Direct Methanol Fuel Cell as the next generation power source

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The demand for clean power source is increasing for solving environmental issues. We have developed 1 kW output direct methanol fuel cell (DMFC) successfully, which is the highest output level in the world in this kind of fuel cell. Methanol, the fuel of DMFCs, has such advantage features as easy handling, high storage stability and high energy storage capability. The exhaust heat from fuel cell is recovered for hot water supplying for customer. The total system energy conversion efficiency is more than 80 %. It can be applied to various markets.

1. Introduction

In order to reduce the pollution and carbon dioxide from ever increasing numbers of transportation such as commercial airplane or ship for environment issues and global warming, it is expected to reduce the transportation fuel consumption and emission in the future. Moreover, the demand of the power source for the passenger service is also increasing. Fuel cells provide an attractive option, which are inherently cleaner power sources and higher efficiency than current auxiliary power units using fossil fuel. Fuel cell will not replace main engine, however they could replace gas turbine auxiliary power unit as the technology becoming more mature. For this application, fuel cells can be used to power non-critical loads like video or illumination for passenger service. Because waste heat from fuel cell can be used, their overall efficiency can be high [1)].

Direct methanol fuel cells (DMFCs) are electrochemical devices that convert chemical energy of liquid methanol directly to electricity. DMFC can provide electricity and heat continuously as long as methanol and oxygen are provided. As methanol is easy to store and transport and has a very high energy density, DMFC presents and inherent advantage on producing a lot of electric power with liquid fuel stored in a fixed volume. The energy density of hydrogen is 520 Wh/L (in case of 2,000 psi gas cylinder). However, methanol has 4,817 Wh/L of energy density Since space and weight are at a premium in most transportation, DMFC is attractive for transportation applications.

On the other hands, smart phone market is spreading rapidly in recent years. The capacity of secondary battery that includes in the smart phone is not enough for daytime operation in some cases. It is expected for this kind of small electronic mobile devices, also, because of its treating easy and high density of fuel. Fujikura also develops small size DMFC.

In this report, these DMFC is introduced.

2. Principle of DMFCs

A direct oxidation fuel cell has a unit cell composed of a membrane-electrode assembly (MEA) sandwiched between separators. The MEA is composed of a solid polymer electrolyte membrane sandwiched between an anode and a cathode, and each of the anode and the cathode includes a catalyst layer and diffusion layer. Such a direct oxidation fuel cell generates power by supplying a fuel and water to the anode and supplying an oxidant to the cathode (see Fig.1). Higher power can be generated by enhancing the MEA area size, or stacking this unit cell. However, excess stack number brings the higher cost and lower reliability. Therefore, enlarging MEA is the best effective way for high power fuel cell output.

There are many kind of challenging theme such as

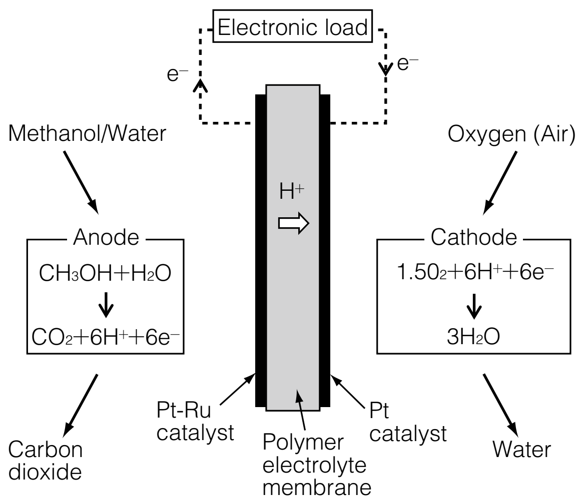

Fig. 1. Basic principle of DMFC.

1 Thermal technology division

optimizing the catalyst and polymer electrolyte, optimizing the structure of the catalyst layer using printing method, improving the electrical conductivity of each material, reducing the electrical contact resistance between the each components and optimizing feeding speed of the fuel and oxidant. Moreover, optimizing whole system optimization is also important. This chemical reaction of power generation is exothermal reaction. Therefore, heat management is also important issue.

