UNIVERSITI PUTRA MALAYSIA

DYE- SENSITIZED SOLAR CELL USING LOCAL NATURAL DYE EXTRACT FROM Melastoma malabathricum L. FRUIT PULP

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By

MUJAHID IQBAL

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Master of Science

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DYE-SENSITIZED SOLAR CELL USING LOCAL NATURAL DYE EXTRACT FROM *Melastoma malabathricum*.L. FRUIT PULP

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Chairman : Associate Professor Suhaidi Bin Shafie, PhD
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olar energy generation become important today due to high energy demand since carbon based fuels contribute to green house that increase the global temperature. Therefore the third generation solar cell namely Dye-sensitized solar cells (DSSCs) have attracted considerable attention due to its advantages such as of low production cost, non-toxic material and simple fabrication process. The existing DSSC mainly implement synthetic dye in the fabrication process while some researcher utilizes natural dye from flowers and fruits for the environmental friendly synthesizer. However these dye are not available locally therefore this thesis focused on the study, fabrication and efficiency enhancement of dye sensitized solar cell based on local natural dye extract namely Melastoma Malabathricum. The fabrication process starts with the preparation of 2 pieces of FTO coated glass (2 × 2 cm2), cleaned and printed with TiO2 paste (1 × 1 cm2) and coated with Pt or Carbon or Graphite thin layer, respectively. The Both glass substrate are then annealed in furnace either in air or Argon gas at 450°C for 30 minutes. In the process, the TiO2 paste printing method has adopted the Screen Printing and Dr. Blade method. The coated glass is then soaked in Melastoma Malabathricum fruit pulp extract for 2 hours and then both glass are sandwiched and injected with electrolyte. The fabricated DSSC is evaluated using UV-Vis and light I-V to characterize the absorption and efficiency, respectively. From the experiment, The best efficiency result is 0.15%, with VOC of 0.568 V, ISC of 0.427 mA and FF of 0.626 has been attained, based on screen printing method and annealed in Argon gas while the efficiency of Blueberry dye based DSSC is only shows 0.079%.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Sarjana Sains

SEL SURIA PEKA PEWARNA BERASASKAN PEWARNA ASLI DIEKSTRAK DARIPADA PULPA BUAH MELASTOMA MALABATHRICUM

Oleh

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Pengerusi : Profesor Madya Suhaidi Bin Shafie, PhD
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Hari ini penjanaan tenaga solar menjadi penting berikutan permintaan tenaga yang tinggi kerana bahan api karbon menyumbang suhu global yang tinggi kepada rumah hijau. Oleh itu sel-sel solar generasi ketiga iaitu pewarna sensitif (DSSCs) telah menarik perhatian kerana kelebihannya seperti kos pengeluaran yang rendah, bahannya bukan toksik dan proses fabrikasinya mudah. DSSC yang sedia ada sebahagian besarnya menggunakan pewarna sintetik dalam proses fabrikasi manakala sesetengah penyelidik menggunakan pewarna semula jadi daripada bunga dan buah-buahan untuk pensintesis mesra alam sekitar. Walau bagaimana pun pewarna ini tidak terdapat di dalam negara ini, oleh itu hasil tesis ini member tumpuan ke pada peningkatan kajian, fabrikasi dan kecekapan pewarna sensitive sel solar berdasarkan ekstrak pewarna semula jadi tempatan iaitu Melastoma Malabathricum. Proses fabrikasi bermula dengan penyediaan 2 keping kaca bersalut FTO (2 ×2 cm2), dibersihkan dan dicetak dengan pes TiO2 (1 × 1 cm2) dan disalut dengan masing-masing platinum, karbon atau lapisan nipis grafit. Kedua-dua substrat kaca kemudiannya dikuatkan dalam relau sama ada di udara atau gas Argon pada 450° C selama 30 minit. Dalam proses ini, kaedah percetakan pes TiO2 telah menerima pakai percetakan skrin dan kaedah Dr. Blade. Kaca bersalut kemudiannya direndam dalam ekstrak pulpa buah-buahan Melastoma Malabathricum selama 2 jam dan kemudian kedua-dua kaca diapit dan disuntik dengan elektrolit. DSSC yang siap difabrikasi dinilai dengan menggunakan UV-Vis dan I-V cahaya untuk mencirikan penyerapan dan kecekapan. Dari eksperimen, hasil kecekapan terbaik adalah 0.15%, dengan VOC, 0.568 V, ISC, 0.427 mA dan FF 0.626 telah dicapai, berdasarkan kaedah percetakan skrin dan kekuatan dalam gas Argon manakala sebagai perbandingan kecekapan pewarna beri biru berasaskan DSSC hanya menunjukkan 0.079%.

