CHAPTER 1

INTRODUCTION TO THE THESIS

1.1 INTRODUCTION

Today, the human population in the world is approximately 7 billion estimated by United States Census Bureau. With the increase in human population, there is an increasing demand for energy. The impact of the slow depletion of energy sources in the earth and the problems due to pollution that arises from their usage are being felt all over the world. Most of the world's energy comes from burning fossil fuels i.e. from coal, oil and gas. In particular, coal and gas have been the two main energy sources in Malaysia [Mekhilef *et al*., 2012]. The burning of fossil fuels by man to meet the ever-increasing demand for energy has resulted in excessive amounts of carbon dioxide that led to global warming. Apart from the fast exhaustion of fossil fuels and the climate change, the increase in fuel price has driven the search for alternative energy resources. The solution is renewable energy that is abundant, clean, probably cheaper, environmentally friendly and will not run out.

Renewable energy is the production of electricity, transport fuel or heat from sources that are inexhaustible such as sunshine, wind, flowing water and waste organic material i.e. biomass energy. The Malaysian government has been playing her part in preserving fossil fuel resources and reducing pollution by taking initiatives and venture into renewable energy technology. Under the 8th Malaysian Plan (2001-2005), the government has declared renewable energy as its fifth fuel resource besides gas, coal, oil and hydro power [Oh *et al*., 2010]. On June 10th 2010, Prime Minister Datuk Seri Najib Razak announced that the country is aiming for a contribution of about 5.5 % from renewable energy (i.e. 98 MW) to the total electricity generated by 2015 under the 10th Malaysian Plan (2011-2015). One of the many steps taken by the Malaysian government is to support and finance universities and institutions in doing research on renewable energy.

One of the renewable energy resources comes from the sun i.e. solar energy. The sun can provide limitless energy for life on earth and it is free. Solar energy is an abundant resource which is believed to have the capability to sufficiently supply the energy demand of the world. According to literature, the radiation energy of the sun received from the outer atmosphere of the earth is 1368 W m^{-2} [Ahmad *et al*., 2011]. Malaysia, being a tropical country with an average daily solar emission of 5.5 kW m^{-2} (equivalent to 15 MJ m^{-2}) is very suitable for the generation of solar energy [Oh *et al*., 2010]. Ahmad *et al*. [2011] reported that the present production of electricity from solar energy in Malaysia is around 1 MW only. At the opening of the 1st International Greentech and Eco Products Exhibition and Conference Malaysia (IGEM) held at the Kuala Lumpur Convention Centre from 14th to 17th October 2010, the Prime Minister has announced that “The government is determined to make Malaysia the regional centre for green energy, specifically solar energy”. The Prime Minister also reported that Malaysia has attracted foreign direct investments (FDIs) in the solar photovoltaic industry for a total of USD 4 billion i.e. more than RM 12 billion based on conversion rate of 1 USD = RM 3.13 .

As early as 2007, a US company, First Solar Incorporation became the first company in Malaysia in the field of solar energy production. A press release by China

Economic News Service dated 4 June 2010 announced that a Taiwanese company, AU Optronics Corporation (AUO) and a US company, SunPower Corporation signed a joint venture pact to build a solar cell factory located in Malacca. AUO SunPower Corporation Sendirian Berhad, the manufacturer of solar cells, solar panels and solar system is expecting to generate more than 1400 MW solar power per year when fully operational in 2013. A US manufacturer of crystalline silicon solar panels, Twin Creeks Technologies Incorporation (TCTI) joint ventured with Perak State Development Corporation (PSDC) through its associate company, Red Solar (M) Sdn. Bhd. to set up 100 MW solar cell and panel manufacturing plant at Perak Hi-Tech Park in Ipoh. The Deputy Prime Minister, Tan Sri Muhyiddin Yassin officiated the groundbreaking of Twin Creeks Malaysia's solar panel factory on 14 December 2010.

Conventional solar cells are usually silicon-based solar cells. Amorphous silicon solar cells are less expensive but exhibit lower efficiency compared to crystalline solar cells [Deb and Sopori, 2000]. Overall, the price of silicon-based solar cells is still considered high. Another type of solar cells is cadmium-based solar cells. One of the leading companies that produce cadmium telluride thin film solar cells is First Solar Incorporation. This manufacturer focuses on producing cost-effective solar panels. Although the cost production of cadmium solar cells is cheaper than silicon-based cells, cadmium is a toxic material. Silicon photovoltaic cells are not only expensive, they also show narrow absorption band in the ultraviolet and violet range. It is known that solar spectral radiation from the sun comprises 96 % visible light and 4 % ultraviolet light. Silicon solar cells use only 4 % of the sun's energy. This leads to the search of photovoltaic cells with wider absorption spectrum in the visible light region.

Dye-sensitized solar cells (DSSC) have emerged as a promising alternative candidate to conventional silicon-based solar cells. Unlike conventional solar cells, the working principle of which is based on charge separation at the interface of two different conducting materials, DSSC is a photoelectrochemical cell using electrolyte as a medium for charge transport.

Photoelectrochemical (PEC) solar cells are also known as semiconductor/ electrolyte junction solar cells which consist of an electrolyte containing a redox mediator sandwiched between a semiconductor photoelectrode and a counter electrode. When light strikes the photoelectrode, the electrons in the ground state of the dye absorb energy and enter the excited state. Electrons in the excited state will then enter the conduction band of the semiconductor and go to the counter electrode through the external circuit. At the counter electrode, the oxidized form of redox mediator is reduced to its original state in the electrolyte and releases the electron back to the dye by oxidation. The cycle continues. The absorption spectrum of dye is wider and covers the visible light region.

1.2 OBJECTIVES OF THE THESIS

In this thesis, DSSCs are fabricated from a combination of materials containing cheap and non-toxic photoelectrode, natural dye, low cost redox mediator-containing polymer electrolyte and counter electrode. The objectives of this work are summarized as below:

- to prepare chitosan-based polymer electrolyte containing redox couple,
- to improve the ionic conductivity of polymer electrolyte by blending chitosan with poly(vinyl alcohol) and poly(ethylene oxide), respectively as well as incorporating ionic liquid,

- to prepare dye sensitizer extracted from natural sources i.e. black rice, blueberry and red cabbage,
- to fabricate DSSC and investigate its performance.

1.3 SCOPE OF THE THESIS

In addition to this introductory chapter, the thesis includes eight other chapters. Chapter 2 focuses on the different types of DSSCs and its working principle, reviews the electrolytes commonly used in DSSCs as well as the selection and properties of the materials used in the fabrication of DSSC. Chapter 3 describes the details of sample preparation and characterizations such as fourier transform infrared (FTIR) spectroscopy, x-ray diffraction (XRD) and electrochemical impedance spectroscopy (EIS). Also, the DSSC fabrication is presented in this chapter.

Chapter 4 displays results from FTIR studies that investigate interactions between polymer-polymer, polymer-salt, and polymer-salt-ionic liquid. Chapter 5 presents XRD results for examining the nature of polymer electrolyte materials. The ionic conductivity of the polymer electrolytes determined from impedance studies are all presented in Chapter 6. This chapter also covers the dielectric studies of the polymer electrolytes. The performance of the DSSCs is presented in Chapter 7. Chapter 8 discusses the thesis and Chapter 9 concludes the thesis with some suggestions for future work.