Akreditasi LIPI Nomor : 536/D/2007
Tanggal 26 Juni 2007

DEVELOPMENT OF LOCAL COMPONENTS FOR FUEL CELL TECHNOLOGY

Eniya Listiani Dewi
Center for Materials Technology (PTM) - BPPT
Jl. MH. Thamrin 8, BPPT II/22, Jakarta 10340

ABSTRACT

DEVELOPMENT OF LOCAL COMPONENTS FOR FUEL CELL TECHNOLOGY. The limitation of oil and gas, dependence of system using energy besides oil fuel, and also awareness of environmental friendly policy have become urgency of fuel cell research. Alternative energy becomes main priority development in the world. Not only in developed countries such as US, Japan, Europe and Canada, many developing countries in Asia are running up to catch the hydrogen used technology. Furthermore, Indonesian policy of energy are shown a requirement to develop on renewable energy and the primary energy mix (Perpres 5/2006, 25 Januari 2006, Kepmen ESDM No. 0983 K/16/MEM/2004, Kepmen ESDM No. 0002/2004, PP No. 03/2005 about change to PP No.89/1989). According to national research strategy, especially of hydrogen and fuel cell technology in 2009, manufacture and production technology, distribution, security of hydrogen and PEMFC technologies is needed. Indeed, in 2025 Indonesia must have national attached PEMFCs 50 kW and capacities goals of 250 MW. On the other hand, vehicle of fuel cell will step into market in the year 2010-2015. The market for mobile fuel cells, with DMFC technologies expected to account for a large portion, is projected to reach US$ 2.6 billion by 2012. Therefore, fuel cell technology is become a crucial technology including of opportunity of local component to contribute in manufacturing fuel cell technology and also a hydrogen storage technology systems. Herein we described the development of various components of fuel cell along with the process such as polyelectrolyte membrane of PEMFC and DMFC, bipolar plate and steam reforming methane with inorganic membrane in BPPT.

Key words : Polymer electrolyte fuel cell, Direct methanol fuel cell, Proton exchange membrane, Graphite bipolar plate, Inorganic membrane, Steam reforming methane

ABSTRAK

PENGEMBANGAN BERBAGAI KOMPONEN LOKAL DALAM TEKNOLOGI *FUEL CELL*. Kepentingan riset *fuel cell* yang makin marak adalah adanya kekhawatiran akan terbatasnya jumlah minyak dan gas, ketergantungan pemakaian energi yang berbasis minyak bumi, dan kepedulian akan teknologi ramah lingkungan yang tinggi. Di dunia, energi alternatif menjadi prioritas utama pembangunan. Tidak hanya pada negara maju seperti Amerika, Jepang, Eropa dan Canada, banyak negara berkembang di Asia yang berlomba menuju pemakaian hidrogen sebagai sumber energi. Perlu diketahui, Indonesia juga telah mencanangkan kebijakan energi yang dibutuhkan masyarakat guna membangun bangsa seperti energi baru terbarukan dan bauran energi primer (Perpres 5/2006, 25 Januari 2006, Kepmen ESDM No. 0983 K/16/MEM/2004, Kepmen ESDM No. 0002/2004, PP No. 03/2005 tentang perubahan atas PP No.89/1989). Berdasarkan pada ARN, khusus untuk hidrogen dan teknologi *fuel cell* pada tahun 2009, diperlukan penguasaan manufaktur, teknologi produksi, distribusi dan keamanan hidrogen serta *PEMFC*. Sedangkan pada ARN tahun 2025, Indonesia diharapkan menguasai teknologi *PEMFC* 50 kW dan mempunyai kapasitas *fuel cell* terpasang nasional sebesar 50 MW. Disamping hal tersebut, dunia telah akan memasukkan produk otomotifnya pada tahun 2010 sampai dengan tahun 2015. Market dari *fuel cell* dengan teknologi *DMFC* diperkirakan akan mencapai jumlah pemakaian terbesar menurut Amerika dengan proyeksi US$ 2.6 milyar pada 2012. Oleh karena itu, penguasaan teknologi *fuel cell* menjadi hal yang sangat penting karena dengan melokalisasi teknologi manufaktur dengan kemungkinan untuk memproduksi komponen *fuel cell* secara lokal juga pada teknologi penyimpanan hidrogen. Pada makalah ini kami menjelaskan tentang kemungkinan pemakaian komponen *fuel cell* dari bahan baku lokal berikut prosesnya seperti membran sebagai polielektrolit pada *PEMFC* dan *DMFC*, bipolar *plate* sebagai separator dan membran inorganik yang dipakai pada *reformer* gas metan penghasil hidrogen di BPPT.

Kata kunci : *Polymer electrolyte fuel cell, Direct methanol fuel cell, Proton exchange membrane, Graphite bipolar plate, Inorganic membrane, Steam reforming methane*

INTRODUCTION

In the near-term, by far the most cost-effective strategy for reducing emissions and replacing fuel use is fuel cell technology. The car of the near future after the hybrid gasoline–electric vehicle is fuel cell cars, because it can replace gasoline consumption with zero carbon fuel and reduce greenhouse gas emissions. It will likely become the dominant vehicle platform by the year 2020. All vehicle pathways require technology advances and strong government action to succeed. Hydrogen is the most challenging of all alternative fuels, particularly because of the enormous effort needed to change our existing gasoline infrastructure. [1].