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I certify that a Thesis Examination Committee has met on 24 May 2016 to conduct the final examination of Mujahid Iqbal on his thesis entitled "Dye-Sensitized Solar Cell using Local Natural Dye Extract from *Melastoma malabathricum* L. Fruit Pulp" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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LIST OF ABBREVIATIONS

DSSC	Dye Sensitized Solar Cell
PV	Photovoltaic
FTO	Fluorine Tin Oxide
ITO	Indium Tin Oxide
TiO2	Titanium Dioxide
FF	Fill Factor
AM	Air Mass
DC	Direct Current
AC	Alternation Current
UPS	Uninterrupted Power Supply
V	Voltage
I	Current
P-Type	Positive Type
N-Type	Negative Type
Nm	Nanometer
Mm	Millimeter
UV	Ultraviolet
Pm	Power Maximum
Vm	Voltage Maximum
Pin	Power Input
Isc	Short Circuit Current
Jsc	Short circuit current density
Voc	Open Circuit Voltage
Pt	Platinum

Rs	Sheet Resistance
ZnO	Zinc Oxide
Nb2O5	Niobium Pentoxide
SnO2	Tin Oxide
CdS	Cadmium Selenide
CO2	Carbon Dioxide
I-V	Relation between Current and Voltages
□	Efficiency
C-Si	Crystalline silicon
GW	Giga Watt
Ru	Ruthenium
GaAs	Gallium Arsenide
CD	cyclodextrin
NEDO	New Energy and Industrial Technology Development

CHAPTER 1

INTRODUCTION

1.1 Background

Nowadays, renewable energy has become a popular energy worldwide due to it producing less carbon and being reliable. The renewable energy comes from the renewable resources but the electricity that use every day such as coal, gas and petroleum. The renewable energy is also called "clean source energy" for the reason that it does not make dirty the water and air. The renewable energy has the important benefits on the environment. Renewable energy technologies are very clean based on energy that has small effects on the environment rather than conventional energy. There are several kinds of renewable energies such as solar energy, hydro energy, wind energy, biomass energy, ocean energy and geothermal energy. The biomass energy it is come from the things that once lived such as dried vegetarians and wood materials, crop residues and garbage materials. It is also recognized "natural materials" and such as wood is a biomass fuel energy material. The renewable energy, therefore as long as carry on to plant new trees replace on those cut down, this will further future always have wood to burn. Therefore, as well with the fossil fuels, the energy power stored in the biomass fuels came originally from the sun. It is such an extremely utilized source of natural energy, almost certainly due to it is very low cost and originally nature, that it is accounts are almost 15% of the worldwide total energy supplying and mostly 35% in developing countries, mostly for heating and cooking. Besides, the wind is basically very good convection currents in the Earth's atmosphere, motivated by the heat energy from the sun nature. This means by that as long as sunlight's, there will be wind energy. The blowing wind has generated great kinetic energy, and this can be converted into electrical energy by the using of wind turbines. The wind rotates the blades, which is spin a shaft, which joints to a generator and produce the electricity. Wind turbines simply cannot work without any air or wind pressure. Nevertheless, if the wind pressure is so high it would be damage the system in the wind turbines. Mostly wind turbines are sited on the high mountain and hills ridges to take the good advantage of the prevailing winds. According to the research in 2013, approximately, 7.9% of electricity produced in the UK, for example, it is come from the wind turbines. That amount of power energy generation is quite enough for 6.8million homes. Meanwhile, for the hydro power natural energy source, moving water has generated kinetic energy and this can be converted into useful energy in different process. The hydroelectric power schemes store the water at high up in dams and the water has a gravitational potential energy which is provided when it falls. The dams are built to keep the water and more electricity is generated if the water level is more in the reservoir. The force and high pressure in the water turns a series of shaft in a generator, spinning shafts in the generator charges millions of coils and magnets to generate electricity, which is regulated by a transfer. This is in that case electricity transported via cables to factories and homes. Deep down in the Earth's skin or outer layer, there is lava (molten rock) which is called geothermal energy. Lava rock is simply rocks that have melted into liquid shape as a resultant of really extreme heat beneath the Earth. This can be found deep down in the earth surface about 1800 miles, but nearest to