Fujikura Ltd, Tokyo, develops a DMFC system with high power performance. There are many issues to be considered in developing a complete miniaturized liquid feed fuel cell system. These issues include liquid fuel storage, air supply, fuel delivery, water management, and thermal management, operating orientation and stability. Fujikura DMFC system considers each of these aspects.

3. Development of 1 kW output DMFCs

A 1 kW output DMFC system is developed at Fujikura under the auspices of the New Energy and Industrial Technology Development Organization (NEDO). This system has the feature of miniaturized size and the capability of 50 deg-C hot water supply using waste heat from fuel cell. Hot water is applied to passenger service in transportation vehicle such as hand wash in toilet. Resent developing progress of the large scale DMFC prototype is reported herein with emphasizing on the fuel delivery subsystem and the gas/liquid separator.

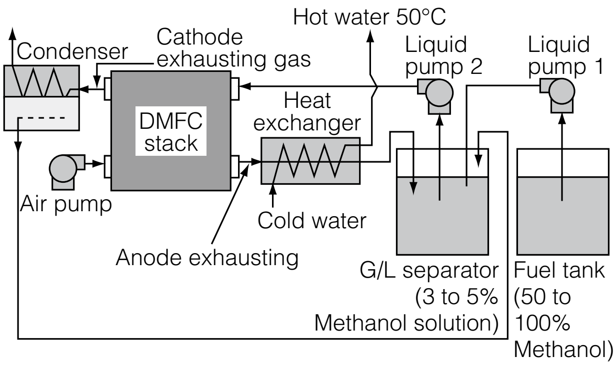

Fig. 2. Design diagram of 1 kW DMFC system.

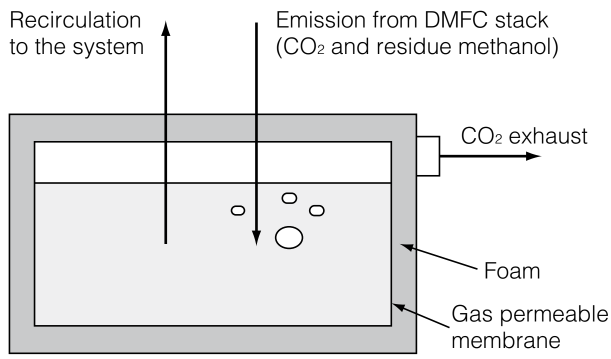

Fig. 3. Working mechanism of gas/liquid separator.

In general, DMFC is suitable for miniaturization of the size comparing with other fuel cell such as hydrogen fuel cell. However, in case that target is large power output, further improvement of output efficiency is needed. Moreover, complete methanol leak prevention system is required for treating a large amount of methanol that has small toxicity.

Recent progress on the high-power DMFC prototype has focused on the fuel delivering subsystem and the gas-liquid separator. Figure 2 shows schematically the design of the DMFC, which consists of a fuel cell stack, a fuel tank, a gas-liquid separator and a fuel delivering subsystem. High concentration methanol is delivered by a pump from the fuel tank to the gas-liquid separator. The methanol is diluted to 3 to 5% by volume in this separator, and then delivered to the DMFC stack by the pump. Carbon dioxide (CO_2) as by-product, water, and unreacted methanol from anode side of fuel cell deliver to gas-liquid separator through the heat exchanger. Hot water generated by heat exchanger is provided for the passenger service as mentioned above. Also, temperature of fuel cell can be kept to be stable without thermal runaway.