The energy supply for a cleaner environment that decreasing global CO_2 emissions, has been revived by the steep increase in oil prices. Thus, now we have to arrive at realistic guidelines that may help society to understand the important issues involved in the move towards a cleaner energy system. Worldwide, research and policy momentum is increasing in the move towards a hydrogen economy. Indonesia relies heavily on fossil fuels to fulfill its energy requirements. It is also a country rich in natural resources, giving it the full range of options for a hydrogen economy. Indonesia should have a completely hydrogen study to analysis of the options available to this country specifically. The study must review the resources, production and utilization technology available for a hydrogen economy in Indonesia, and discusses some of the advantages and disadvantages of the different options. It points out that natural gas, coal, biomass and water are the most promising hydrogen sources at this stage, while polymer electrolyte, solid oxide and molten carbonate fuel cells may hold the advantage for utilizing hydrogen-rich gases for stationary power in Indonesia. This paper presents an introduction of fuel cell technology and our research progress of materials as components fuel cells.

WHAT IS FUEL CELL

A fuel cell is an electro-chemical energy device that converts the chemical energy of fuel directly into electricity and heat, with water as a by-product of the reaction. Unlike conventional engines, they do not burn the fuel and run pistons or shafts, and so have fewer efficiency losses, low emissions and no moving parts. As a renewable energy source, fuel cells are widely considered one of the most promising energy sources because of their high energy efficiency, extremely low emission of oxides of nitrogen and sulfur, and very low noise, as well as the cleanness of their energy production.

Based on the types of electrolytes used, they are categorized into polymer electrolyte membrane fuel cells (PEMFCs), solid oxide fuel cells (SOFCs), phosphoric acid fuel cells (PAFCs), molten carbonate fuel cells (MCFCs), direct methanol fuel cells (DMFCs) and metal air fuel cells (MAFCs) [2]. Furthermore, another fuel cells that nowadays become a unique systems is microbial fuel cell. A microbial fuel cell (MFC) is a bioreactor that converts chemical energy in the chemical bonds in organic compounds to electrical energy through catalytic reactions of microorganisms under anaerobic conditions. [3, 4].

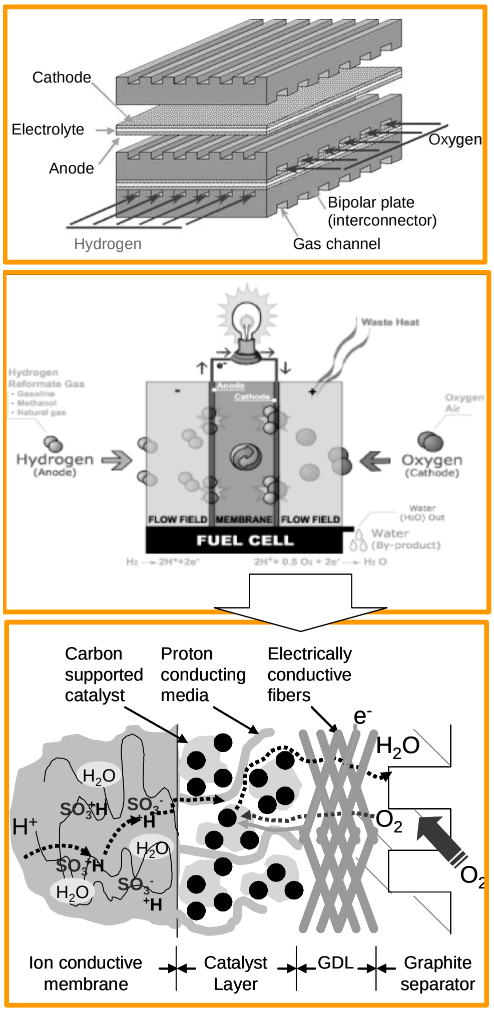

Figure 1. Scheme of fuel cell stack and the reaction mechanism

FUEL CELL STRUCTURE

A PEMFC consists of the polymer electrolyte membrane sandwiched between two electrodes (anode and cathode), to form a membrane electrode assembly (MEA), which is further sandwich between two bipolar plates housing the flow channel of hydrogen and oxygen. The main technological challenges are the formulation of better anode catalyst to lower the anode overpotentials, and the improvement of membranes and cathode catalyst in order to overcome cathode poisoning and fuel losses by migration of methanol from anode to cathode [2].

In the electrolyte, only ions can exit, while electrons are not allowed to go through. Thus, the current collector needs a path like an external circuit from the anode to the cathode to produce electricity because of a potential difference between the anode and cathode. The important aspects of fuel cell design depending on the water management, the method of cooling the fuel cell, the method of connecting cells in series, the operational temperature, the reactant used etc [5].

To produce a higher voltage, multiple cells must be connected in series. Typically, a single cell produces a voltage between 0 and 1V based on the polarization *I–V* curve, which expresses the relationship between stack voltage and load current. The voltage is nonlinear and mainly depends on current density, cell temperature, reactant partial pressure, and membrane humidity [5].

The overall electro-chemical reactions for a PEM fuel cell fed with a hydrogen-containing anode gas and an oxygen-containing cathode gas, are given as follows:

Anode : $2H_2 \rightarrow 4H^+ + 4e^-$ .... (1)

Cathode : $O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$ .... (2)

Overall : $2H_2 + O_2 \rightarrow 2H_2O$ + electricity + heat ...(3)

Polymer Electrolyte

The ion-exchange membrane, such as Nafion (DuPont) is commonly used as electrolyte in PEMFCs, owing to good chemical, permselectivity and ionic conductivity. The Nafion structure consist of a linier backbone of fluorocarbon chains as hydrophobic domain and ethylether pendant groups with sulfonic acid cation exchange sites as hydrophilic domain. Proton was known to transfer mainly through the cylindrical hydrophilic ion rich domain. In the operational fuel cells, the proton conductivity is directly proportional to the water content offers a low resistance to current flow and increased overall efficiency. However in the ideal case, water forms at the cathode would keep the electrolyte at the correct level of hydration, but air would be blown over the cathode, the electro-osmotic drag and the effect of air at high temperature that would have dried out any excess water. Unfortunately, Nafion membranes do not sustain prolong operation at temperature higher than 130 °C due to the dehydration with consequent lower conductivity and performance losses.

