UNIVERSITI TEKNOLOGI MARA | Cawangan Perak

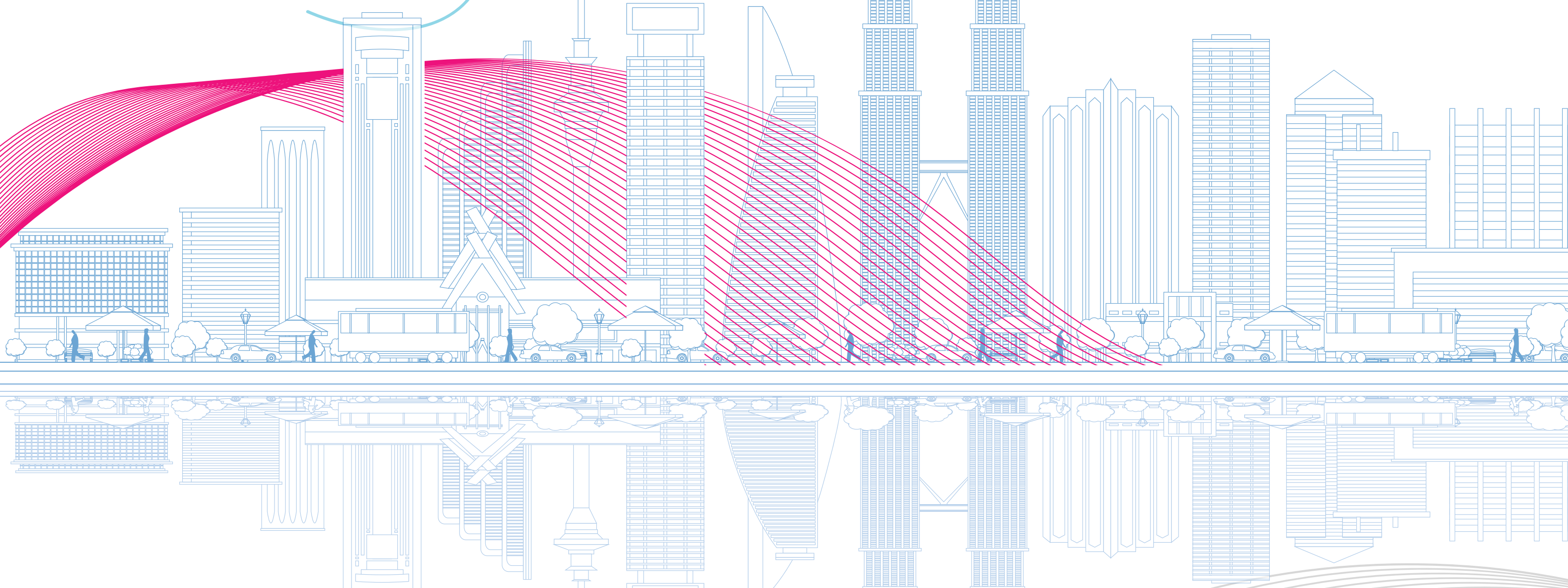
e - Proceedings

IUGeT

Proceeding for International Undergraduates Get Together 2024 (IUGeT 2024)

"Undergraduates' Digital Engagement Towards Global Ingenuity"

2nd Edition



Organiser :

Department of Built Environment Studies and Technology, College of Built Environment, UiTM Perak Branch

Co-organiser :

INSPIRED 2024. Office of Research, Industrial Linkages, Community & Alumni (PJIMA), UiTM Perak Branch

Bauchemic (Malaysia) Sdn Bhd

Universitas Sebelas Maret

Universitas Tridinanti (UNANTI)

Publication date :

November 2024

e - Proceedings

Proceeding for International Undergraduates Get Together 2024 (IUGeT 2024)

"Undergraduates' Digital Engagement Towards Global Ingenuity"

Organiser :

Department of Built Environment Studies and Technology, College of Built Environment, UiTM Perak Branch

Co-organiser :

