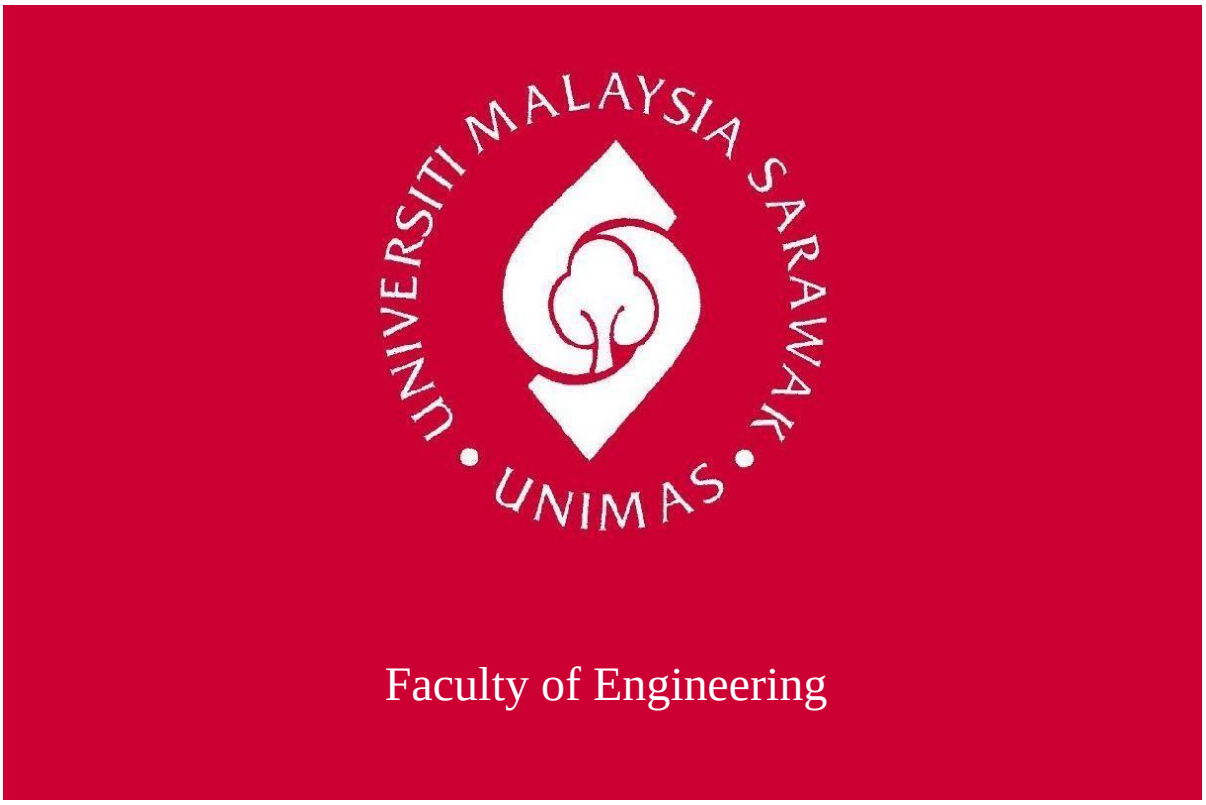

STUDY ON THE PUSH COATING FOR A LARGER MODULE OF ACTIVE LAYER FILMS

NG JI WEI

Bachelor of Engineering with Honors

(Mechanical and Manufacturing Engineering)

2020

UNIVERSITI MALAYSIA SARAWAK

Grade: _____

Please tick (√)

Final Year Project Report ☑

Masters ☐

PhD ☐

DECLARATION OF ORIGINAL WORK

This declaration is made on the ……15……day of……August……2020.