Several advantages result by operating a polymer electrolyte fuel cell (PEFC) at elevated temperatures (above 100 °C), such as faster heat rejection rates, easier and more efficient water management, higher reaction rates, improved CO tolerance by the anode electrocatalyst and more useful waste heat. Several approaches have been adopted to extend the operating temperature of the polymer electrolyte membrane (PEM) from the traditional 60–80 °C to temperatures around 120 °C.

Although Nafion is used both in hydrogen fuel cells (PEMFC) or in direct methanol fuel cells (DMFC) there are some problems such as dehydration in high temperature and a high methanol permeability that caused the depolarization losses and conversion losses could affecting the performance of fuel cell, but no single membrane is emerging as absolutely superior to others. There are many researches of the polymer electrolyte membranes (PEM) that are both under development and commercialized for PEMFC. Although varying for different applications, common requirements for replacing the Nafion membranes properties are as follows:

- Operation at high temperature
- Low methanol crossover (MCO) ($<10^{-6}$ mol/min.cm) or low methanol diffusion coefficient in the membrane ($<5.6x10^{-6}$ cm^2/s at T=25 °C) [6]
- High ionic conductivity (>80 mS/cm) [6]
- High conductivity in high operational temperature >100 °C
- High ion exchange capacity (> 1.0 meq/g)
- Low water swelling (< 30 % per dry weight)
- Low ruthenium crossover (in the case that the anode catalyst contains Ru)
- Low cost (<$10 kW-1 based on a PEMFC) [7]
- High chemical and mechanical durability especially at T>80°C (for increased CO tolerance)

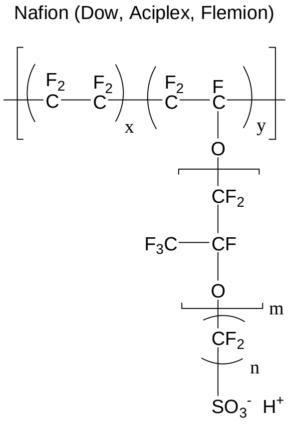

Figure 2. Nafion structure

Unlike the membranes for hydrogen fuelled PEM fuel cells, among which perfluorosulfonic acid based membranes show complete domination, the membranes for DMFC have numerous variations, each has its advantages and disadvantages.

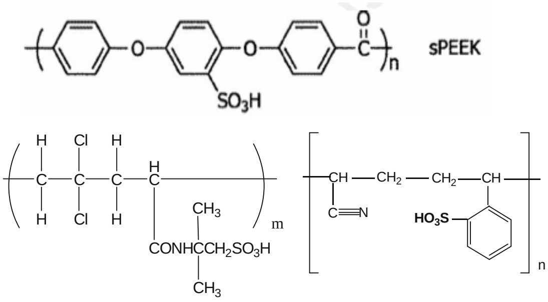

Figure 3. Chemical structure of PEEK, acrylamide copolymer and ABS polymer

Based on Nafion, there are a Dow Chemical (USA) [8], Asahi Glass Engineering (Japan) (Flemion®R, IEC 1.0meq/g dry resin, 50μm dried film thickness) [9], Asahi Kasei (Japan) (Aciplex-S®, based on a weak functional acid (-COOH) instead of the SO_3H groups in Nafion®) [10], W.L. Gore & Associates (USA) (Gore-Tex®, Gore-Select®) [11], and 3P Energy (Germany) [12].

The membranes are also have some various properties, including: methanol crossover, proton conductivity, durability, thermal stability and maximum power density. Hydrocarbon and composite fluorinated membranes currently show the most potential for low cost membranes with low methanol permeability and high durability [13].

The most commonly used membranes for DMFCs, the Dupont's Nafion® membranes do not satisfy all of these requirements and have the following disadvantages:

- High cost, \$600-1200 /m^2
- High cost per unit power, 300€ /kW at 240mW/cm^2
- High MCO
- High ruthenium crossover (in the case that the anode catalyst contains Ru) from the anode and its re-deposition on the cathode [14]

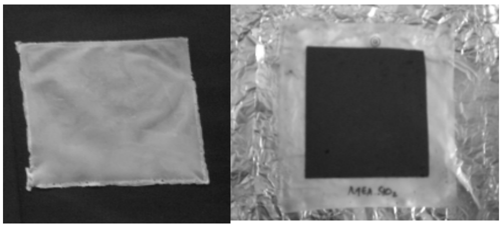

Figure 4. Acrylonitril-acrylamide copolymer membrane and its MEA fabrication

In ordering to solve the PEMFC's problems, the control of methanol permeability and the water management has been studied by the addition some hydrophilic particle inside the membrane [15], and self humidification by dispersing small amounts of Pt and/or metal oxide in Nafion film [16]. By introducing a small amount of silica powder in Nafion, a more crystalline polymer is produced [17]. Thus we have a Nafion 117 modified membrane with silica filler, with the aim of retaining of absorbed water inside the cell and to prevent quickly drying performance, have been added and recasting in different thickness of membranes which shown 50% methanol permeability reduced [18].