the surface rock layers are very hot enough to retain water and air spaces, which is temperature at about 50-60℃ F (10-16℃). Geothermal technology takes good advantage of the hot layer close to the Earth's surface temperature to generate power energy. Solar energy converts sunlight energy into electrical energy. Solar energy now comes up more thoughtful and significant for a long time because of the massive amount of energy. Ocean energy from the ocean (sea) has retains unbelievable amount of power and energy potential. Therefore the marine technology has not been completely delivered own its potential. The UK is most believed that to be a leading participant in Marine energy. Even though, currently it is maximum capacity is about 9MW, it is on working to deliver 120MW by 2020 [37].

Meanwhile, a solar cell converts sunlight energy into electrical energy. There are four main types of solar cell or photovoltaic technologies which are silicon crystalline, hybrid, thin film and dye sensitized solar cell. The first type of solar cell is silicon crystalline, and there are two types of monocrystalline and polycrystalline. Crystalline silicon consists of small crystals, a continuous crystal. Crystalline silicon is the main semiconducting material used in solar cell technology for the production of solar cells. These cells are assembled into solar panels as a component of a solar cell system to produce solar power from the sunlight energy. The highest efficiency for monocrystalline is silicon 18%-23%. The second type of solar cell is hybrid photovoltaic solar cell. The hybrid solar cells system combine advantages of both inorganic and organic semiconductors materials that are known hybrid solar cell. A hybrid solar cell has organic material that depends on conjugated polymers that absorb sunlight from the sun source as the transport and donor holes. Hybrid solar cell inorganic materials are used the acceptor and electrons transfer in the structure system. The hybrid solar cell system has only low cost by roll to roll in processing but also for saleable solar cell power energy conversion efficiency. The highest conversion efficiency that has been attained by the hybrid photovoltaic system is 30% according to latest research. Meanwhile, the third type of solar cell branch is thin film and it has been proven to have greater efficiency than thin film amorphous coefficient. Afterward, the thin film solar cell is the second generation of solar cell that is made by depositing more thin layers, solar cell material as a substrate, such as metal, plastic and glass. Thin film technologies that are implemented in several commercial technologies consisted of cadmium telluride (CdTe) and (CIGS). Thin films thickness varies from a few nanometers (nm) to ten of micrometers (μm), much smaller than thin-film's opponent technology, the conventional, and the first generation of crystalline solar cell that uses small wafers of up to 200 μm. The thin films solar cell allows being flexible, very lower in weight and very friction. However, it has significantly improved over the years; on the other hand, the thin films technologies that are still in an initial stage of progressing research or with minimum commercial accessibility are regularly classify as promising technology. The highest efficiency of the thin film solar cell is 16% - 20%. Amorphous system, as consuming a good enactment, has a low efficiency and an essentially meaningful extra breach to attain the similar comparative production as further expertise [34].

