DESIGN, FABRICATION AND EXPERIMENTAL STUDY OF A MINI ALKALINE FUEL CELL FOR MICRO-ELECTRONIC AND MECHANICAL APPLICATION

Hon Kah Jui

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ABSTRAK

"Fuel Cell" ialah sejenis alat yang dapat menjanakan kuasa elektrik tanpa proses pembakaran. Selain itu, ia hanya menghasilkan sedikit bunyi, tidak bergegar, dan tidak mencemarkan udara atau menghasilkan kesan rumah hijau. Dalam projek ini, satu "Fuel Cell" akan direka dan dibina serta diuji kebekesanannya. Objektif utama bagi penyelidikan ini ialah untuk mereka dan membina satu mikro "Fuel Cell" yang dapat menghasilkan amaun elektrik yang kecil. Elektrik yang dijanakan telah terbukti dapat digunakan untuk mikro-elektronik atau aplikasi isyarat mekanikal seperti Pico Scope. Oleh itu, ia dapat digunakan sebagai penunjuk kepada isyarat yang tidak normal seperti gangguan yang terjana pada wayar Pico-Scope.

ABSTRACT

Fuel cell is a device that can produce electricity without any internal combustion; they did not produce any noise, vibration and air pollution. In this project, a mini dissolved alkaline fuel cell has been designed, fabricated and laboratory tested. The purpose for this exercise is to design and fabricate a micro dissolved alkaline fuel cell for generating a small amount of electricity. The voltage generated had been proven to be useful for micro-electronic and mechanical signal application i.e. the Pico scope. The Pico- Scope can be function as a detector to detect unwanted signal such as interference.

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1.1.1 Introduction

"The advent of fuel cells for the generation of electricity for portable, small and large scale stationary and automotive purposes portends radical changes in electricity supply over coming decades[3] "

Fuel cells are devices used to produce electrical power, and are beginning to receive a large amount of public attention. This section is intended to provide an introduction into fuel cells, what they are, what they can do, why they are important and what the commercial implications of fuel cell. Fuel cells sound like a science-fiction fantasy: an efficient, nonpolluting power source that produces no noise and has no moving parts. But such cells not only exist, they have been providing electricity on spacecraft since the 1960s. In more down-to-earth applications, they could be used as electricity-generating plants or as a power source for nearly exhaust-free automobiles[2]. The main sticking point is the high cost of manufacturing the devices, which has largely limited them to a handful of exotic applications. Now falling prices and new technologies suggest that the fuel cell's day may finally have arrived[1].

A fuel cell is an electrochemical device that produces electricity from a combined chemical reaction and electrical charge transport that occurs within the fuel cell. This is very similar to the way a battery produces electricity. However, unlike a battery, a fuel cell only produces electricity while fuel is supplied to it and almost endlessly rechargeable. The reaction is at relatively low temperatures, and no combustion takes place in the fuel cell. The primary fuel used in fuel cells is hydrogen. When hydrogen is supplied, a chemical reaction, between hydrogen and air produces electricity, pure water and some heat. In fuel cells, as in batteries, silent reactions produce an electric current. The cells run on hydrogen, which reacts with oxygen from the air in such a way that a voltage is generated between two electrodes; the reactions occur in a chemical mediator known as an electrolyte. (Some designs consume hydrogen directly; others start with natural gas that is converted to hydrogen before entering the cell.) The electrical power available is proportional to the rate of fuel flowing into the fuel cell, limited by the physical size of the fuel cell. Compared with conventional fossil-fuel power sources, fuel cells are exceptionally clean and efficient. Practically their only waste product is water; natural gas-fueled cells do produce some carbon dioxide as well, though less than would be created if the fuel were burned.

There are eight primary types of fuel cells, each distinguished by the type of the electrolyte that is used to carry charge between the fuel and the oxygen in the air. Because fuel cells produce power without combustion, they are considerably more efficient than their internal combustion engine counterparts. Gasoline engines in automobiles are approximately 13 to 25 percent efficient. That's right, 75 to 87 percent of the gasoline you put in your tank does not participate in moving your automobile. A fuel cell attached to an electric motor can be in excess of 40 percent efficient. Today, fuel cells that can be used in automobiles and other vehicles are being produced with efficiencies of 45 to 58 percent.