On the other hands, the CO_2, water, and unreacted methanol removed from the DMFC stack must be separated completely so that the methanol and water can be recycled. Separation of these enhances safety, and separation of methanol improves fuel utilization. Separation of gases from liquids in mixed-phase system has traditionally relied gravity. However, the gravity method is direction dependent and is therefore inadequate in the fuel cell context, where separation must occur in all directions. Fujikura has developed a gas-liquid separator that uses a gas-permeable membrane polymer sheet to separate CO_2 from water and methanol mixture (Figure 3). The separator has two outlets. The first connected to the fuel delivery subsystem, and the second is used for the exhaust of CO_2. When a mixture of water, methanol, and CO_2 gas enter the reservoir through the inlet connecting to the DMFC stack, the water and methanol are captured in the reservoir; CO_2 is expelled from the reservoir to an inner compartment filled with porous foam and is exchange through the exhaust port. This orientation free

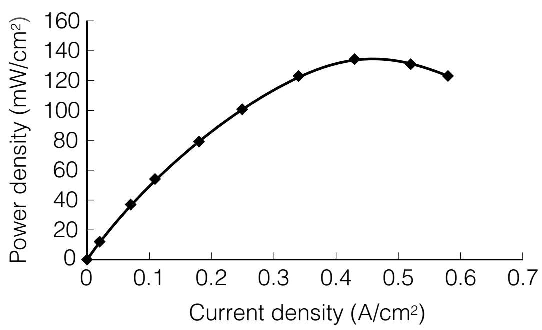

Fig. 4. Power density as a function of current density.

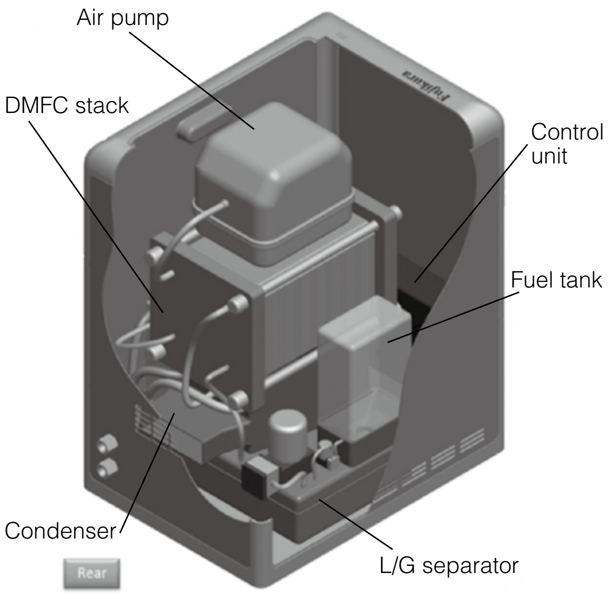

Fig. 5. Interior of the 1 kW DMFC.

Fig. 6. DMFC for small portable electronic device.

feature can make DMFC system to be safety even under strong vibration such as the aviation.

Fujikura is also developing a high efficiency MEA using own catalyst printing technologies. At the moment, the fuel cell output power density is 134 mW/ cm^2 at a temperature of 80 deg-C (Figure 4). The high output power density facilitates miniaturization of the system. The hot water supply at a temperature of 50 deg-C is obtained by exchanging heat with the liquid exhausted from the fuel cell stack at 80 deg-C. The overall energy conversion efficiency of the present DMFC system exceeds 80%.

Figure 5 shows is a cutaway schematic of the developed DMFC system with an output power of 1 kW. Its external dimensions are 60 × 44 × 33 cm.

4. Portable DMFC for small portable electronic devices

This application is mobile uses so that further miniaturization and cost reduction is required. Fujikura develops 1 W output portable DMFC with high system efficiency, low cost and high reliability using high efficiency MEA as mentioned above and complete passive fuel feeding system. Prototype of portable DMFC is shown in Figure 6. Dimension is 135 × 75 × 23 mm. Further power output is possible combining secondary battery.

5. Conclusion

Fujikura developed 1 kW output DMFC with 60 × 44 × 33 cm size for transportation vehicle such as aviation. Highest level of power output in the world by optimization of MEA and fuel cell system has been achieved with safety and miniaturized size. Also, 1 W portable DMFC for portable electric device has been developed with 135 × 75 × 23 mm. Miniaturization, low cost and high reliability has been achieved using high efficiency MEA and complete passive fuel feeding system.

Reference

1) Z. Guo, et. al.: "Development of Large Scale DMFC System for Aviation Applications", 8th Annual International Energy Conversion Engineering Conference, August 2010, Nashville, Tennessee, USA.