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# Introduction

As high-tech multifunctional and miniature devices such as laptop computers, digital video recorders, digital multimedia phones and PDAs become more widely used, new power sources need to be developed that have much longer run time and stronger power than those that current power sources, namely lithium batteries, provide. A fuel cell, which is a device that generates electricity by a chemical reaction, is considered the promising candidate for replacing them. Among various fuel cells, direct methanol fuel cell (DMFC) is the most suitable power source because it does not require any fuel processing equipment and can be operated at low temperatures. Also DMFC has advantages of easy transportation and storage of the fuel, and reduced system weight and size [1, 2]. However, in order to develop a micro fuel cell needs much examination due to a limited weight and size and a high performance, durability. To meet these requirements, the MEA has to perform well and the stack design has to be very compact.

# DMFC description

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## Concept of DMFC

Direct-methanol fuel cells or DMFCs are a subcategory of proton-exchange fuel cells where the methanol  fuel is not reformed as in the indirect methanol fuel cell, but fed directly to the fuel cell operating at a temperature. Because the methanol and water is fed directly into the fuel cell, steam reforming is not required. Storage of methanol is much easier than for hydrogen as it does not need high pressures or low temperatures, because methanol is a liquid from  to . The energy density of methanol - the amount of energy contained in a given volume - is an order of magnitude greater than even highly compressed hydrogen. The waste products with these types of fuel cells are carbon dioxide and water.

The efficiency of current direct-methanol fuel cells is low due to the high permeation of methanol through the membrane materials used, which is known as methanol crossover.

Nowadays DMFCs are limited in the power they can produce, but can still store a high energy content in a small space. This means they can produce a small amount of power over a long period of time. This makes them presently ill-suited for powering vehicles (at least directly), but ideal for consumer goods such as mobile phones, digital cameras or laptops.

Methanol is toxic and flammable. However, the International Civil Aviation Organization's (ICAO) Dangerous Goods Panel (DGP) voted in November 2005 to allow passengers to carry and use micro fuel cells and methanol fuel cartridges when aboard airplanes to power laptop computers and other consumer electronic devices. On September 24th, 2007, the US Department of Transportation issued a proposed rulemaking to allow airline passengers to carry fuel cell cartridges on board. The Department of Transportation issued a final ruling on April 30, 2008, permitting passengers and crew to carry an approved fuel cell with an installed methanol cartridge and up to two additional spare cartridges. It is worth noting that 200 ml maximum methanol cartridge volume allowed in the final ruling is double the 100 ml limit on liquids allowed by the Transportation and Security Administration in carry-on bags.

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## Chemical reaction

The DMFC relies upon the oxidation of methanol on a catalyst layer to form carbon dioxide. Water is consumed at the anode and is produced at the cathode. Positive ions  are transported across the proton exchange membrane – often made from Nafion (Nafion is a sulfonated tetrafluoroethylene copolymer discovered in the late 1960s by Walther Grot of DuPont [3]. It is the first of a class of synthetic polymers with ionic properties which are called ionomers) – to the cathode where they react with oxygen to produce water. Electrons are transported through an external circuit from anode to cathode, providing power to connected devices.

**Fuel**

**Air**

Current

collector

Anode

Current

collector

Cathode

Proton Exchange Membrane (PEM)

Carbon dioxide

Water

Electrical circuit

*Figure 1. The overall reaction in a DMFC*

The reactions are:

Anode:

Cathode: 

Overall reaction: 

Methanol and water are adsorbed on a catalyst usually made of platinum and ruthenium particles, and lose protons until carbon dioxide is formed. As water is consumed at the anode in the reaction, pure methanol cannot be used without provision of water via either passive transport such as back diffusion, or active transport such as pumping. The need for water limits the energy density of the fuel.

Nowadays, platinum is used as a catalyst for both half-reactions. This contributes to the loss of cell voltage potential, as any methanol that is present in the cathode chamber will oxidize. If another catalyst could be found for the reduction of oxygen, the problem of methanol crossover would likely be significantly lessened. Furthermore, platinum is very expensive and contributes to the high cost per kilowatt of these cells.

During the methanol oxidation reaction carbon monoxide  is formed, which strongly adsorbs onto the platinum catalyst, reducing the surface area and thus the performance of the cell.