INSPIRED 2024. Office of Research, Industrial Linkages, Community & Alumni (PJIMA), UiTM Perak Branch

Bauchemic (Malaysia) Sdn Bhd

Universitas Sebelas Maret

Universitas Tridinanti (UNANTI)

Perpustakaan Negara Malaysia Cataloguing in Publication Data

No e- ISBN: 978-967-2776-42-0

Cover Design: Muhammad Anas Othman
Typesetting : Arial

e-ISBN: 978-967-2776-42-0

iVUTI 2024 Committee

Project Leader
Ts Muhammad Naim Mahyuddin

Assistant Project Leader 1
Dr Ezzat Fahmi Ahmad

Assistant Project Leader 2
En Mohd Fadzli Mustaffa

Secretariat 1
Syahmimi Ayuni Ramli

Secretariat 2
Nur Afiqah Anuar

Treasurer
Dr Izrahayu Che Hashim

Registration Team
Dr Asmaa' Che Kassim
Dr Fatin Syazwina Abdul Shukor
Dr Suwaibatul Islamiah Abdullah Sani

Certification Team
Ts Nurul Huda Abdul Hadi
Ir Raja Nurulhaiza Raja Nhari
Dr Siti Jamiah Tun Jamil

Graphic Team
Mohammad Fitry Md Wadzir
Jannatun Naemah Ismam,
Nor Azizah Talkis
Wan Nur Hanani Wan Abdullah

Promotion Team
Nurulanis Ahmad@Mohamed
Najma Azman
Ts Sr Dr Asmat Ismail

Evaluation Team
Dr Suzanah Abdullah
Haslina Hashim
Azlizan Adila Mohamad
Noorsazwan Ahmad Pugi
Gs Dr Munirah Radin Mohd Mohktar
Mohd Najib Husain

Publication Team
Nur'Ain Ismail (Head)
Siti Nurhayati Hussin (Chief)
Dr Nuramira Anuar (Sub-chief)
Dr Paul Gnanaselvam A/L Pakirnathan
Noorlinda Alang
Norasyikin Abdul Malik
Halimatussaadiah Iksan
Nurdiyana Mohamad Yusof
Syaza Kamarudin
Dr Wan Nordiana Wan Ali
Dr Ida Nianti Mohd Zin
Dr Nurul Sahida Fauzi
Dr Noor Rizallinda Mohd Ishak
Dr Lizawati Abdullah
Iza Faradiba Mohd Patel
Nurfatima Wahida Nasir
Nazirul Mubin Mohd Noor

e-ISBN: 978-967-2776-42-0

NUMERICAL MODELLING OF HIGH EFFICIENCY GaAs/Si SOLAR CELL USING VARIOUS DLARC

Fatinah Najwa Roslan[1], Madhiyah Yahaya Bermakai[2*]

[1,2] Faculty of Applied Sciences, Universiti Teknologi MARA, Perlis Branch, 02600, Arau, Perlis, Malaysia

*madhiyah@uitm.edu.my

Abstract
Photovoltaic technology refers to the ability of a solar cell to convert solar energy into electrical energy through the absorption of sunlight. Prioritizing the utilization of the anti-reflective coating (ARC) is essential to optimize the functioning of the technology. In this investigation, however, the primary focus will be on the ARC material to maximize the solar cell's efficiency. Finding a material for a double-layer anti-reflective coating (DLARC) that will maximize solar cell absorption in GaAs/Si is the major goal of this design. In addition, research is being done on the photovoltaic characteristics of various materials for the DLARC in GaAs/Si solar cells and the efficiency of silicon, or Si, as the p-type and gallium arsenide, or GaAs, in solar cells. Using the Personal Computer 1-Dimensional (PC1D) simulation, the researchers will conduct the experiment, which several prior researchers have utilized. According to the predicted outcomes, double-layer anti-reflective coating (DLARC) will be more efficient than single-layer anti-reflective coating (SLARC). Additionally, experimenting using the material's variables to achieve the greatest efficiency will reveal the attributes that can aid in selecting the ideal material for DLARC. Identifying the right material for DLARC will result in a drop in light reflectance and a rise in light absorption, potentially increasing the efficiency of the solar cell. In conclusion, DLARC pairing material selection for GaAs/Si solar cells may be ascertained using PC1D modelling. Among the nine designs, Scheme 8's $MgF2/Si3N4$ yields the best solar cell efficiency (18.48%).