Alternatives to Nafion® (commercially price \$500-1200), our research are often significantly cheaper, i.e. sulfonated PEEK (commercially prices \$375) [19], acrylonitrile-acrylamide sulfonic acid copolymer [20], and sulfonated styrene-butadiene with modification of silica membranes were develop to applied as electrolyte membrane for fuel cells. These membranes showed some significant results of lowering methanol permeability in DMFC.

In addition to this structural modification, the incorporation of hydrophilic inorganic particles may retain more water and may contribute to better methanol exclusion. It also could advantageously influence the water transfer to the cathode [21].

Electrode

For commercialization of polymer electrolyte membrane fuel cells (PEMFC), stack fabrication cost should be significantly reduced. The cost reduction can be achieved by reducing electrode catalyst loading via effective use of platinum. Normally in a PEMFC, partial pressure of the reactant gases decreases from inlet to outlet of the gas flow field due to consumption of hydrogen and oxygen by the electrochemical reactions and hence local current density decreases gradually. Thus, by increasing electrode catalyst loading from the gas inlet to the gas outlet at a given average loading, efficiency of catalyst utilization might be improved. Since oxygen reduction reaction is much slower than hydrogen oxidation reaction and mass transport loss is severer in cathode than in anode, particularly when air is fed, gradient cathode catalyst loading would be more effective than that of anode.

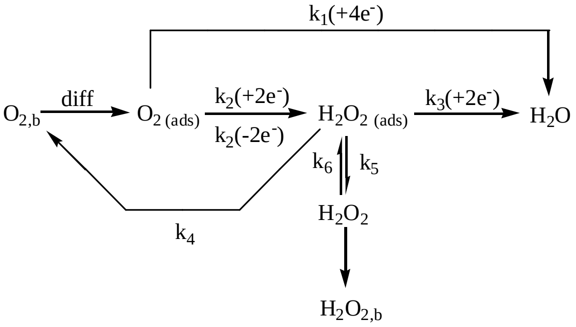

Figure 5. Electron transfer reaction on cathode

Recently advances have been made in cathode design which has raised performance levels in PEMFCs. The new electrocatalysts [22] and cathode designs have increased electrical efficiency and power densities to the PEMFC stack, needed for commercial use. Improvements have also been achieved at the anode, by developments in platinum-ruthenium anodes for carbon monoxide and cell reversal tolerance. While the use of a high level of platinum (Pt) loading in proton exchange membrane fuel cells (PEMFCs) can amplify the trade off toward higher performance and longer lifespan for these PEMFCs, the development of PEMFC electrocatalysts with low-Pt-loadings and high-Pt-utilization is critical. The Pt loading of the cathode electrocatalyst is traditionally the same or more than that of the anode electrocatalyst due to different electrochemical kinetics at both electrode interfaces. In other words, O_2 kinetics (at high potentials) and O_2 diffusion (at low potentials) at the cathode are the primary limitation of the fuel cell performance (Figure 5). Therefore, increased Pt loading at the cathode is needed to increase the rate of O_2 reduction (by increasing the available sites) and reduce the O_2 diffusion resistances. Therefore, research on reducing the Pt loading has focused more on the cathode electrocatalyst than the anode electrocatalyst [23]. However, there is a limitation in increasing Pt utilization based on MEA when only considering the Pt loading on the cathode electrocatalysts. It is to be expected that the nanostructure of the catalyst will influence its performance and stability. Carbon nanotubes are increasingly becoming proposed as catalyst support materials [24].

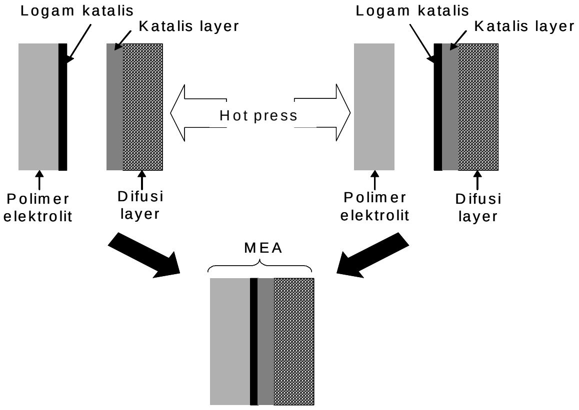

Figure 6. MEA fabrication method use diffusion layer and catalyst layer

In MEA fabrications, we still use a traditional method to assembly the carbon paper containing catalyst with membrane [25]. To achieve economical Pt loadings in the MEA (< 1 mg Pt cm.2) the electrocatalysts are supported on high surface area carbon blacks with a high mesoporous area (> 75 m2 g.1 C) and a degree of graphitic character. Common supports are available from Cabot Corporation (Vulcan XC72R, Black Pearls BP 2000), Ketjen Black International, Chevron (Shawinigan) and Denka.

Separator

The bipolar plates perform as the current conductors between cells, provide conduits for reactant gases flow, and constitute the backbone of a power stack. They are commonly made of graphite composite for high corrosion resistance and good surface contact resistance; however their manufacturability, permeability, and durability for shock and vibration are unfavorable in comparison to metals. On the other hand, various methods and techniques must be developed to combat metallic corrosion and eliminate the passive layer that causes unacceptable reduction in contact resistance and possible fouling of the catalyst and the ionomer. Thus recently metallic bipolar plates have received considerable attention in the research community [26].

The bipolar flow-field plate is the main hardware component of the PEMFC, and its variant the direct methanol fuel cell (DMFC). This has to fulfill several requirements, namely:

- good electrical conductivity;
- non-porous and leak-free conduit for the reacting gases;
- provision for distribution of the fuel and oxidant gases and water and product gas removal;
- provision for stack cooling, by water or air;
- good thermal conductivity to achieve stack cooling and satisfactory temperature distribution between cells;
- construction to high tolerance in large volumes;
- acceptable corrosion resistance;
- good mechanical stability at low thickness;
- low weight, especially for transport applications;
- Low cost.

