Highly Efficient Polymer Electrolyte Fuel Cell (PEFC) Contributing to the Environment

TADASHI GENGO*1 YOSHINORI KOBAYASHI*1
YASUSHI MORI*1 HIROSHI HIRAYAMA*2
TOSHIHIRO TANI*2 SETSUO OHMOTO*3
SHIGERU TSURUMAKI*4

Based on the accumulation of the basic technology for catalysts, combustion, heat transfer, etc., Mitsubishi Heavy Industries, Ltd. (MHI) has been developing the technology for high performance membrane electrode assemblies (MEA) for polymer electrolyte fuel cells (PEFC) and has also been developing the major components such as the reformer and fuel cell stack. At the same time MHI is working on the development of a PEFC system for stationary distributed power sources and power sources in special environments by using the company's system design and control technology. An outline of the development status of MHI's PEFC is introduced below.

1. Introduction

Fuel cells are next-generation low emissions and high efficiency power source and their use is expected to become widespread in the near future. In particular, the application of of PEFC to distributed power supplies, and movable bodies is accelerating through making the best use of its low temperature operation at 80 to 120°C. This report introduces the basic PEFC technology implemented by MHI, the kerosene-fueled stationary power supply system now in development, the hydrogen-fueled system for special applications, and the full closed type ultra-high efficiency power generation system.

2. Development of basic technology

MHI has identified that hydroxyl radicals are the main factor which deteriorate polymer membranes, due to the retention of an open circuit voltage (OCV) associated with the startup and shutdown of the system as well as to the hydrogen peroxide by-product inside the electrode catalyst layer under dry conditions. Based on this finding, MHI has developed an original long-life MEA which forms a radical capture layer to capture or stabilize the hydrogen peroxide radicals before they reach the polymer membrane (**Fig. 1**).

MHI is now implementing a short stack test by using this MEA and is in process of confirming it has sufficient stability and a voltage drop rate of 3 mV/1,000 hrs has so far been confirmed (**Fig. 2**).

Next, to investigate the polymer membrane deterioration inhibition effect of the radical capture layer, we measured the amount of fluorine ions contained in the discharged water during the generation of electricity. (The elution of fluorine

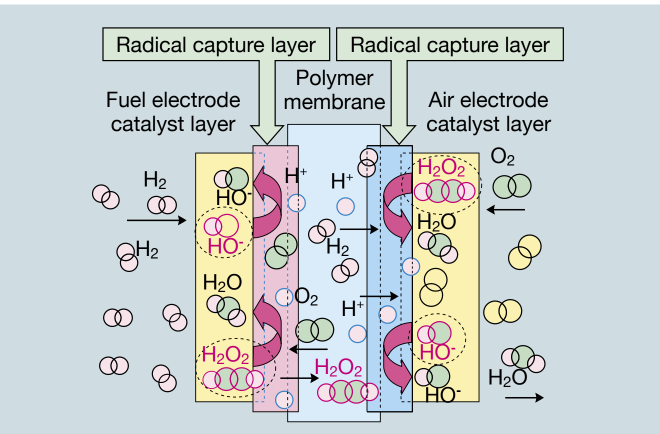

Fig. 1 Radical capture layer
Deterioration of the polymer membrane is prevented by the radical capture layer which is formed in the boundary between the polymer membrane and the catalyst layer.

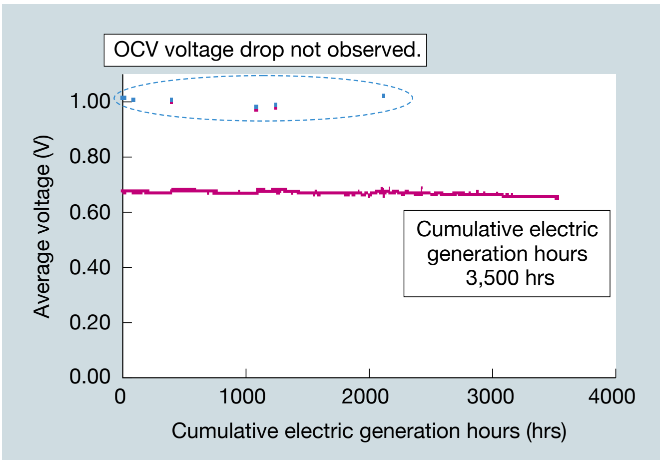

Fig. 2 Stability of radical capturing layer MEA
Voltage stability in the early stage of power generation was confirmed.

*1 Power Systems Headquarters
*2 Kobe Shipyard & Machinery Works
*3 Hiroshima Research & Development Center, Technical Headquarters
*4 Nagasaki Research & Development Center, Technical Headquarters

ions composing the polymer if the polymer membrane has been decomposed due to deterioration has been confirmed.) The amount of elution of fluorine ions from MEA with the radical capture layer is lower than that from MEA without the radical capture layer and thus a high deterioration inhibition effect is indicated (**Fig. 3**).