The fourth and last type of solar cell branch is dye sensitized solar cell technology and dye sensitized solar cell technology also known Gratzel cells, was presented for the first time in 1991 by chemist O' Regan and Gratzel at the Swiss Federal Institute of Technology, Lausanne, and his co-researcher members who worked on the dye sensitized solar cell together. Dye sensitized solar cell is a very simple materials and very lost cost, but the conversion efficiency is also below that of solid state semiconductor technologies. The dye sensitized solar cell is the third branch of solar cell [7]. Solar power generation has prominent as one of the most speedily growing renewable natural source of electricity. The solar cell power generation has the great advantages over other forms of electricity generation source of energy. Solar cell power generation does not need fossil fuels and there is less reliant on this limited and more expensive natural source. Solar cell power produces electricity with a limited impact on the environment as compared to the different forms of electricity generation. A solar system is a function of the number of solar panels installed, application of the solar cell technology are flexible and readily scalable. The solar cell energy in spite the cost and the main an advantage of solar cell systems is that can be implemented in remote areas. Sometimes photovoltaic system is a much better life cycle as a cost option.

There have been some repetition of dye sensitized solar cell expertise and dye sensitized solar cell technologies is the family member of amorphous or thin film photovoltaic devices. The investigator and researchers have been working with layers of photosensitive deposit prepared for ultra-thin, nano-sized semiconductor crystals over a thin layer of TiO_2. The photons direct hit on the photosensitive layer, and generate electrons-hole pairs on the layer. The DSSC is capable to produce the high value of an electrical power from sensitization of dye including natural dyes utilizing in solar cell [33]. Currently, the modern technology of DSSC based on ruthenium polypyridyl complexes as the energetic materials has largely power conversion efficiency approximately about 12% under tested standard (AM 1.5) lighting source. In spite of that, the shortage and very high cost of artificial based dye such as ruthenium complexes may limit their improvement for large scale enactment. Last few years rapidly growing research on organic dyes, organic dyes have more attracted considerable due to high molar extinction coefficient, friendly environment and low costs [28]. Essentially, there have been utilized many natural fruits, petals and roots dyes as a sensitizer in dye sensitized solar cell, more than hundreds natural dyes extracts which are utilized in solar cell, as well as some examples here, *melastoma malabathricum*, mangosteen, strawberries, dragon, black rice, rose petal, blackberry, pomegranate extract, red hibiscus tea (in simple terms have to describe natural dyes obtaining from fruits, seeds, petals) and etc [5, 10, 25,]. The previous researchers presented several results on *melastoma malabathricum* which have sort circuit current of $0.33mA/cm^2$, $0.22mA/cm^2$, $0.18mA/cm^2$ and $0.36mA/cm^2$and, open circuit voltage of 0.732V, 0.698V, 0.335V and 0.742V, with the fill factor or FF is 54.575, 77.94, 96.448 and 57.012, and efficiencies of 0.033%, 0.031%, 0.015% and 0.039% individually. Every sample has retained varies temperature likewise at, 450 ℃, 400 ℃, 350 ℃ and 300 ℃. The enactment of dye sensitized solar cell is strongly affected by sensitizer dye and wide band gap materials implementing such as ZnO, Nb2O5 and TiO_2. The TiO_2 is the best materials due to its good capability to consecutively transfer the electron from one place to another place [4].

1.2 Problem Statement

There are several concerns on problems which motivated the author to carry this research. Firstly, Ruthenium is a type of rare material and might not be available for long term [1]. While, Ruthenium based sensitizer is the most popular synthetic dye used for DSSC fabrication, their synthesis cost is very high resulting these materials to be very expensive in the market. Furthermore, Ruthenium based dyes are very complex in the synthesis process. Secondly, in term of environmental issue, the Ruthenium based synthetic dyes are very harmful to the environment because of their high reaction in the waste water, while their smells are very irritating comes out from chemical mixing [2, 14]. Finally, the solar cell conversion efficiency for DSSC with natural dye is very low including the one implemented with *melastoma malabathricum* extract natural dye [3, 4, 30]. The efficiency can be affected by many factors such as purity of TiO_2 and the thickness of TiO_2 coated layer in the DSSC.