Student's Declaration:

I Ng Ji Wei, 56931, Faculty of Engineering ----------

--- (PLEASE INDICATE STUDENT'S NAME, MATRIC NO. AND FACULTY) hereby declare that the work entitled Study on the Push Coating for A Larger Module of Active Layer Films is my original work. I have not copied from any other students' work or from any other sources except where due reference or acknowledgement is made explicitly in the text, nor has any part been written for me by another person.

15/8/2020
Date submitted

Ng Ji Wei (56931)
Name of the student (Matric No.)

Supervisor's Declaration:

I NUR TAHIRAH BT RAZALI (SUPERVISOR'S NAME) hereby certifies that the work entitled Study on the Push Coating for A Larger Module of Active Layer Films (TITLE) was prepared by the above named student, and was submitted to the "FACULTY" as a * partial/full fulfillment for the conferment of Bachelor of Engineering with Honours (Mechanical and Manufacturing Engineering) (PLEASE INDICATE THE DEGREE), and the aforementioned work, to the best of my knowledge, is the said student's work.

Received for examination by:  Date: 16th August 2020

(Nur Tahirah binti Razali)

I declare that Project/Thesis is classified as (Please tick (√)):

☐ **CONFIDENTIAL** (Contains confidential information under the Official Secret Act 1972)*****
☐ **RESTRICTED** (Contains restricted information as specified by the organisation where research was done)*****
☑ **OPEN ACCESS**

Validation of Project/Thesis

I therefore duly affirmed with free consent and willingness declare that this said Project/Thesis shall be placed officially in the Centre for Academic Information Services with the abiding interest and rights as follows:

- This Project/Thesis is the sole legal property of Universiti Malaysia Sarawak (UNIMAS).
- The Centre for Academic Information Services has the lawful right to make copies for the purpose of academic and research only and not for other purpose.
- The Centre for Academic Information Services has the lawful right to digitalise the content for the Local Content Database.
- The Centre for Academic Information Services has the lawful right to make copies of the Project/Thesis for academic exchange between Higher Learning Institute.
- No dispute or any claim shall arise from the student itself neither third party on this Project/Thesis once it becomes the sole property of UNIMAS.
- This Project/Thesis or any material, data and information related to it shall not be distributed, published or disclosed to any party by the student except with UNIMAS permission.

Student signature _____ (15/8/2020)
(Date)

Supervisor signature:
(16th August 2020)

Current Address:
PT 281 TAMAN MEGAH JAYA, KAMPUNG KUMBANG PA' AMIN, 17000 PASIR MAS, KELANTAN.

Notes: ***** If the Project/Thesis is **CONFIDENTIAL** or **RESTRICTED**, please attach together as annexure a letter from the organisation with the period and reasons of confidentiality and restriction.

[The instrument is duly prepared by The Centre for Academic Information Services]

STUDY ON THE PUSH COATING FOR A LARGER MODULE OF ACTIVE LAYER FILMS

NG JI WEI

A dissertation submitted in partial fulfilment

of the requirement for degree of

Bachelor of Engineering with Honours

(Mechanical and Manufacturing Engineering)

Faculty of Engineering

Universiti Malaysia Sarawak

2020

To my beloved family and friends.

ACKNOWLEDGEMENT

First, I would like to thank the Faculty of Engineering Universiti Malaysia Sarawak (UNIMAS) for allowing me to complete my Final Year Project (FYP) with the title of “Study on the push coating for a larger module of active layer films”. In this project, I had the golden opportunity to gain experiences from different aspects that could help me and improve my capability as a future engineer. Next, I would like to express my utmost gratitude to my FYP’s supervisor, Dr. Nur Tahirah Razali for guiding me throughout this project. She provides me the related information for this project and encourages me in completing this project. Furthermore, she also guided me during the experimental session in the energy laboratory to perform the spin and push coating correctly. This thesis could not be completed without her unlimited supervision. Lastly, a million billion trillion zillion thanks to all the people who involved in this project directly or indirectly for supporting me throughout this project.