Keywords: *Gallium Arsenide, silicon, solar cells, PC1D simulation, double layer anti-reflective coatings*

1. INTRODUCTION

Energy is the most essential component needed to complete all human tasks and the most universal measure of all work by human beings and nature (Kumar Shah, 2021). Solar cells, which can convert sunlight into electricity, find wide usage nowadays. Bell Laboratories invented the first practical use of solar cells in 1954 using silicon p-n-type solar cells (Hussain B. et al., 2015). However, there are still a few main issues from the first solar cell, which are low efficiency and high cost of solar panels. To overcome these problems, researchers have explored a wide range of solar cell types. Numerous researchers have identified the highest efficiency, despite its expensive cost because of the raw material in the solar panel. This improvement has allowed the efficiency of solar cells to increase in order to work effectively and lower the cost of solar panels. While experimenting with solar cells, researchers have explored various factors to increase their efficiency, such as adjusting the thickness of the p-n type and anti-reflective coating (ARC), selecting the optimal number of ARC layers, and implementing surface texturing on the solar cell.

Adding ARC on the top surface of a solar cell can reduce the reflection of sunlight and indirectly can absorb as much as it can. There are a few types of ARCs which are single-layer anti-reflective coating, double-layer anti-reflective coating (SLARC), double-layer anti-reflective coating (DLARC), and multilayer anti-reflective coating (MLARC).

e-ISBN: 978-967-2776-42-0

The efficiency of the ARC is dependent on the number of layers. Only at a certain wavelength can a single layer ARC decrease reflectance to nearly zero. It is necessary to use double or multi-layer ARC to further minimize reflections across a larger wavelength range (Al-Montazer, 2019). In this study, different types of materials were used to study the most efficient material of DLARC using PC1D simulation. From the result, DLARC is the most suitable ARC for solar cells.

2. MATERIALS AND METHODS

The purpose of this paper is to study the design of the solar cell. For the n-type and p-type, Gallium Arsenide (GaAs) and Silicon (Si) have been chosen to be used in the solar cell respectively, as shown in Figure 1. Furthermore, the study will examine the material of the double-layer anti-reflective coating (DLARC) using simulation. As shown in Figure 1, the surface texturing for the ARC that will be used is planar.

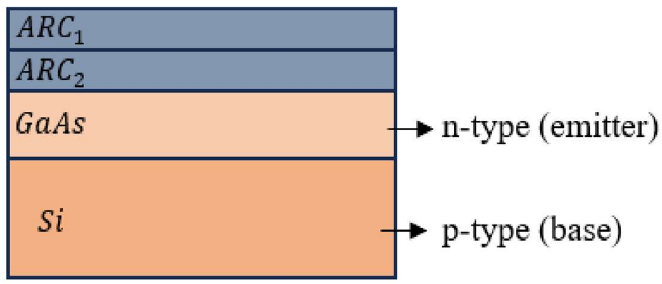


Figure 1. Design of GaAs/Si Solar cell

To run the experiment effectively, constant and variable parameters need to be identified before starting the experiment in the simulation. Table 1 shows the constant parameters in PC1D simulation.

