ANALYSIS OF INVERTED PLANAR PEROVSKITE SOLAR CELLS WITH GRAPHENE OXIDE AS HTL USING TAGUCHI METHOD.

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This report is submitted in partial fulfillment of the requirements for the degree of Bachelor of Electronic Engineering with Honours

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DEDICATION

First and foremost, I am very grateful to all the family members for their valuable guidance and support in the completion of this project in its entirety. I would like to express our deepest appreciation to all those who provided us the possibility to complete our Integrated Design Project. A special gratitude I give to my supervisor, PM. Dr. Fauziyah Binti Salehuddin and co supervisor Ts. Dr. Faiz Bin Arith whose contribution in stimulating suggestions and encouragement and help me a lot in this project and with much appreciation too because she and he gave the knowledge about this project to use all required equipment and the necessary materials to complete the project. Besides, not to forget our coordinator of this PSM Project, Dr. Mas Haslinda who keep reminding us about the important things that must be implemented before the due date and always give us moral support to complete our project. Next, I also appreciate the guidance given by panels that have improved our project and the knowledge that gives us the idea to complete this project. Finally, gratitude goes to all my friends who directly or indirectly helped me to complete this project

ABSTRACT

This project studies optimization of graphene oxide (GO) as hole transport layer (HTL) in inverted perovskite solar cells (IPSC) using Taguchi method. This method is used to optimize the data from numerical modelling which is Solar Cell Capacitance Simulator-One Dimensional (SCAPS-1D). While it has variations parameters result and different factors it also requires a lot of time consuming to implement an analysis process. Taguchi method was reported can find the most prominent factor and reduce variations parameters. The Taguchi algorithm is implemented in this experiment because it is based on orthogonal array (OA) experiments, which provides substantially lower variance for the experiment with optimal control parameter values. SCAPS-1D are used to simulate the IPSC with GO as HTL. The result obtained from the software are then analyzed and compared the performance of the solar cell. Analyze the IPSC with GO as HTL with parameter power conversion efficiency (PCE), fill factor (FF) and achieve optimum performance with open circuit voltage (V_{OC}) and a density of current short circuit (J_{SC}), all of which have substantial effects on the performance of the PSCs device.

ABSTRAK

Projek ini mengkaji pengoptimuman graphene oxide (GO) sebagai lapisan pengangkutan lubang (HTL) dalam sel solar perovskite terbalik (IPSC) menggunakan kaedah Taguchi. Kaedah ini digunakan untuk mengoptimumkan data daripada pemodelan berangka iaitu Solar Cell Capacitance Simulator-One Dimensional (SCAPS-1D). Walaupun ia mempunyai hasil parameter variasi dan faktor yang berbeza, ia juga memerlukan banyak masa untuk melakukan proses analisis. Kaedah Taguchi dilaporkan boleh mencari faktor yang paling menonjol dan mengurangkan parameter variasi. Algoritma Taguchi dilaksanakan dalam eksperimen ini kerana ia berdasarkan eksperimen tatasusunan ortogon (OA), yang memberikan varians yang jauh lebih rendah untuk eksperimen dengan nilai parameter kawalan optimum. SCAPS-1D digunakan untuk mensimulasikan IPSC dengan GO sebagai HTL. Hasil yang diperoleh daripada perisian kemudiannya dianalisis dan dibandingkan prestasi sel suria. Analisis IPSC dengan GO sebagai HTL dengan kecekapan penukaran kuasa parameter (PCE), faktor isian (FF) dan capai prestasi optimum dengan VOC *dan,* JSC *yang kesemuanya mempunyai kesan yang besar pada prestasi peranti PSC.*

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HTL	:	Hole Transport Layer
ETL	:	Electron Transport Layer
GO	:	Graphene Oxide
r GO	:	Reduce Graphene Oxide
PSC	:	Perovskite Solar Cell
IPSC	:	Inverted Perovskites Solar Cell
SCAPS	:	Solar Cell Capacitance Simulator
PCE	:	Power Conversion Efficiency
FF	:	Fill Factor
V_{oc}	:	Open Circuit Voltage
J_{sc}	:	Density of Short Circuit Current
OPV	:	Organic Perovskites
OA	:	Orthogonal Array
ITO	:	Indium Tin Oxide
FTO	:	Fluoride Tin Ox
Ag	:	Silver

CHAPTER 1

INTRODUCTION

This chapter describes the idea of the GO as an HTL in the solar cell which includes the background of the project, problem statement, objectives, and scope of the project.