The design of bipolar plates for PEMFCs is dependent on the cell architecture, on the fuel to be used, and on the method of stack cooling (e.g., water or air-cooling). To date, most of the fuel cells have employed traditional plate-frame architecture so that the cells are planar and gas flow distribution to the cells is provided by the bipolar plate. The bipolar plate therefore incorporates gas channels machined or etched into the surface. These supply the fuel and oxidant gases and also provide a means for removing water from the cells. Some alternative designs of plate have been suggested for non-planar cell architecture and may provide higher volumetric power densities, whilst maintaining low contact resistance and good structural integrity. Metallic bipolar plates and membrane electrode assembly (MEA) are two crucial components of a PEM power stack and their durability and fabrication cost must be optimized to allow fuel cells to penetrate the commercial market and compete with other energy sources.

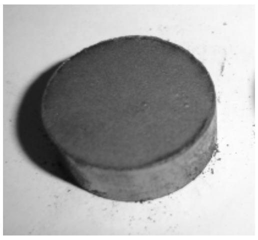

Figure 7. Powder Metalurgi Bipolar Grafit capsule

Hydrogen Storage and Other Parts

These PEFC prospects primarily depend on stable and economical high-purity hydrogen supplies, the scale of application, the existence of more efficient competitive power sources and the social viewpoints such as the health and environment benefits as well as infrastructural aspects associated with traditional power supply and demand. PEFC have the most promising applications to buses, recreation vehicles, and lightweight vehicles.

Without doubt, the technology for a stable supply of high-purity hydrogen along with the corresponding infrastructure is essential for the success of PEFC in various application fields.

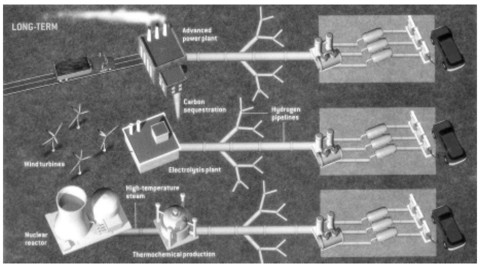

Figure 8. Scheme of hydrogen production and its infrastructures

In fuel cells systems, other component need to complete the fuel cell reaction process. A hydrogen tank is critically needed in high pressure tank, liquid hydrogen or metal hydride. At the anode side, a fuel processor, called a reformer, which generates hydrogen through reforming methane or other fuels like natural gas, can be used instead of the pressurized hydrogen tank. A pressure regulator and purging of the hydrogen component are also needed. At the cathode side, there is an air supply system that contains a compressor, air filter, and air flow controller to maintain the oxygen partial pressure. At both sides, a humidifier is required to prevent dehydration of the fuel cell membrane. In addition, a heat exchanger, water tank, water separator, and pump may also be needed for water and heat management in the FC systems [5].

Stacking Research

Beside some polymer electrolyte membrane research, herein we described PEMFC research including direct methanol fuel cell (DMFC) and also inorganic membrane of Pd/SS as separator gas of methane to produce hydrogen.

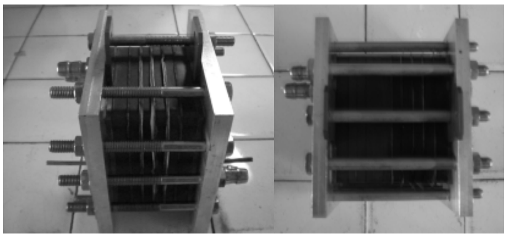

Figure 9. A 5 and 10 cells stack of PEFC with 60% local component

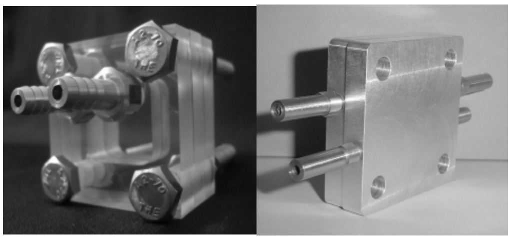

Figure 10. A room temperature and high temperature of 5 cm2 DMFC stacks

BPPT released of the fuel cell research roadmap, a five-year, strategic guide to maximize the opportunity of local component involvement in the fuel cell manufacture. The Roadmap includes the programs and activities that BPPT must focus on to create an environment that supports the research, development and early model application of fuel cells. By creating a Roadmap with defined strategies that leverage our strengths in manufacturing while also encouraging research and development of new innovations. We are targeting to make a 1 kW PEMFC with more than 80 % of local component materials in 2010.

There are several compelling technological and commercial reasons for operating H_2/air PEM fuel cells at temperatures above 100 °C. Rates of electrochemical kinetics are enhanced, water management and cooling is simplified, useful waste heat can be recovered, and lower quality reformed hydrogen may be used as the fuel. Herein we provide a fabrication of PEM fuel cells (PEMFCs) from the perspective of specific materials, designs, and testing/diagnostics. High temperature membrane development accounts for 90 % of the published research in the field of high temperature-PEMFCs, as described above. Despite this, the status of membrane development for high temperature/low humidity operation is less than satisfactory [27]. Connecting MEA in 5-10 cells of 36 cm^2 PEFC using Nafion and non-Nafion membranes electrolyte are shown about 5 watt.