Table 1. Constant parameters in PC1D simulation

Parameter	Setting	Reference
Device area	100 cm^2	
Surface texturing	Planar	
Types of Anti-Reflective Coating (ARC)	Double-Layer Anti Reflective Coating (DLARC)	
Region 1	**n-type (emitter)**	
Material	Gallium Arsenide (GaAs)	
Thickness (μm)	50	(Dhamija et al.,2014)
Bandgap (eV)	1.42	(Dhamija et al.,2014)
Refractive index	3.86	
Background Doping ($cm - 3$)	1e16	(Dhamija et al.,2014)
Region 2	**p-type (base)**	
Material	Silicon (Si)	
Thickness (μm)	400	(Naim et al., 2021)
Bandgap (eV)	1.124	(Naim et al., 2021)
Refractive index	3.44	(Naim et al., 2021)
Background doping ($cm - 3$)	8e16	(Dhamija et al.,2014)

In this study, nine solar cell schemes will be examined using PC1D simulation. Table 2 provides the details of each of the nine schemes.

e-ISBN: 978-967-2776-42-0

Table 2. Details of ARC layers for nine schemes

Scheme	Top layer ARC	n_1	Bottom layer ARC	n_2
Scheme 1	SiO_2	1.457	TiO_2	2.540
Scheme 2	TiO_2	2.540	GaAs	3.860
Scheme 3	Si_2N_3	2.000	TiO_2	2.540
Scheme 4	SiO_2	1.457	GaAs	3.860
Scheme 5	Al_2O_3	1.600	TiO_2	2.540
Scheme 6	MgF_2	1.382	TiO_2	2.540
Scheme 7	Al_2O_3	1.600	GaAs	3.860
Scheme 8	MgF_2	1.382	Si_2N_3	2.000
Scheme 9	SiO_2	1.457	Si_2N_3	2.000

3. RESULTS AND DISCUSSION

Using the PC1D simulation, the researchers performed all the schemes and recorded the results of short-circuit current $I\ SC$, power base output $Pmax$, and open circuit voltage $V\ OC$ in Table 3 below. Fill factor, FF, and efficiency, η for each scheme of DLARC, are also calculated and shown in Table 3.

Table 3. Result of GaAs/Si on solar cells

Scheme	I_{SC} (A)	P_{max} (W)	V_{OC} (V)	FF	η (%)
Reference	2.116	1.305	0.7297	0.84518	13.05
Scheme 1	2.905	1.829	0.7374	0.85382	18.29
Scheme 2	2.543	1.583	0.7342	0.84785	15.83
Scheme 3	2.739	1.718	0.7360	0.85220	17.18
Scheme 4	2.734	1.714	0.7359	0.85191	17.14
Scheme 5	2.913	1.834	0.7375	0.85368	18.32
Scheme 6	2.879	1.813	0.7372	0.85422	18.13
Scheme 7	2.846	1.792	0.7369	0.85447	17.92
Scheme 8	2.937	1.848	0.7377	0.85290	18.48
Scheme 9	2.902	1.827	0.7374	0.85376	18.27

Referring to the reference's value, it reveals that ARC takes an enormous responsibility for increasing the efficiency of the solar cell. Among all the schemes, it shows that Scheme 8 has the highest current and voltage, which are 2.937A and 0.7377V respectively. This result can lead to high efficiency of the solar cell. Scheme 8 used $MgF2/Si3N4$ ($nMgF2$:1.382; $nSi3N4$:2.000) as the material of the anti-reflective coating (ARC) which this material has a lower refractive index. By applying a lower refractive index than the material of a solar cell, it can function to reduce the reflection of light well. Also, a lower refractive index can increase the transmission of light into the solar cell.

Transmission is important in the solar cell because it can allow photons to pass through the solar cell and indirectly can convert the light into electricity. Thus, this is the reason Scheme 8 has the highest production of current. The relation between the current and voltage of each scheme is demonstrated in Figure 2. Refractive index is the main important property because it gives a big effect to the results of the schemes. The lower refractive index of ARC compared to the solar cell allows for the absorption of numerous photons by the solar cell, leading to the generation of a substantial amount of current indirectly. The power of the scheme depends on the current and voltage that is produced in the solar cell. Thus, when the current is high, the power also becomes high (Figure 3).