1.3 Objective

The purpose of this research is to study the performance of dye sensitized solar cell utilizing inexpensive and environmental friendly *melastoma malabathricum* as a sensitizer by platinum and carbon catalyst. The main objective in this research is to utilize the dye extracted from *melastoma malabathricum* fruit pulps in dye sensitized solar cell (DSSC). The performances of *melastoma malabathricum* to achieve the main objectives of this research are as follows:

- To characterize optical properties of melastoma malabathricum base dye on TiO2 nanoparticles using UV-Vis spectroscopy.
- To implement and optimize DSSC utilizing melastoma malabathricum dye in order to obtain the best energy conversion efficiency.
- To characterize the electrical performance of fabricated *melastoma malabathricum* dye based DSSC with platinum and carbon catalyst.

1.4 Project Scope

This research concentrates on performance study of *melastoma malabathricum* dye based dye sensitized solar cell (DSSC). Dye sensitized solar cell converted the sunlight energy into electrical energy by using *melastoma malabathricum* natural dye extract as a sensitizer. Anthocyanin's natural dyes are very beneficial and abundant stains retained by the containing purple cabbage, cherries, blueberries, beets, raspberries, fruits and vegetables and purple grapes. Natural dyes extracts can be implemented for the same purpose in the dye sensitized solar cell with an acceptable and affective efficiency can be found in flowers, fruites and leaves by simple technique. The main advantage of natural dye is non toxicity and complete biodegradation. According to literature, DSSC's prepared with many natural dyes has been used as a sensitizer such as, lac, red, sandalwood mangosteen shell due to availability locally. This project focuses on *melastoma malabathricum* which is

abundantly available in Malaysia. I-V characteristics tested is based on AM 1.5 solar irradiation generated from solar cell [35].

1.5 Thesis Contribution

Dye sensitized solar cell developed has used local natural dye extracts from the *melastoma malabathricum* as a sensitizer. *Melastoma malabathricum* fruit normally can be found in tropical countries like, Malaysia, Thailand, Brunei, Indonesia, Philippines, India, and Singapore. The local natural dye extract has provided us good absorbance of sun light due and capable to be used in DSSC.

1.6 Thesis Layout

The first chapter provides an overview of dye sensitized solar cell and *melastoma malabathricum* as sensitizer and dye sensitized solar cell fabrication process. It begins with the analysis of dye sensitized solar cell and their characterization. This chapter also elaborates on the scope of research performed and the objective to be achieved based on study of dye sensitized solar cell. The outline of this thesis is also explained in detail at the end of this chapter.

Chapter two then presents the literature review related to the research made in dye sensitized solar cell fabrication and *melastoma malabathricum* as sensitizer in dye sensitized solar cell. The scope of literature review covers the related researches on dye sensitized solar cell, critique of the dye sensitized solar cell and *melastoma malabathricum* natural dyes extracted for this research. Certain parts of this chapter explained and showed the latest research on renewable energy and their classification of solar cell. Literature review studies on the subject matter will be able to provide various useful inputs in fabrication process methodology.

Chapter three explains the required methodology in manufacturing of the dye sensitized solar cell. This chapter begins through the completely detailed elaboration on the research performed at the first stage of manufacturing and optimization of dye sensitized solar cell. This chapter also covers the performed methodologies to produce the complete dye sensitized solar cell and also their description. Furthermore will have the capabilities of fabricate dye sensitized solar cell.

Chapter four covers the complete analysis of dye sensitized solar cell from the experimental results and discussion carried out on the dye sensitized solar cell. This chapter concludes the investigation made of the results from *melastoma malabathricum* natural dye extracted and the behaviour of dye sensitized solar cell. Completing the chapter with thorough explanation on the analysis performed on the dye sensitized solar cell.

Chapter five is a summary of the final outcome from the proposed research and further potential future work of dye sensitized solar cell. This chapter concludes the research and fabrication of the dye sensitized solar cell. Conclusions achieved are initially proposed research methodology and the collected experimental results. Finally this chapter proposed recommendations and future works of dye sensitized solar cell.

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