ABSTRACT

A solar cell is used to convert solar energy into electricity by the photovoltaic effect. There are multiple different functional layers in a solar cell and the active layer is the core of a solar cell as the photovoltaic effect takes place over there. Spin coating is the conventional method to deposits the thin film of active layer by the centrifugal force, however, spin coating discards a large amount of hazardous solvent wastage during the process, it is highly expensive in terms of materials and it only able to fabricate a small and limited coverage area. Therefore, to resolve these problems, push coating is introduced, another method that deposits the thin film by the capillary force. In this project, both spin and push coating methods are performed to study the film condition produced. Besides, the Polydimethylsiloxane (PDMS) stamp condition throughout the push coating is studied in this project as well. In this project, the spin coating is performed under different condition including the stamping duration and additional weight on the PDMS stamp while the spin coating is performed as a reference of the film condition to compare with push coating. Throughout the push coating, the film condition obtained is different from every trial and the PDMS stamp is swollen after the stamping process. In the push coating, the PDMS stamp's mass increased due to the solvent retention; the PDMS stamp bent as well due to the solvent sorption and desorption kinetics. The adsorbed solvent in the swollen stamp can be removed by annealing the stamp. The push coating is performed at a larger substrate (5×5 cm^2), the film condition is improved after applied additional weight on top of the PDMS stamp and by increasing the stamping duration. In the spin coating, the film condition is smoother than all the films produced by the push coating method. In conclusion, in this project, the push coating can perform at a larger substrate (5×5 cm^2), which is much larger than all the previous research (2.5×2.5 cm^2). Unfortunately, further investigation is required to obtain the optimum results for the film's thickness and condition.

ABSTRAK

Sel solar digunakan untuk menukar tenaga suria menjadi elektrik dengan kesan fotovoltaik. Terdapat beberapa lapisan fungsional yang berbeza dalam sel solar dan lapisan aktif adalah paling penting kerana di situlah kesan fotovoltaik berlaku. *Spin coating* adalah kaedah konvensional untuk menghasilkan lapisan nipis lapisan aktif oleh daya sentrifugal, namun, *spin coating* mengeluarkan pembaziran pelarut berbahaya yang banyak semasa prosesnya, ia sangat mahal dari segi bahan dan hanya mampu membuat kawasan liputan kecil dan terhad. Oleh itu, untuk menyelesai masalah ini, *push coating* diperkenalkan, kaedah lain yang menghasilkan lapisan nipis oleh daya kapilari. Dalam projek ini, kedua-dua kaedah *spin and push coating* dilakukan untuk mengkaji keadaan filem yang dihasilkan. Selain itu, keadaan cap *Polydimethylsiloxane* (PDMS) di semua *push coating* juga dikaji dalam projek ini. Dalam projek ini, *spin coating* dilakukan dalam keadaan yang berbeza termasuk jangka masa mengecap dan berat tambahan pada cap PDMS, sementara *spin coating* dilakukan sebagai rujukan keadaan filem untuk dibandingkan dengan *push coating*. Sepanjang *push coating*, keadaan filem yang diperoleh adalah berbeza dari setiap percubaan dan cap PDMS membengkak setelah proses mencapainya. Pada *push coating*, jisim cap PDMS meningkat kerana pengekalan pelarut; cap PDMS bengkok juga kerana *solvent sorption and desorption kinetics*. Pelarut yang menyerap pada cap yang bengkak dapat dikeluarkan dengan memanaskan cap. *Push coating* dilakukan pada substrat yang lebih besar (5×5 cm^2), keadaan filem bertambah baik setelah menggunakan berat tambahan di atas cap PDMS dan dengan meningkatkan jangka masa stamping. Dalam *spin coating*, keadaan filem lebih halus daripada semua filem yang dihasilkan dengan kaedah *push coating*. Kesimpulannya, dalam projek ini, *push coating* boleh berfungsi pada substrat yang lebih besar (5×5 cm^2), yang jauh lebih besar daripada semua penyelidikan sebelumnya (2.5×2.5 cm^2). Malangnya, penyelidikan lebih lanjut diperlukan untuk mendapatkan hasil yang optimum untuk ketebalan dan keadaan filem ini.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