1.1 Background of project

The sun is a renewable resource that has the ability to sustain life on earth by providing clean, renewable energy to all of its inhabitants. Nowadays, renewable energy is the fastest-growing energy source worldwide because it is sustainable and does not produce pollution to the environment. It is projected that the current share of renewable energy sources in global energy consumption surpasses 20 % and continues to rise. Renewable energy sources, as ecologically beneficial energy resources, will become even more significant in the future because it limitless and influence the additional energy forms in addition to the conventional power plants that are already in use [1].

The common source of renewable energy used worldwide is solar energy. It is a renewable energy source capable of providing sufficient power to households. Solar energy is an inexhaustible source of renewable energy derived from the sun's electromagnetic radiation. It generates electricity and heat fully sustainably and at no expense. Solar energy does not contribute to global warming or air pollution. The sun emits energy in the form of solar radiation, which is converted into usable energy by technology such as solar cells, also known as photovoltaic or PV cells.

Solar PV technology is a viable technique to collect solar energy since it creates electricity directly from solar radiation on-site through the photovoltaic effect of solar cells [2]. When a PV cell is exposed to sunlight, solar energy is transformed into electricity by the photovoltaic effect. Photovoltaic effect plays a key role in producing electricity from solar radiation.

Perovskite has the outstanding capabilities for use as light harvesters in solar cells due to the ability to adjust its optical properties. Perovskite materials can be used not only as a light-absorbing layer but also as an electron/hole transport layer due to its high extinction coefficient, high charge mobility, long carrier lifespan, and long carrier diffusion distance [3]. It also acts as a charge carrying material. Perovskite solar cells have two structure which is n-i-p (regular) and p-i-n (inverted). The different between these two structures is the position of HTL and ETL. For the perovskite solar cells with inverted structure (IPSC) the HTL layer place on top of TCO (transparent conducting oxide) substrate while perovskite solar cells with regular structure (PSC) the HTL layer place between metal and perovskite substrate.

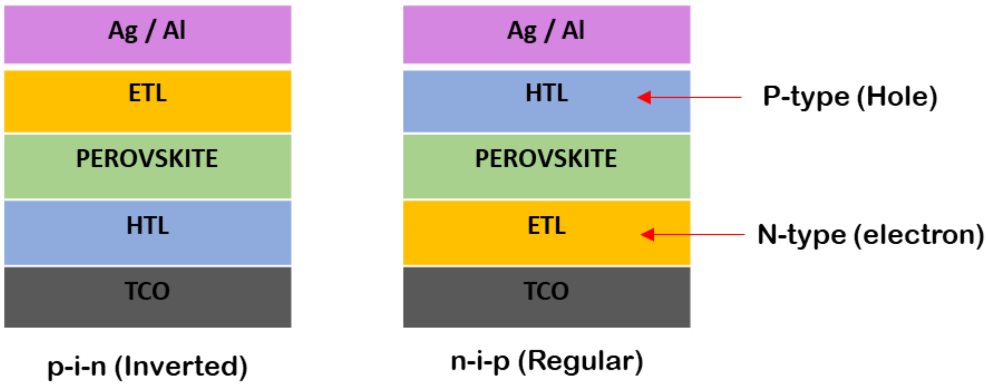

Figure 1.1: Inverted and Regular Planar Structure of Perovskite Solar Cells

The ETL and HTL layers offers a driving force for the carrier transport. These two layers may also provide protection of the perovskite layer from moisture and metal diffusion from connection. Both of it can reduce the cell's PV performance. After that, TCO substrate is needed for perovskite solar cells. It should have excellent transmission, conductivity, and adherence to the deposited layers.

The object of the Taguchi method is to identify the most significant components in a manufacturing process for accomplishing beneficial goals. These parameters are systematically modified across two or more tiers. To demonstrate the effects of each probable primary factor, the tests are designed in accordance with an orthogonal array. Orthogonal Array (OA) is one of the most significant advantages of the Taguchi method. Taguchi method also helps in minimizing the number of experiments required in optimization purpose [4].