More exciting is the possibility of installing fuel cells in automobiles, where they potentially have significant advantages over polluting internal-combustion engines or power-poor batteries in electric vehicles. Within the past year, both Toyota and Daimler-Benz have exhibited PEM cell-powered automobiles. The main difficulty with using fuel cells in passenger vehicles is in supplying the hydrogen. Although the gas can be compressed, companies are worried about safety should a pressurized hydrogen tank be damaged in an accident. Toyota's demonstration car solved the problem by storing the hydrogen in hydrides, compounds that can stockpile hydrogen in a safe, but heavy and cumbersome chamber. Toyota and Daimler-Benz are also exploring a technique for producing the hydrogen as needed by breaking down a fuel such as methanol, which is far easier to transport and pump into a car[1].

When portability is not an issue, as it is not for municipal utilities, other possibilities open up. "Molten carbonate" and "solid oxide" fuel-cell technologies, for instance, could bring extraordinary efficiencies to power-generating stations. These devices run at far higher temperatures than PEM or phosphoric acid cells. Molten carbonate and solid oxide cells might be able to achieve an impressive efficiency of 55 percent or more, according to Robert R. Rose of Fuel Cells 2000, an advocacy group. The hot steam and carbon dioxide they produce can be used to drive a gas turbine that generates additional electricity, an approach that could push their efficiency to an unheard-of 80 percent. They are potentially up to twice as efficient as a typical oil- or coal-fired plant[1].

Since a fuel cell is a device that produces electricity directly from hydrogen fuel, its application can be for anything that requires power in the form of electricity, rotary power or heat. A unique characteristic of all fuel cells is that they can be made small enough to power a cellular phone or large enough to power a town, without significantly changing the design. Therefore the markets for fuel cells are virtually unlimited. Some major applications include all ground or surface vehicles, such as cars, utility vehicles, trains, boats, jet skis, snow mobiles, motorcycles, etc. There are also applications in power production, such as commercial utility power, remote power and portable power production.

In 1990 few automobile companies or utilities were openly pursuing the fuel cell as a production power plant. Today every major automobile company in the United States, Europe and Japan has a serious fuel cell program. On March 17, 1999, DaimlerChrysler unveiled its hydrogen, fuel cell powered concept car called the NECAR IV. It has a refueling range of 280 miles and can travel at 90 MPH. Also, more than 100 fuel cells large enough to power small buildings or neighborhoods have been commercially produced and deployed throughout the world. It is reasonable to expect almost every power producing device in the world to be replaced by fuel cell devices over the next 50 to 80 years. Clearly, the market potential for such an endeavor is in the trillions of dollars. The fuel cell has recently been termed the "Micro chip of the energy industry". Two important advantages of fuel cells are that they do not produce polluting emissions or greenhouse gases, and do not require supplies of foreign oil[2].

Just like any new technology that has been introduced into society, the best early market applications for fuel cells are in the small, high value niche markets. From there, economies of scale and other drivers expand the market and drive further development, in turn expanding markets. All this is still subject to traditional "valley of death syndrome" issues in new business and technology development[2].

However, the level of development and international interest to date assure that fuel cells will play a significant role in nations' economies. The automobile is one of the most difficult markets for the fuel cell and most likely will be one of the last major markets into which they will be introduced.

Over the next five years we expect fuel cells to be commercially introduced into several transportation and utility power markets. In transportation we see applications in specific service vehicles, electric scooters and certain marine applications. For utility applications there are high value niche markets in remote villages around the world. Two billion people, one-third of the world's population currently does not have electricity. Additionally, remote and portable power is two other important early applications for fuel cells[2].

There are currently a couple dozen small and large companies manufacturing fuel cells. However the opportunity for growth in this market is tremendous. There is, and will be competitive opportunities for manufacturing, integrating and deploying fuel cells and related equipment for decades to come. Fuel cells still face tough competition in a world with cheap oil, but they are no longer only of interest to Space Shuttle astronauts. And if you live in a part of the world where electricity is expensive or far away, they may be coming soon to your neighborhood[2].

