Material and Heat Management in a DMFC for Portable Usage

Yuusuke SATO, Kei MATSUOKA, Eiichi SAKAUE

Corporate Research and Development Center
Toshiba Corp.
1, Komukai Toshiba-Cho, Saiwai-Ku
Kawasaki, 212-8582, JAPAN
ysato@msl.rdc.toshiba.co.jp

Kyoji HAYASHI

Mechanical Development Center
PC Development Center
TOSHIBA CORPORATION Personal Computer & Network Company

Abstract

A Direct Methanol Fuel Cell (DMFC) is one of the candidates for the next generation power source for portable equipments, such as portable PCs, cellular phones, PDAs, etc. because of higher energy density of fuel than that of secondary batteries. DMFC is a kind of chemical plants; fuel and air are injected to a stack, and the exhaust from a stack need to be processed, also the feed rate, concentration of methanol and temperature need to be controlled.

We designed a DMFC system for portable usage based on cell performance and operating conditions. Cell performance such as I-V characteristic, methanol crossover affects on not only power generation efficiency but also heat radiation. Heat radiation from DMFC system is one of the important issues to be paid attention to make a DMFC system be small and be operated stably.

We developed a prototype DMFC system in order to supply power for a B5 size note PC. Average 13W power was supplied to a PC from a DMFC, and neat methanol consumption as fuel was about 10cc per hour.

DMFC system for portable usage

There are several types of DMFC system, such as passive type and active type. An active type of DMFC appears to be suitable to supply several tens of wattage to portable equipment because of higher power density of cells. As shown in Fig.1, methanol/water as a fuel and air is supplied to a DMFC to generate electricity. Heat and water are generated as byproduct. The generated electricity also changes in the form of heat finally. In order to make a DMFC possible to be used as power supply in portable equipment, enthalpy of fuel, and water produced by fuel cell and water supplied as fuel should be released to ambient air.

A lithium ion battery (LIB) is widely used in a portable equipment as a rechargeable battery. Specific energy density of LIB is about 0.4Wh/cc. The enthalpy of methanol is 5Wh/cc (727kJ/mol). The specific energy density of methanol depends on electric power generation efficiency of DMFC, and in the case of 20-30% of electric power generation efficiency, it is about 1-1.5Wh/cc. Figure 2 shows the relationship between electric energy and volume of LIB and DMFC. A DMFC has main unit volume even if no fuel is included. The size of main unit varies depending on the DMFC system design, such as supply wattage, performance of cells, and type of DMFC. In terms of volume, DMFC has disadvantage as compared to LIB, because of the necessity to include a main unit. However, in the large electric energy, DMFC volume with a main unit and fuel becomes smaller than volume of LIB due to higher specific power density of methanol. Volume advantage of DMFC will not be utilized if diluted methanol having concentration below ca. 30vol% is used as a fuel.

Figure 3 shows schematic energy diagram of DMFC. Cell voltage becomes lower as current density is increased. And so called methanol crossover takes place. Electric power generated is a portion of enthalpy of utilized methanol, i.e. power generation and methanol crossover. A part of generated electricity is used for auxiliary units, such as pumps, fans, sensors, circuits. There is DC/DC conversion loss, also. Power supply to equipment is lower than power generated in the cells.

Anode reaction and cathode reaction are as follows:

Anode reaction : $CH_3OH + H_2O \rightarrow CO_2 + 6H^+ + 6e^-$
Cathode reaction: $3/2O_2 + 6H^+ + 6e^- \rightarrow 3H_2O$

If 1/3 of water generated in the cathode reaction is utilized for anode reaction, it is possible to use high concentrated methanol in a cartridge. One of such kind of DMFC systems is shown in Fig. 4. Diluted methanol is supplied to anode. CO_2 produced in the anode reaction is separated from anode out flow. Unreacted methanol and water is recycled into a mix tank. Concentrated methanol is supplied to the mix tank from a cartridge. Air is supplied to cathode. Water vapor, liquid water and unreacted O_2/N_2 are exhausted from cathode. It is necessary to release latent heat for water condensation by a radiator to recover necessary amount of water from cathode exhaust gas. Heat generated at the stack is released to ambient air both by radiators and by water latent heat exhausted from a cathode radiator.

Figure 5 shows typical result regarding the amount of water exhausted from cathode. Water is generated in both the cathode reaction and crossover methanol oxidation. Electro-osmosis drug by proton and diffusion/flow across membrane bring water form the anode side to the cathode. Amount of permeated water is much larger than amount of generated water. The solid line in Fig. 5 shows typical amount of vapor accompanied by cathode exhaust gas under certain gas flow rate condition. The cathode exhaust gas should be cooled to a temperature around 40°C in order to recover 1/3 of water generated in power generation, as is shown in Fig. 5.

Based on cell performance, system design, and operating conditions, it is possible to estimate DMFC system size. A DMFC system was designed to achieve 13W of electric power supply capability for a B5 size note PC, which system concept is shown in Fig. 4. Picture of a prototype DMFC and its specification are shown in Fig. 6. Neat methanol consumption rate as fuel was about 10cc per hour, which correspond to 1.3Wh/cc of specific methanol power density and 26% of power convert efficiency from methanol.