AFM	Atomic Force Microscopy
a-Si	Amorphous Silicon
BIPVs	Building Integrated Photovoltaic
CdTe	Cadmium Telluride
CIGS	Copper Indium Gallium Di-Selenide
COVID-19	Coronavirus Disease 2019
CPV	Concentrating Photovoltaic
DMAPA	Dimethylaminopropylamine
DSSC	Dye Sensitized Solar Cell
FYP	Final Year Project
ITO	Indium Tin Oxide
I-V	Current-Voltage
MPP	Maximum Power Point
P3HT: PCBM	Poly (3-hexylthiophene): [6, 6]-Phenyl-C_{61}-Butyric Acid Methyl Ester
PDMS	Polydimethylsiloxane
PEDOT: PSS	Poly (3, 4-ethylenedioxythiophene): Poly(styrene sulfonate)
QD	Quantum Dots
UV-VIS	Ultraviolet-Visible Spectroscopy

CHAPTER 1

INTRODUCTION

1.1 Background of Research

Energy is the ability to perform work. It is measured by the unit of Joule (J) in the SI system. Energy can exist in many forms such as mechanical energy, chemical energy, nuclear and electric energy, in which different forms of energy have different characteristics and functions. According to the law of conservation of energy, energy cannot be created nor destroyed, but it can transform from form to form. This property made energy is closely related to mass as both of them cannot be created nor destroyed. Energy is important as the living organisms required it to survive, for example by gaining chemical energy through consuming food. Energy is categorized into two groups which are renewable and non-renewable energy.

Non-renewable energy is collected from resources that will be used up and will not be replenished in a human timescale. The most common examples of non-renewable energy resources are fossil fuels, coal, petroleum, and natural gas (Shafiei & Salim, 2014). Non-renewable energy resources are used to generate power by burning it, for example by burning petroleum to generate power for vehicles. However, burning fossil fuels will emit carbon dioxide as the main element in the fossil fuels are carbon (Shafiei & Salim, 2014). Emission of carbon dioxide is harmful to living organisms and it will cause the greenhouse effect.

An alternative is needed to replace non-renewable energy, therefore renewable energies are introduced. Renewable energy is obtained from the resources that will naturally be replenished on a human timescale which are totally opposed to the non-renewable energy. Examples of renewable energy resources are sunlight, wind, waves, and tides. The less carbon-

intensity of renewable energy made it an energy system with higher sustainability compared to non-renewable energy (Rahman & Velayutham, 2019). As a result, renewable energy ended up to be more popular over time not only because of the environmental effects caused by fossil fuels, greenhouse gas emissions, and also its unpredictable and unaffordable costs. In the future, renewable energy will have the most rapid growth in electricity generation and it is predicted to provide just about 30% of power demand in 2023 (International Energy Agency, 2018).

In the electricity sector, several ways are used to generate electricity including burning fossil fuels and coals, hydroelectricity, wind electricity, and solar cell. The higher sustainability and affordable costs of renewable energy make it a more popular resource and slowly replacing the non-renewable energy resources. The most common electricity generator used nowadays is hydroelectricity, wind electricity, and solar cell. Some of the renewable energy-based electricity generators required huge areas to operate, for example, hydroelectricity and wind electricity, therefore solar cell is the alternative to replace them in the new generation.

A solar cell, the so-called photovoltaic cell is an electrical device that converts solar energy directly into electricity through the photovoltaic effect. The structure of a solar cell is divided into a layer by layer with its specific function, where an active layer considers as a critical part for the photovoltaic effect to take place (Helgesen et. al, 2012). Conventionally, the active layer film of a polymer solar cell is fabricated by a method called spin coating. However, spin coating is not sustainable as it has weaknesses such as small coverage areas (limitations on the fabricated module size), produce plenty of hazardous wastage disposal throughout the process and it is costly as well.