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## Components of typical DFMC

DMFC generally consists of membrane-electrode assembly (MEA), gas diffusion layer (GDL), bipolar plates. MEA is comprised by a polymer electrolyte membrane and electrode catalyst layers and gas diffusion layers. Polymer electrolyte membrane has to have two properties: conducting  ions from the anode to the cathode and providing electrical insulation between the anode and the cathode to force the electrons to move from the anode to the cathode all the way through an external circuit. A sulfonated tetrafluorethylene copolymer such as Nafion developed by Dupont is usually used as a polymer electrolyte membrane but recently hydrocarbon series which improved a methanol crossover begin to be applied [4]. The best catalyst for both the anode and the cathode is platinum. The platinum is prepared into very small particles on the surface of carbon powders to increase the reaction area and rate of the electrodes[5]. A carbon backing material such as carbon cloth or paper is usually called the gas diffusion layer. It provides the basic mechanical structure for the electrode and carries away reaction products from the catalyst and reactants towards the catalyst. Also it provides an electrical connection between the catalyst and the bipolar plate. Bipolar plates separate individual cells in a fuel cell stack. Each bipolar plate distributes reactants over the cell surface through the system of channels and collects current produced by individual cell and transports this current from one cell to another [6]. Machined graphite is traditionally used as the bipolar plates due to a good conductivity but metals and composite materials are under development to substitute for it because of its high cost and larger volume. Gasket to prevent liquid and gas leakage is PTFE and end plates are a stainless steel or a copper coated by gold.

**Anode end plate**

**Cathode end plate**

**MEA**

**GDL**

**Graphite plate**

**Gasket**

**Current collector**

*Figure 2. Construction and main components of DMFC.*

Figure 2 shows construction of direct methanol fuel cell, having MEA and the modular components of anode and cathode. MEA is mounted within bipolar plates consisting of two electrically conducting field plates in which channels are fabricated, as shown in Figure 2. PTFE (polytetrafluoroethylene) gaskets are fitted adjacent to flow channels to act as efficient gas seals around the edges of the Nafion membrane[7, 8].

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# Micro Fuel Cell Stack for cellular Phone

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## Developments of micro fuel cell for cellular phones

Many micro fuel cell designed for cellular phones were demonstrated by many Japanese and Korean electronic companies such as Toshiba, Hitachi, Fujitsu and Samsung.

|  |  |  |  |
| --- | --- | --- | --- |
| **Company** | **Size (cc)** | **Power (W)** | **Year of demonstration** |
| Toshiba | 200 | 0.3 | 2005 |
| Hitachi | 122 | 0.3 | 2005 |
| Fujitsu | 160 | 9 | 2005 |
| Samsung | 100 | 2 | 2006 |

Table 1. Characteristics of the fuel cells for cellular phones

Fuel cells mentioned in Table 1 are based on DMFC technology. They are compact between 100 and 200 cc and produce power between 0.3 and 9 W. The fuel cell for the cellular phone developed by Toshiba is a hybrid type, which is combined at the back of the handset with lithium ion battery. It can increase the battery run time 2.5 times longer with a single refill. The fuel cell for the cellular phone developed by Hitachi is also a hybrid type but it is more compact. One feature is that whenever its methanol fuel becomes low, it can be easily refilled from a compact cartridge[9]. The fuel cell developed by Fujitsu enables eight hours of continuous talk and improved the capacity by increasing the methanol concentration from 30% to over 99% and developing a method of recycling the generated water [10]. Samsung demonstrated the world’s smallest fuel cell mobile device charger. It produces 2W is 5mm thick and weight 5.3 ounces. It includes user-replaceable methanol cartridges. It is designed to recharge the battery system in a PDA, cell phone or digital camera [11].

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## Proposed design of micro fuel cell

Stack design is being suggested to be with five cells that have an electrode area around . It has the internal manifolds for supply of air and fuel. Its dimensions are 50×75 ×15 mm, this dimensions are common PDA phone sizes. Each cell of this DMFC stack has an active area around , such area is reasonable for current cell size. Ballard Power Systems Inc. recommends Nafion based MEA with GDS22100 on the anode and P75T on the cathode. GDS22100 prevents methanol crossover by controlling the methanol permeation rate. Figure 3 shows I-V curves for the mentioned idea [12].

*Figure 3. Voltage versus current density for Ballard’s MEA.*

Graphite could be used as bipolar plates with two flow paths.

It could be easily estimated that proposed fuel cell stack will give about 3W power, this power is enough to charge PDA phone battery.

Such fuel cell could be used like charger or even like component of mentioned hybrid power source for mobile devices, such system can provide longer life-time than common Lithium battery, but the worse things of such system are increasing sizes and mass of PDA, so it is still necessary to find some better materials and technologies for DMFC.

Of course is should be noted that such “design” is just proposal and in order to calculate output power and other important features experimental work must be provided, otherwise it is just discussion about theoretical possibility.

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