum value was obtained at 7500 Å with *Jsc* and *Voc*, respectively 49.66 mA/cm and 0.625 V. The combination of the optimum thickness of each layer gave an increase in the performance of the resulting *J-V* characteristics. The *Jsc* and *Voc* values of 53.3 mA/cm and 0.65 V, respectively, were obtained when the a-Si: H-based solar cell device was deposited at a thickness of 190 Å / 7500 Å / 150Å.

Acknowledgment

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References

[1] Kabir MI, S A Shahahmadi, V Lim, S Zaidi, K Sopian, and N Amin 2012 Amorphous Silicon Single-Junction Thin-Film Solar Cell Exceeding 10% Efficiency by Design Optimization. *International Journal of Photoenergy* **2012**:1-7

[2] Siddique MA, M K Hasan, M A Matin, N Amin, and M M Rahman 2017 Modeling and Simulation of Highly Efficient Amorphous Silicon Single Junction Solar Cell, *Proceedings of The International Conference on Mechanical Engineering and Renewable Energy* (ICMERE) 18-20 December 2017, (Chittagong-Bangladesh)

[3] Ali N Ali, T A Ali, N H Rafat 2019 *IEEE Journal of Photovoltaics* PP(99):1-10

[4] Usman I, and T Winata 2008 *Jurnal Matematika dan Sains.***13** (4): 109-113

[5] Usman, I 2006 Penumbuhan Lapisan Tipis Silikon Amorf Terhidrogenasi dengan Teknik HWC-VHF-PECVD dan Aplikasinya pada Divais Sel surya *Thesis* Bandung: Institut Teknologi Bandung

[6] Purwandari E, and T Winata 2012 *Jurnal Gradien.* **8** (1): 716-721

[7] Solehuddin M 2016 Simulasi 2D perhitungan efisiensi konversi energi sel surya persambungan p-i-n berbasis material silikon amorf terhidrogenasi (a-Si:H) *Thesis* (Jember: Universitas Jember)

[8] Benigno I and Darminto 2017 Effect of intrinsic layer energy gap and thicknesses optimization on the efficiency of p-i-n amorphous silicon solar cell, *IPTEK*, *Journal of Science***2** (3):37–42

[9] Rusman. 2015. Pengaruh Variasi Beban terhadap Efisiensi Solar Cell dengan Kapasitas 50 WP. *Jurnal Teknik Mesin Universitas Muhammadiyah Metro*. **4**(2): 84-90

[10] Stuckelberger M E 2014 Hydrogenated Amorphous Silicon Impact of Process Conditions on Material Properties and Solar Cell Efficiency *Thesis* (Swiss: Ecole Polytechnique Federale De Lausanne)

[11] Hamakawa Y 1981 Recent Progress Of The Amorphous Silicon Solar Cells and Their Technology *Journal de Physique Colloques* **4**2(C4):1131-1142

[12] H Fujiwara and M Kondo 2007 *J. Appl.Phys* **101**(5):54516 Takahashi K dan M Konagai 1986*Amorphous Silicon Solar Cells*(London: North Oxford Academic Pub. Ltd.)