1.2 Problem Statement

Nowadays, Go Green is happening everywhere and the development of green technology is evolving from days to days in order to keep the Earth clean and sustainable for the human being to stay. Hence, renewable energy is chosen over non-renewable energy in electricity generation due to its less-carbon intensity content. Several power generators such as hydropower, wind power, biomass power, and solar power are widely used in various applications especially the industrial field. The unlimited sources from the sun turned solar energy into one of the best choices to replace non-renewable energy sources. It is been claimed that solar energy could be the best option to replace fossil fuels in the future (Kannan & Vakeesan, 2016). In the 21st century, a number of researches on solar energy have been done

in order to replace non-renewable energy, which are fossil fuels and oils (Shaikh, 2017). A photovoltaic cell, also known as a solar cell is the device that converts solar energy into electricity, and it is evolved into the third generation until the present. The technologies that are used to fabricate the active layer of the solar cell are spin, slot-die, spray, knife, and push coating, where the spin coating is the current conventional technology. However, there are some limitations of the spin coating such as follows:

- The spin coating only capable to fabricate a small and limited coverage area.
- During the spin coating process, a large amount of hazardous solvent wastage is disposed.
- The fabrication cost for spin coating is highly expensive as most of the active material and the solvent are discarded during the deposition process.

As an alternative, the push coating deposition technique is introduced in order to replace the conventional technique as push coating is capable to produce a large coverage area and it is more sustainable in terms of cost.

1.3 Objectives of Research

This project aims to study the push coating technique in a large substrate and compare the characteristics of the deposited films between the spin and push coating techniques. In order to achieve the desired aim, several objectives are established. The objectives are stated as below,

i. To study on the related parameters for the push coating technique. The parameters such as the weight and stamping duration.
ii. To analyse the surface condition of the push coating film, which is the surface smoothness of the film.

1.4 Scope of Research

Essentially, the aim of conducting this particular project is to investigate the active layers that are produced by the push coating method. In order to conduct this research in a systematic and orderly manner, the scope of research should be identified and refer to it as a guideline for this specific project. In this project, the study will only conduct on the active layer film but not going to fabricate the full device of the polymer solar cell. The active layers are

produced by using spin and push coating methods under different conditions, such as PDMS stamp thickness and temperature in a larger substrate. The purpose of producing the active layers by two different methods is to compare the film conditions of the spin and push coating. Since the push coating is a new method for active layer fabrication, therefore a comparison is conducted with the standard method, which is the spin coating in order to evaluate the performance of the latest technology. After the fabrication, each active layer is compared in terms of their surface roughness and thickness by using atomic force miscopy (AFM). However, due to the lockdown of Coronavirus Disease 2019 (COVID-19) the samples are unable to outsource for AFM service. As alternative, after the fabrication, each active layer is compared in terms of their surface condition only through naked eyes. The experiment is conducted under different conditions such as the stamping duration and additional weight on the PDMS stamp; the film condition is observed and investigates the effect of the related parameter to it.

1.5 Research gap

There are not many studies that focused on the push coating method (Ikawa et al., 2012; Inaba et al., 2019; Kobayashi et al. , 2015; Vohra et al., 2017). In chapter 2, there is a limitation on the study of the push coating in which the scientists only investigate the push coating in a laboratory scale film but not on a larger scale. Recently, Inaba et al. (2019) conducted a study on the push coated active layer film with an area of 1 cm^2. Therefore, this research will conduct a study on a larger substrate (25 cm^2) of active layer film.

1.6 Organization of thesis

This thesis consists of five chapters in which different chapters explain different aspects. The chapters are categorized as introduction, literature review, methodology, results and discussion, and conclusion and recommendations.