1.2 Problem Statement

The important characteristics of HTL is high conductivity, high transparency, favorable solution processability and stability, high WF and good hole mobility [5]. In this experiment, IPSC devices can improve the stability of solar cell compared to

Planar Perovskite Solar Cells (PSC) [6]. Next, OPV cells have a substantially lower efficiency than inorganic-based devices, which is a major flaw at the moment. Organic semiconductors have a bigger band gap than inorganic semiconductors. Nevertheless, OPV use Spiro-OMeTAD which is dopants in that material show strong water absorbency, stability issues arising from photochemical degradation (exposure to moisture or humidity) which seriously threatens the service life of PSCs. The costs of organic materials such as spiro-OMeTAD, PEDOT:PSS, PTAA and P3HT are all prohibitively high for large-scale applications [7]. The industrial growth and market potential of photovoltaic solar cells (PSCs) is constrained by their high cost and instability in water, heat, and light, despite the fact that all of these materials provide higher open-circuit voltages and higher efficiencies. [8].

1.3 Objective

Specifically, the objectives of the project are:

(i) To simulate the inverted Planar Perovskite Solar Cells (IPSC) with GO as HTL using SCAPS-1D software.

(ii) To analyze the parameters such as power conversion efficiency (PCE), fill factor (FF), density of short-circuit current (J_{sc}) and open-circuit voltage (V_{oc}).

(iii)To optimize the GO layer as HTL of the IPSC using Taguchi Method.

1.4 Scope of work

This project is to analyze GO as HTL layer on the emerging solar cell which is IPSC. The analysis is conducted by simulation method using SCAPS-1D software. After simulation, analyzed from I-V curve the power conversion efficiency (PCE), fill factor (FF) and achieve optimum performance with open circuit voltage (V_{OC}) and a density of current short circuit (J_{SC}). The efficiency of the solar cells will be optimized by controlling several parameters of the HTL. The parameters included are the HTL thickness, doping density, working temperature, and defect density [8]. To achieve maximum efficiency, those parameters of each layer of the solar cell were researched thoroughly. Taguchi Method is a process for optimizing a number of control parameters that directly determine the target or desired output value. The optimization process then entails establishing the optimal control factor levels to obtain the desired outcome.

1.5 Thesis outline

This thesis consists of five chapters and those are introduction, literature review, methodology, results, and discussion and finally conclusion and recommendation. Each section explains in detail with the depth of this project. The introduction of this project is explained in Chapter 1. In this section explanation of the background, objectives of the project, problem statement, project scope and thesis outline are listed with details.

The literature review is described in Chapter 2. The project's research was reviewed in order to compile all key information. In addition, a few initiatives identical to this thesis were researched to ensure a positive outcome. This project's methodology is described in the Chapter 3. This chapter will cover the project activities, which includes the entire design using SCAP-1D software and optimize using L9 OA Taguchi Method. This chapter will go through each simulation design in detail.

The results and discussion from this project's simulation are described in Chapter 4. This chapter will explain the results obtained and also analyzed and discussed the results. To obtain a better efficiency, the optimum value based on optimization using

Taguchi method need to be obtained. The efficiency of IPSC with GO as HTL can be determined and compare before and after optimization. The project's conclusion and recommendations are described in Chapter 5. The entire project and the achievement of project objectives are concluded in this section. The recommendation is to conduct further study in order to improve the situation.

CHAPTER 2

BACKGROUND STUDY

This chapter provides an overview of theoretical frameworks which includes the previous research on GO and other HTL materials.

2.1 Inverted Perovskite Solar Cells (IPSC)

Perovskite solar cells have experienced a rapid development and shown great potential as the next-generation photovoltaics. For the inverted perovskite solar cells PSCs, the device efficiency has reached a power conversion efficiency (PCE) 23.7%. According to the M. Degani et al., (2021) inverted perovskite solar cells use a novel technique to optimize the interfaces by promoting high-quality film formation on top of the HTL and inducing effective defect passivation at the perovskite interface. This improvement can increase in the fill factor (FF) accompanied by a small increase in the short circuit current (J_{sc}) and open circuit voltage (V_{oc}). Hence, the inverted perovskite solar cells have a high PCE and low hysteresis. The efficiency of IPSC more than 21% which is comparable to the highest performing regular type PSCs [9].