1.1.1 Principle of Fuel Cell

Fuel cell is an electrochemical device that can produce electricity continuously by separating the fuel usually hydrogen gas via a catalyst[4]. In other words to say, fuel cells are energy conversion devices that can transform the energy stored in a fuel into electricity and heat[5]. And the fuel is oxidized electrochemically without burning in flame. The protons from hydrogen gas flow through a membrane and will combine with oxygen to form water with the help of catalyst. The electrons are flowing from anode to cathode to create electricity. Pure hydrogen and oxygen as the reactants are supplied to the cell to produce electrical energy. Thus, a fuel cell can produce electricity continuously as long as the oxygen and hydrogen are supplied to the cell.

A fuel cell consists of an anode (a negative electrode that repels electrons), an electrolyte membrane in the middle, and a cathode (a positive electrode that attracts electrons). As hydrogen flows into the fuel cell anode, platinum coating on the anode helps to separate the gas into protons (hydrogen ions) and electrons. The electrolyte membrane in the middle allows only the protons to pass through the membrane to the cathode side of the fuel cell. The electrons cannot pass through this membrane and flow through an external circuit in the form of electric current. This current can power an electric load, such as a motor or small fan. The fuel cell provides a DC (direct current) voltage. As oxygen flows into the fuel cell cathode, another platinum coating helps the oxygen, protons, and electrons combine to produce pure water and heat. Individual fuel cells can be then combined into a fuel cell "stack". The number of fuel cells in the stack determines the overall voltage, and the surface area of each cell determines the overall current. Multiplying the voltage by the current yields the total electrical power generated.

There are several different types of fuel cells, each using a different chemistry. Fuel cells are usually classified by the type of electrolyte they use. A factor that draws interest to the fuel cell is that it can operate at efficiencies two to three times that of the internal combustion engine, and it requires no moving parts. Since it converts the fuel, hydrogen, and oxygen directly to electrical energy, the only by-products are heat and water. Without combustion, fuel cells are virtually pollution free. Although hydrogen is the most common fuel used to power a fuel cell, research is being done on a new type of fuel cell that operates using methanol (without using a reformer to convert it to hydrogen) and oxygen. However, this type of fuel cell remains in the early stages of development.

1.1.2 Types of fuel cells

There are several types of fuel cells being design and used at all around the world. Below are some of general classifications;

a) Solid Oxide Fuel Cell (SOFC)

This type of fuel cell can be used at high power consumption machines such as industrial and large scale central electricity generating stations. The output of this type fuel cell is up to 100KW. Solid Oxide Fuel Cell use a hard ceramic compound of metal (such as calcium or zirconium) oxides (chemically, oxygen) as their electrolyte. Reformer is not necessary used to extract hydrogen from fuel due to the high operating temperature that can be as high as 1000°C.

b) Molten Carbonate Fuel Cell (MCFC)

These fuel cells use a liquid solution of lithium, sodium and/or potassium carbonates, soaked in a matrix for an electrolyte. They promise high fuel-to-electricity efficiencies, about 60% normally or 85% with cogeneration, and operate at about 1,200 °F or 650° C. Units with output up to 2 megawatts (MW) have been constructed, and designs exist for units up to 100 MW. The nickel electrode-catalysts of molten carbonate fuel cells are inexpensive compared to those used in other cells.

c) **Phosphoric Acid Fuel Cells (PAFC)**

Phosphoric acid fuel cells use phosphoric acid as the electrolyte to produce electricity. Existing PAFC have outputs up to 200 kW, and 1 MW units have been tested. Its efficiency ranges from 40 to 80 % and operating temperature is around 150 to 200° C (about 300 to 400° F). Disadvantages of PAF include: it uses expensive platinum as a catalyst, it generates low current and power comparably to other types of fuel cells, and it generally has a large size and weight.

d) **Direct Methanol Fuel Cells (DMFC)**

This kind of cells is quiet similar to Proton Exchange Membrane Fuel Cells (PEM). They both use a polymer membrane as the electrolyte. However, in the DMFC, the anode catalyst itself draws the hydrogen from the liquid methanol, eliminating the need for a fuel reformer. Direct methanol fuel cells use methanol as electrolyte instead of hydrogen. The Operating temperatures of direct methanol fuel cells are in the same range as PEM fuel cells – 50 to 100°C (122 to 212°F).

e) Alkaline Fuel Cells (AFC)