Chapter 1 consists of the overview of this project in which it briefs about both the renewable and non-renewable energy. The problem statement, objectives of the research, scope of research, and research gaps are included in this chapter as well.

Chapter 2 discusses the literature review of the research. In the literature review, it is narrowed down to the solar cells, polymer solar cells, active layers, and characterization of

solar cells. Besides, this chapter also included the studies which have been done on the field of this research. The motive of chapter 2 is to assist the readers to gain insight into the field of this research, which is the push coating method.

Chapter 3 describes the methodology of this research. The methodology consists of the workflow and processes involved in fabricating the active layers with the spin and push coating methods and then compare their surface condition. The tabulation of data is also shown in this chapter as well.

Chapter 4 shows the results and discussion of this research. The results including the PDMS stamp condition and film condition that produced by both spin and push coating. The discussion part explained the reasons for getting these outcomes.

Chapter 5 is the conclusion and recommendations and this research. In the conclusion part, the main points and focus throughout this project are summarised. This chapter also discusses the recommendations to improve the film condition as references for future studies.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter reviews of solar energy which focused on its strength and applications. A solar cell is used to convert solar energy into electrical energy, the type of solar cell is discusses based on the generation. In this chapter, the literature review of conventional and inverted polymer solar cells is discussed which mainly focused on their structure and working mechanism. Furthermore, one of the solar cell layers, which is the active layer is discussed on the techniques of fabrication and its characterization.

2.2 Renewable energy – Solar energy

The energy obtained from renewable resources is known as renewable energy, in which the resources will replenish naturally in a certain period. Nowadays, renewable energy is often used in power generation due to its low carbon-intensity which causes fewer pollutions to the Earth and its lower cost compared to the non-renewable energy resources, fossil fuels. There is various type of renewable energy such as hydro energy, biomass energy, wind energy, and solar energy. In the 21st century, a number of researches on solar energy have been done in order to replace non-renewable energy, fossil fuels, and oils (Candanedo & Athienitis, 2009; Rahman & Velayutham, 2019; Shaikh, 2017).

Solar energy is the energy obtained from the sun and subsequently converting it into thermal or electrical energy. It is been claimed that solar energy is the best energy that is

capable to replace the fossil fuels in the future (Kannan & Vakeesan, 2016). Solar energy considered as the most abundant energy source of renewable energy as the sun emits it at the rate of 3.8×10^{23} kW and approximately 1.8×10^{14} kW is intercepted by the Earth. On Earth, solar energy exists in various forms including heat and light energy, these energies are then converted into electricity to generate power. Besides, solar energy is free reachable to ordinary people and it has a lower cost in terms of manpower compared to conventional energy production technology.

Solar energy is widely used in various applications because of its freely available and eco-friendly. One of the applications of solar energy is the building integrated photovoltaic (BIPVs), a method to replace conventional building materials with photovoltaic materials. Arrays of photovoltaic panels are mounted on the roof or walls of buildings to store solar energy from the sun and then generate electricity to supply the households. BIPVs are claimed to be the most economical and reliable technology for electricity consumption of households (Candanedo & Athienitis, 2009).

2.3 Solar cell

Nowadays, renewable energy is often used in the electricity sector for power generation. There are various ways to generate power including hydropower, wind power, biomass, and solar power. Solar power is the conversion of solar energy into electricity with the help of photovoltaic cells, which is also known as solar cells.

The history of the solar cell begins in 1839 when Alexandre-Edmond Bercquerel discover the photovoltaic (PV) effect (Becquerel, 1839). In 1946, Russel Ohl had invented the first modern solar cell, silicon wafer-based solar cell. In the earlier generation, solar cells are designed to be thin silicon wafers with the function of converting solar energy from the sunlight into electrical power. While the modern solar cell is made up of semiconductor materials with the same function.

2.3.1 First generation of solar cells

The first generation solar cells are fabricated on silicon wafers. The silicon wafer-based is the traditional and well-known technology due to its high power efficiency (Sharma et al.,