e-ISBN: 978-967-2776-42-0

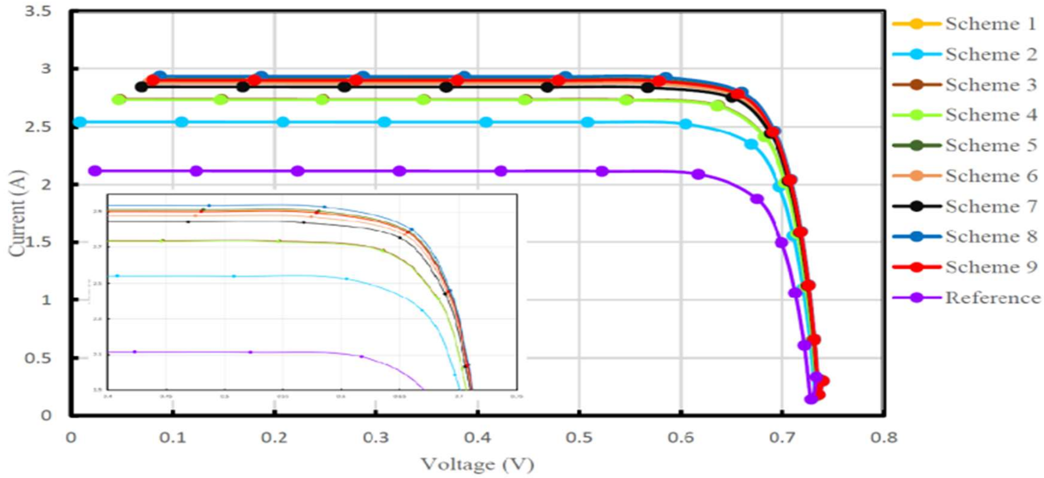


Figure 2. I-V curve for nine schemes. Reference is included for comparison

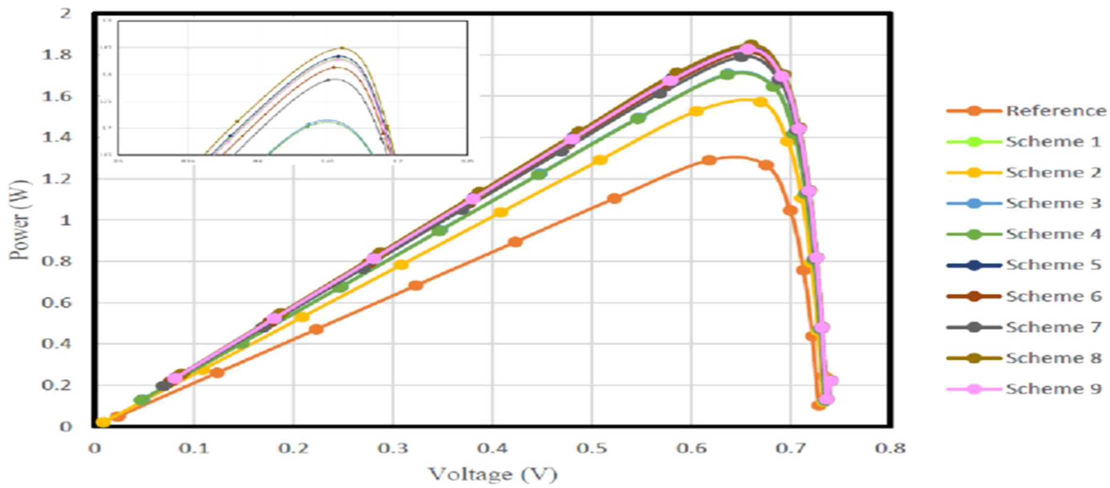


Figure 3. P-V curve for nine schemes. Reference is included for comparison

4. CONCLUSION

One of the factors is that using an anti-reflective coating (ARC) can minimize the reflection of light into the air. In this thesis, we will focus on investigating the efficiency of solar cells by using a double-layer anti-reflective coating (DLARC). In conclusion, the selection of pairing material of DLARC for GaAs/Si solar cells can be determined by using PC1D simulation. Out of the nine schemes, it shows that $MgF2/Si3N4$ in Scheme 8 produces the highest efficiency (18.48%) of solar cells. A few factors that affect the efficiency can be detected while examining this experiment, one of them is the refractive index of the material of ARC. The refractive index of the pairing material of Scheme 8 is the lowest compared to other schemes. Thus, the researcher can focus on the refractive index of the material to produce high efficiency in the future.