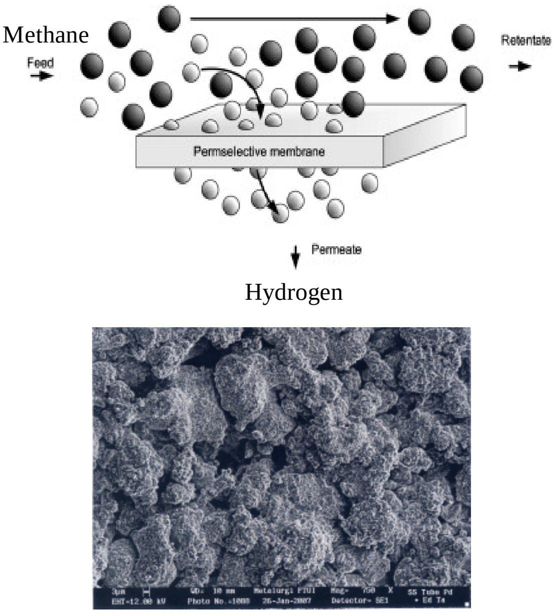

Figure 11. (a) Scheme of gas permeation on membrane. (b) SEM photograph of inorganic membrane Pd coating on porous-SUS with magnitude of 200 times

In our laboratory, a 5 cm^2 DMFC single cell was fabricated and used to determine the power density of nano-composite polymer electrolyte membrane.

Methanol is an attractive fuel because its energy density is much higher than that of hydrogen, and it is an inexpensive liquid that is easy to handle, store and transport. Although DMFC and PEFC have almost the same thermodynamic reversible potential as 1.21 and 1.23 V at 25C, in practice, a DMFC has much lower open circuit voltage (OCV). The reasons are methanol crossover, some carbon monoxide which can poison the cathode and also an oxidation reaction consumed cathode reactant. In order to solve the crossover problem, we developed an acrylonitrile-acrylamide sulfonic acid polymer and sulfonated PEEK with addition of silica powder as electrolyte in DMFC [28,29].

Figure 12. SS compartment of steam reforming methane

Hydrogen as a high-quality and clean energy carrier has attracted renewed and ever-increasing attention around the world in recent years, mainly due to developments in fuel cells and environmental pressures including climate change issues. In thermochemical processes for hydrogen production from fossil fuels, separation and purification is a critical technology. Where water–gas shift reaction is involved for converting the carbon monoxide to hydrogen, membrane reactors show great promises for shifting the equilibrium. Membranes are also important to the subsequent purification of hydrogen. For hydrogen production and purification, there are generally two classes of membranes both being inorganic: dense phase metal and metal alloys, and porous ceramic membranes. Porous ceramic membranes are normally prepared by sol–gel or hydrothermal methods, and have high stability and durability in high temperature, harsh impurity and hydrothermal environments. In particular, microporous membranes show promises in water gas shift reaction at higher temperatures. In groups of hydrogen productions, we develop the Pd-inorganic membrane that use as separator in steam reforming methane. In this research, we use porous metal and ceramic membranes, then coating them with Palladium catalyst and compare their separation properties and performance in membrane reactor systems. The preparation, characterization and permeation of the various membranes will be determined by SEM, XRD and test cell with glass and or stainless steel compartment.

PEMFC IN TRANSPORTATION

Among the various types of fuel cells, proton exchange membrane fuel cells (PEMFCs) possess a series of highly advantageous features hold excellent potential for cost effectiveness, such as a low-operating temperature (60-80C), sustained operation at high-current density and high power density, low weight, compactness and relatively simple design, potential for low cost and volume, long stack life, fast start-ups and suitability for discontinuous operation and high conversion energy efficiency (40 - 70%), near zero emission, quite operation, stacking in various capacity and also it is available for an alternative fuel (nature gas, methana, alcohol, biogas, coal gasification etc.) [5].

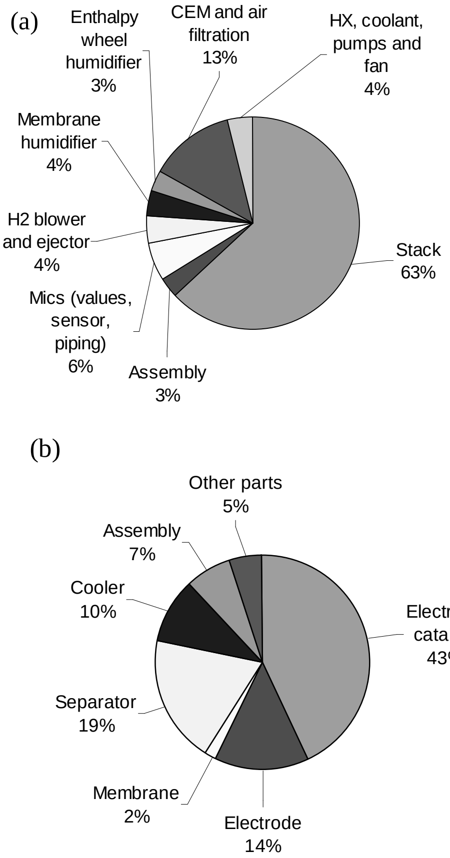

Figure 13. (a) Breakdown stack and component cost contribution for an 80-kW direct hydrogen fuel cell (Ballard Mark V PEMFC at 70C). (b) Cost per unit stack PEFC (DOE 2002).