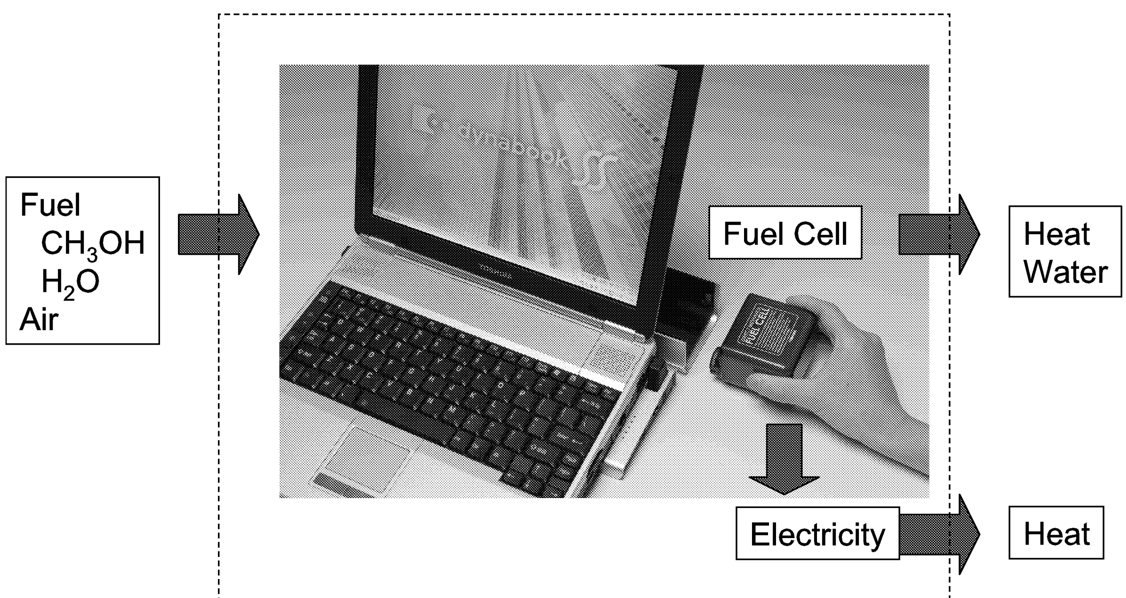

Fig.1 Overall balance of material and energy

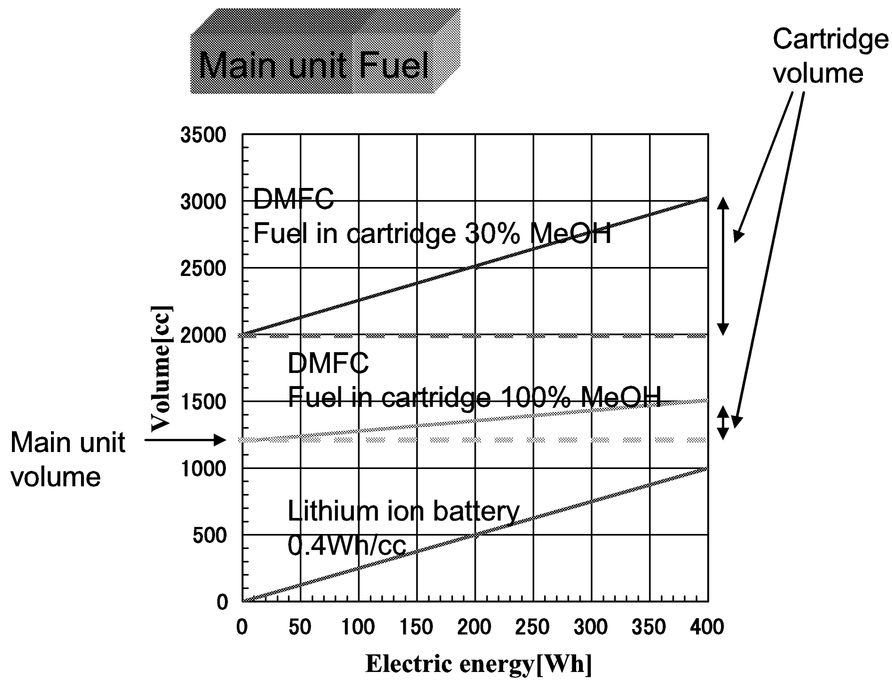

Fig. 2 Relationship between electric energy and volume of secondary batteries and DMFCs