5. ACKNOWLEDGMENT

The authors would like to thank the Faculty of Applied Sciences, Universiti Teknologi MARA (UiTM), Perlis Branch, Malaysia for supporting this research.

e-ISBN: 978-967-2776-42-0

6. REFERENCES

Al-Montazer Mandong, M. & Abdullah, Ü. Z. Ü. M. (2019). Analysis of silicon solar cell device parameters using pc1d. *Sakarya University Journal of Science, 23(6),* 1190-1197.

Dhamija, P., Jha, P., & Sathya, P. (2014). Performance analysis of silicon and GaAs single junction solar cell using PC1D. *International Journal of Applied Engineering Research, 9(17),* 2833-2842.

Hussain, B., Aslam, A., Khan, T., Creighton, M., & Zohuri, B. (2019). Electron affinity and Bandgap optimization of zinc oxide for improved performance of ZnO/SI Heterojunction solar cell using PC1D simulations. *Electronics, 8(2*), 238.

Kumar Shah, D., KC, D., Umar, A., Algadi, H., Akhtar, M. S., & Yang, O. B. (2022). Influence of efficient thickness of antireflection coating layer of HfO2 for crystalline silicon solar cell. *Inorganics, 10(10),* 171.

Naim, H., Shah, D. K., Bouadi, A., Siddiqui, M. R., Akhtar, M. S., & Kim, C. Y. (2021). An in-depth optimization of thickness of base and emitter of ZnO/SI heterojunction-based crystalline silicon solar cell: A simulation method. *Journal of Electronic Materials, 51(2),* 586-593.

Pejabat Perpustakaan
Librarian Office

Universiti Teknologi MARA
Cawangan Perak
Kampus Seri Iskandar
32610 Bandar Baru Seri Iskandar,
Perak Darul Ridzuan, MALAYSIA
Tel: (+605) 374 2093/2453 Faks: (+605) 374 2299

UNIVERSITI TEKNOLOGI MARA

Surat kami : 700-KPK (PRP.UP.1/20/1)
Tarikh : 20 Januari 2023

Prof. Madya Dr. Nur Hisham Ibrahim
Rektor
Universiti Teknologi MARA
Cawangan Perak

Tuan,

PERMOHONAN KELULUSAN MEMUAT NAIK PENERBITAN UiTM CAWANGAN PERAK MELALUI REPOSITORI INSTITUSI UiTM (IR)

Perkara di atas adalah dirujuk.

2. Adalah dimaklumkan bahawa pihak kami ingin memohon kelulusan tuan untuk mengimbas (*digitize*) dan memuat naik semua jenis penerbitan di bawah UiTM Cawangan Perak melalui Repositori Institusi UiTM, PTAR.

3. Tujuan permohonan ini adalah bagi membolehkan akses yang lebih meluas oleh pengguna perpustakaan terhadap semua maklumat yang terkandung di dalam penerbitan melalui laman Web PTAR UiTM Cawangan Perak.

Kelulusan daripada pihak tuan dalam perkara ini amat dihargai.

Sekian, terima kasih.

Setuju.

"BERKHIDMAT UNTUK NEGARA"

27.1.2023

Saya yang menjalankan amanah,

PROF. MADYA DR. NUR HISHAM IBRAHIM
REKTOR
UNIVERSITI TEKNOLOGI MARA
CAWANGAN PERAK
KAMPUS SERI ISKANDAR

SITI BASRIYAH SHAIK BAHARUDIN
Timbalan Ketua Pustakawan

nar