Due to these multiple advantages, the PEMFC has become the best candidate for an alternative power source in transportation and stationary power systems. PEM fuel cell is recognized by the U.S. Department of Energy (DOE) as the main candidate to replace the internal combustion engine in transportation applications. For stationary and transportation applications, fuel cells are required to achieve and efficiency equal to or higher than 40%. However, because the efficiency decreases as the power output increases, as more cells request power, more expenses need to be integrated to achieve a high efficiency for the maximum power output. To date, although many techniques of optimization of fuel cell systems have been developed, but many of them are restricted to only one optimization objective, such as performance or cost. To commercialize the PEMFC, cost and efficiency need to be taken into account. Thus, achieving an optimal PEMFC system design has become a major topic in recent years. The DOE gave 2010 targets for portable fuel cells, which will be necessary to achieve the aforementioned forecasts. The DOE 2010 targets are power density, 100 W/L, energy density, 1000 Wh/L, lifetime, 5000h and cost, $3 per W. For understanding the partially cost of components fuel cell, Fig. 1 shown a component cost of one system and stack per unit PEMFC. According to the cost analysis, catalyst is take a 43% parts per unit cell following with bipolar plates cost, where a unit stack also take a 63% cost of system PEMFCs.

Among the technological challenges in terms of PEMFC electrodes, the creating of an anode electrocatalyst tolerant to CO at levels of 50 ppm is deemed to be the most significant barrier, followed by a cathode electrocatalyst able to reduce the overpotential encountered under open circuit conditions and significantly enhance the exchange current density. The electrode fabrication cost can be reduced through several approaches such as reducing the platinum (Pt) loadings on both electrocatalysts and by achieving a more effective membrane electrolyte assembly (MEA). The limited supply and high cost of the Pt used in PEMFC electrocatalysts necessitate a reduction in the Pt level [30]. In addition, the U.S. Department of Energy (DOE) has set long-term goals for PEMFC performance in a 50 kW stack that included operation with cathode loadings of 0.05 mg cm”2 or less [31].

On the other hand, the effect of contamination on PEM fuel cell must be accounting as disadvantages side of fuel cells. The contaminants included were fuel impurities (CO, CO_2, H_2S, and NH_3); air pollutants (NO_x, SO_x, CO, and CO_2); and cationic ions Fe^{3+} and Cu^{2+} resulting from the corrosion of fuel cell stack system components. It was found that even trace amounts of impurities present in either fuel or air streams or fuel cell system components could severely poison the anode, membrane, and cathode, particularly at low-temperature operation, which resulted in dramatic performance drop [32].

Many automotive industries were produced fuel cell cars that use proton exchange membrane fuel cells (PEMFCs), have recently passed the test or demonstration phase and have partially reached the commercialization stage due to the impressive worldwide research effort. Despite the currently promising achievements and the plausible prospects of PEMFCs, there are many challenges remaining that need to be overcome before PEMFCs can successfully and economically substitute for the various traditional energy systems. With the many promising research efforts in overcoming these challenges, the most important tools for the commercialization of PEMFCs will be the technical data and information from a real PEMFC application test systems such as transportation, residential power generation and portable computers [33].

APPLICATIONS

The market introduction of portable fuel cells would be, i.e. automotive (Honda, Toyota, Benz, Chrysler, Post German), portable generators (Tokyo gas, Witting House Siemens) and microfuel cells (NEC, Toshiba, Motorola). After discussing the benefits of these products, and surveying the projections of their costs and market forecasts, conclusions on the business models of the main actors in the portable fuel cell sectors are drawn. Perhaps because there has been a great deal of imprecision in defining the costs and benefits of portable fuel cells, market forecasts have been in some cases extremely optimistic. It can be concluded that fuel cells will hit the market later than previously envisaged and that they are unlikely to become popular through hybridisation with batteries, i.e. portable chargers. Although microfuel cells are likely to become a mass-marketed product, they first need to become an ordinary one and this will happen only when users will be unable to distinguish between electronic devices powered by fuel cells and those powered by batteries, with the exception of the different amounts of energy supplied. Otherwise, portable fuel cells are likely to be confined to a small niche of power-thirsty professional users

Figure 14. Some applications of fuel cells

The commercialization of a new technology is a challenging and uncertain process. Likewise, the emerging fuel cell industry experiences numerous technical and market uncertainties to shift from primarily Research and Development activities to activities in production, marketing and sales. Researcher needs a better understanding of the management challenges fuel cell firms face in the current pre-commercialization phase such as a characterization (i) the technology, (ii) the market for FC products, (iii) the environment and (iv) the fuel cell industry to highlight the key uncertainties and challenges of managing the commercialization of fuel cell technology [34].

CONCLUSIONS

In the paper, the possibility study of polymer electrolyte membranes, graphite bipolar plate composites, some component stacking of PEMFC and inorganic membrane separator of steam reforming methane are propose. However locals $B!G (B materials still have many side to develop, some of the component that described above are have possibility to replace the common used component in fuel cells. Furthermore, for the cost has been reduced for the component single fuel cell, which could be a good future prospect in fuel cells applications.

REFERENCES

[1]. JOSEPH ROMM, *Energy Policy*, **34** (17) (2006) 2609-2614

[2]. G. HOOGERS, *Fuel Cell Technology Handbook*, CRC Press, Chapter 1, (2003) 1-5

[3]. ZHUWEI DU, HAORAN LI and TINGYUE GU, *Biotechnology Advances*, **25** (5) (2007) 464-482

[4]. COUTO, S.R. HERRERA, J.L.T., Industrial and Biotechnical Applications of Laccases : *A Review*, *Biotechnology Advances*, **24** (2006) 500-513

[5]. J. LARMINIE, A. DICKS, *Fuel Cell System Explained*, Chapter 1, (2003) 1-24

[6]. A.S. ARICÒA, S. SRINIVASAN, V. ANTONUCCIA, *Fuel Cells*, **1** (2001) 133-161

[7]. F.R. KALHAMMER, P.R. PROKOPIUS, V.P. ROAN, G.E. VOECKS, Status and Prospects of Fuel Cells As Automobile Engines, *A Report of the Fuel Cell Technical Advisory Panel*, July (1998)