Alkaline Fuel Cells (AFC) was the first type of fuel cell that used for manned space applications and it produces drinking water and electricity. AFC contain a potassium hydroxide (KOH) solution as the electrolyte. It operates with in the range of 100°C -250°C. The Output of this type fuel cell is ranges from 300 watts (W) to 5 kilowatts (kW).

f) Proton Exchange Membrane Fuel Cells (PEM)

This is the most common type of fuel cell that used in transportation field. Normally it will operate at the one kW per liter of volumetric powered level at a temperature under 100°C (212 °F). A PEM contains an electrolyte that is a layer of solid polymer (usually a sulfuric acid polymer that allows protons to be transmitted from one face to the other (Gottesfeld and Zawadinski, 1998). PEM require hydrogen and oxygen as inputs. The cell outputs generally range from 50 to 250 kW.

1.2 Objective

The main objective for this research is to design and fabricate an efficient fuel cell so that it can be used to generate a micro electric current for dedicated application. Since the technology of fuel cell is still quite new in Malaysia and many other countries, hopefully, after this research is carried out here, at Unimas, more people will have the knowledge of fuel cell and its associated usage and advantages. The objectives of the current research can be outlined as follow:

a) Understanding the fundamental properties and the history of fuel cell.

b) Literature review

c) Design of a fuel cell (Alkaline Fuel Cell).

d) Construction of a fuel cell prototype (Alkaline Fuel Cell).

e) Measurement of data, data collection and experimenting of the prototype built.

1.3 Methodology of Research

Below are some methods that have been carrying out to make this project possible:

a) Preliminary study and literature review.

- To understand the working principle of a fuel cell.
- To learn out various types of fuel cell and the elements of a fuel cell.
- To understand the calculation of the efficiency of a fuel cell.
- To find out affordable type of fuel cell that can be design and used locally at UNIMAS.

b) Experiments

- To find the parameters that influencing the efficiency of the system.

c) Calculations

- Calculate the output voltage and ampere.

d) Analytical method and theoretical study

- Some mathematical derivation of efficiency of fuel cells.

The work chart for this research is given in Figure 1.1, Appendix A.

1.4 Problem Statement

1) **Cost -** The high capital cost for fuel cells is a largest problem contributing to the development of fuel cell technology in Malaysia. In order for fuel cells to compete realistically with contemporary power generation technology, they must become more competitive from the standpoint of both capital and installed cost (the cost per kilowatt required to purchase and install a power system). For our project to design and fabricate a mini fuel cell in UNIMAS, the cost is a major problem in order to get high efficient electrode such as platinum.
2) **Technology & Facilities** – This newer technology had came across a problem which there are no any suitable facilities in Malaysia such as a machine which can enable us to construct a bipolar plate for the best contact to produce high efficiency electricity.
3) **Lack Of Information** – In Malaysia, it is difficult to find any related information about Fuel Cell Technology. Furthermore, there are no any related consultancies that can assist us when doing this project. The information that had been taken from references such as Web site and reference books are all from oversea countries which are not in complete and still in fundamental research.

1.5 References for Chapter 1

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Chapter 2 Literature Review.

2.1 Foreword

This literature review is a summary from several journals, books, articles and web site that are doing research about fuel cells technology over the past few years. There are 8 different types of fuel cell technologies available but the most important type of fuel cell are Proton exchange Membrane Fuel cells, Direct Methanol Fuel Cells, Phosphoric Acid Fuel Cells, Molten Carbonate Fuel Cells, Solid Oxide Fuel Cells and Alkaline Fuel Cells.

This chapter gives a brief overview of the technologies and their present state of development.

2.2 Literature Review According to Types of Fuel Cells

2.2.1 Proton Exchange Membrane Fuel Cells (PEMFC)

The PEMFC consists of porous carbon electrodes bonded to a very thin sulphonated polymer membrane. PEMFC used Sulphonated polymer membrane as their electrolyte. The fuel that needed to operate this kind of fuel cell is Hydrogen and pressurized air. The cell operating temperature is quiet low that is about 60-90°C and operating pressure can be in the range of 1-8 atmosphere.

PEMFC have very high efficiency compared to others fuel cell. The efficiency for this kind of fuel cells is approximately 50%. The PEMFC also provides a very high power