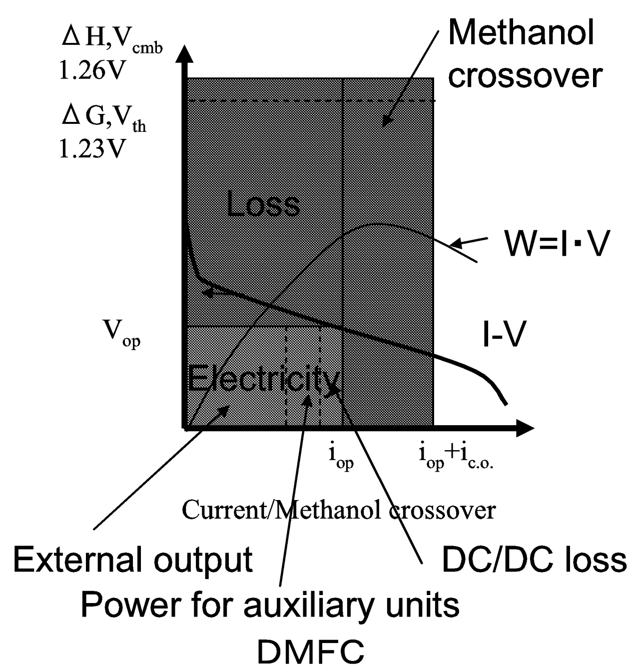

Fig. 3 Schematic energy diagram of a DMFC

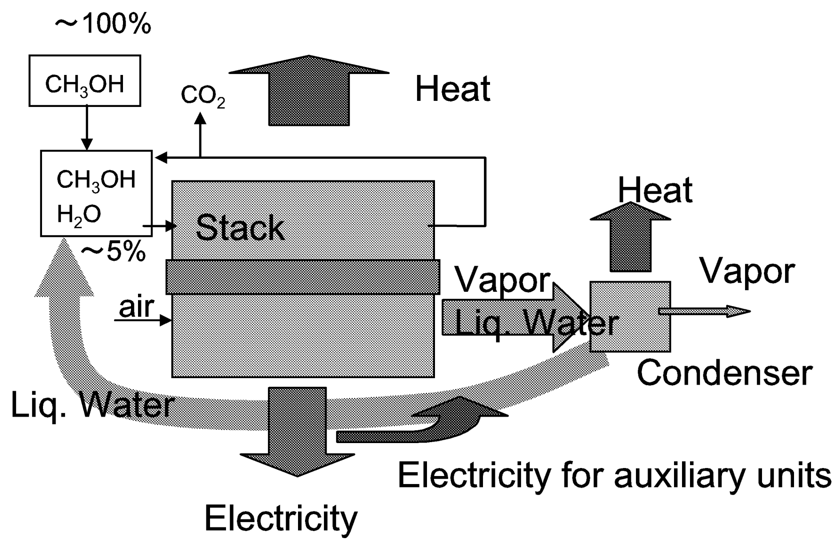

Fig.4 Example of flow sheet of an active type DMFC

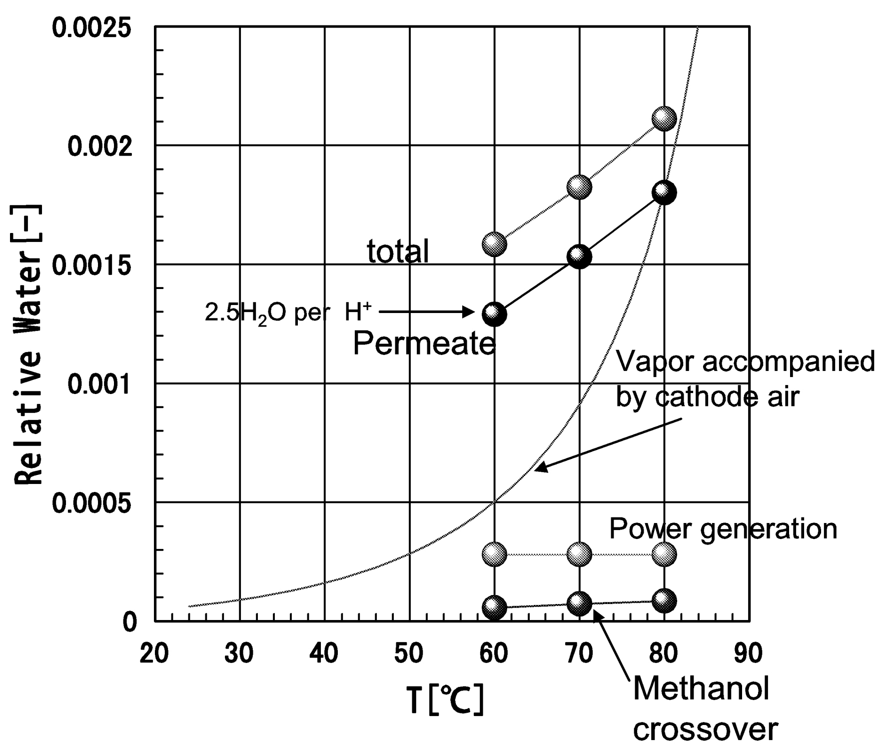

Fig. 5 Water amount in cathode exhaust gas

DMFC Size : W320xD75xH60mm including cartridge space
Output for PC : 10-13W
Running time : 10h per cartridge
Cartridge : W57xD65xH47 Methanol（>95%）: 100cc
Environmental temperature : 10-30℃ humidity : 30-70%

Fig.6 Proto type DMFC with a note PC