[8]. A. KUVER, K. POTJE-KAMLOTH, *Electrochim. Acta*, **43** (1998) 2527-2535

[9]. M. YOSHITAKE, Y. KUNISA, E. ENDOH, E. YANAGISAWA, *US Patent* 6,933,071 (August 23, 2005)

[10]. N. MIYAKE, M. WAKIZOE, E. HONDA, T. OHTA, Abs# W-1880, *Fourth International Symposium on Proton Conducting Membrane Fuel Cells*, October 3-8, (2004)

[11]. R.M. PENNER, C.R. MARTIN, *J. Electrochem. Soc.*, **132** (1985) 514-515., B. BAHAR, A.R. HOBSON, J.A. KOLDE, D. ZUCKERBROD, *US. Patent* 5,547,551 (August 20, 1996)

[12]. 3P Energy website: http://www.3p-energy.de

[13]. VLADIMIR NEBURCHILOV, JONATHAN MARTIN, HAIJIANG WANG and JIUJUN ZHANG, *J. Power Sources*, **169** (2) (2007) 221-238

[14]. P. PIELA, C. EICKES, E. BROSHA, F. GARZON, P. ZELENAY, *J. Electrochem. Soc.*, **151** (2004) A2053-A2059

[15]. T. ARIMURA, D. OSTROVSKII, T. OKADA, G. XIE, *Solid State Ionics*, **118** (1999) 1-10

[16]. M. WATANABE, H. UCHIDA, M. EMORI, *J. Phys. Chem. B*, **102** (1998) 3129-3137

[17]. V. ANTONUCCI, A. ARICO, *European Patent 1990*, EP 0 926 754 A1, 1-5

[18]. ENIYA LISTIANI DEWI, *Procc. Reg. Symp. Membr. Tech*., (2005), 1-6, ENIYA L DEWI, ROHMADI, Modifikasi Nafion dan Pengaruhnya terhadap Difusi CH_3OH sebagai Elektrolit Padat Direct Methanol Fuel Cell, *Jurnal Sains Materi Indonesia*, (2007) (*inpress*)

[19]. SRI HANDAYANI, WIDODO WAHYU PURWANTO, ENIYA LISTIANI DEWI, ROEKMIJATI W. S., *Jurnal Sains Materi Indonesia*, **8** (2) (2007) 129-133

[20]. ENIYA L DEWI, New Materials for Fuel Cell Development, *Proceedings of 1st International Conferences on Chemical Sciences (ICCS-2007)*, (2007)

[21]. P. DIMITROVA, K. A. FRIEDRICH, U. STIMMING, B. VOGT, *Solid State Ionics*, **150** (2002) 115-122

[22]. ENIYA L DEWI, KENICHI OYAIZU, HIROYUKI NISHIDE, EISHUN TSUCHIDA, *J. Power Sources*, **130** (2004) 286-290

[23]. JUNG-HO WEE, KWAN-YOUNG LEE, SUNG HYUN KIM, *J. Power Sources*, **165** (2007) 667-677

[24]. B. XUE, P. CHEN, Q. HONG, J.Y. LIN, K.L. TAN, *J. Mater. Chem*. **11** (2001) 2387; B. RAJESH, K.R. THAMPI, J.M. BONARD, B. VISWANATHAN, *J. Mater. Chem*. **10** (2000) 1575.; Z. LIU, L.M. GAN, L. HONG, W. CHEN, J.Y. LEE, *J. Power Sources*, **139** (2005) 73–78

[25]. ENIYA L DEWI, A Half-Cell Investigation of DMFC's Electrode Using Platinum Alloys, *Indonesian Nanoletter at International Symposium on Nanotechnology & Catalysis*, ISSN 1907-803, **2** (1) (2007) 84-86

[26]. H. TAWFIK, Y. HUNG and D. MAHAJAN, *J. Power Sources*, **163** (2) (2007) 755-767

[27]. JIANLU ZHANG, ZHONG XIE, JIUJUN ZHANG, YANGHUA TANG, CHAOJIE SONG, TITICHAI NAVESSIN, ZHIQING SHI, DATONG SONG, HAIJIANG WANG, DAVID P. WILKINSON, ZHONG-SHENG LIU and STEVEN HOLDCROFT, *J. Power Sources*, **160** (2) (2006) 872-891

[28]. ENIYA LISTIANI DEWI, *Procc. Reg. Symp. Membr. Tech*., (2005) 1-6

[29]. ENIYA L DEWI, ROHMADI, *Jurnal Sains Materi Indonesia*, (2007) (*inpress*)

[30]. JUNG-HO WEE, KWAN-YOUNG LEE, SUNG HYUN KIM, *J. Power Sources*, **165** (2007) 667-677

[31]. A.T. HAUG, R.E. WHITE, J.W.WEIDNER,W. HUANG, S. SHI, T. STONER,N. RANA, *J. Electrochem. Soc*., **149** (2002) A280–A287

[32]. XUAN CHENG, ZHENG SHI, NANCY GLASS, LU ZHANG, JIUJUN ZHANG, DATONG SONG, ZHONG-SHENG LIU, HAIJIANG WANG and JUN SHEN, *J. Power Sources,* **165** (2) (2007) 739-756

[33]. JUNG-HO WEE, *Renewable and Sustainable Energy Reviews,* **11** (8) (2007) 1720-1738

[34]. HANNA L. HELLMAN and ROBERT VAN DEN HOED, *Int. J. Hydrogen Energy,* **32** (3) (2007) 305-315