3. Actual application to stationary use

MHI is developing a kerosene-fueled 10 kW class PEFC system in cooperation with Nippon Oil Corporation (NOC) for the "Stationary Fuel Cell Demonstration Study in Fiscal Year 2003," a government-sponsored project of the New Energy Foundation (NEF). A field demonstration of the system was carried out at a convenience store from February 2004 for one year. In addition, in June 2005, MHI installed the same type of PEFC system in a commercial hotel (Hiroshima Diamond Hotel) in the city of Hiroshima, where the total efficiency of 83% was achieved and the cumulative power generation of 10,000 hours was attained by June 2007 (**Fig. 4**).

Furthermore, in December 2006 MHI installed an improved system of the same type in a public warm water swimming pool and achieved the target generating efficiency of over 36% (LHV: lower heating value) and is still performing continuous operation tests.

In addition, MHI is also developing a pure hydrogen-fueled 10 kW class PEFC system for power supplies to deployment in vehicles. The pure hydrogen type fuel cell starts quickly, achieves clean power generation and there is less noise and vibration. Because of these characteristics, it is thought that the mobile pure hydrogen-fueled PEFC systems will be very convenience for wide-spread use such as an emergency power supply in disasters, a power supply for construction and illumination in ill-ventilated places, and as a power supply for outdoor events (**Fig. 5**).

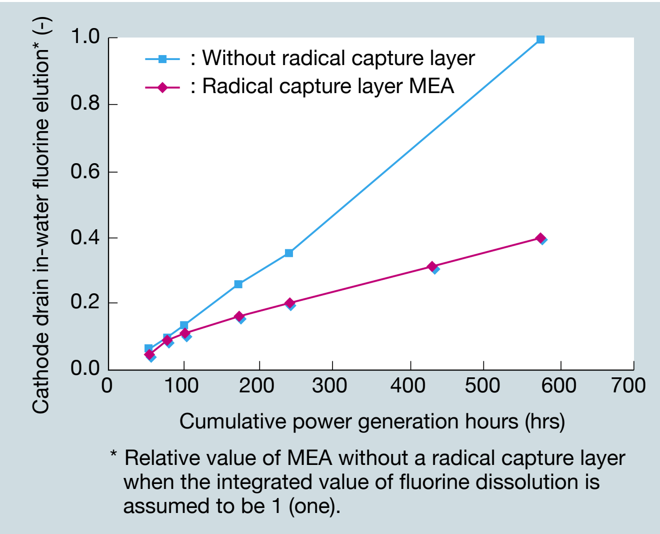

Fig. 3 Deterioration inhibition effect of radical capture layer MEA
Fluorine elution restriction effect by the radical capture layer and polymer membrane deterioration inhibition effect were confirmed.

Fig. 4 Kerosene-fueled 10 kW class PEFC system
MHI performed a demonstration test at a hotel which requires power generation 24 hours a day and a huge hot water supply. As a result, the target performance was achieved.

Fig. 5 Pure hydrogen-fueled 10 kW class PEFC system
This system is useful in applications which requires features such as quick start-up, clean power generation, and less noise and vibration.

4. Actual use in special applications

The PEFC is compact and highly efficient, has good operability and a high generating efficiency of nearly 60% through the use of pure hydrogen and oxygen fuel, and the advantage that water is the only discharge from power generation. Making best use of its characteristics, its use as a power source in closed space is also promising. One example of a closed space is underwater vehicles, for which specific technological challenges that are not found in the stationary system and mobile land vehicles are additionally

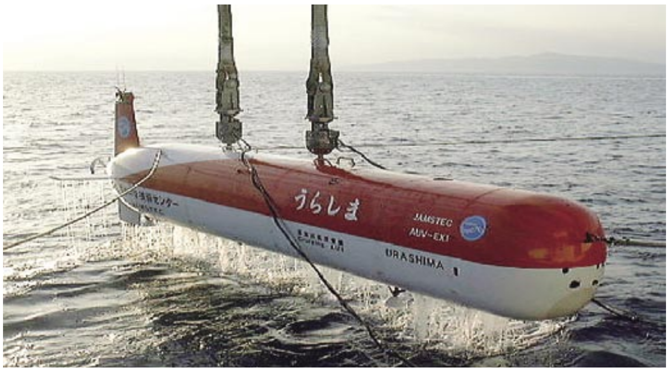

Fig. 6 Autonomous underwater vehicle Urashima
Urashima achieved 317 km continuous navigation which is a world record for an autonomous underwater vehicle. (Photograph supplied by JAMSTEC.)

Table 1 Main specifications of PEFC on Urashima

Output	4 kW (2 kW × 2)
Operation temperature	60°C
Power generation efficiency	54%
Fuel	Pure hydrogen/pure oxygen

Fig. 7 PEFC installed on Urashima
The 4 kW class fully closed loop type was adopted for use in the operational environment of a closed underwater space.

required, including the fuel supply system, discharge treatment, retention of operating temperature, and high airtightness. MHI has overcome these technological challenges through the adoption of a metallic separator and has manufactured a 4 kW class fully closed type PEFC as the power source for Urashima, an autonomous underwater vehicle (AUV) of the Japan Agency for Marine-Earth Science and Technology (JAMSTEC). Using this equipment, Urashima attained 56 hours continuous operation in a running test carried out in Suruga Bay in February 2005 and achieved continuous navigation for 317 km which is a world record for an autonomous underwater vehicle (**Figs. 6 & 7, Table 1**).

This fully closed type PEFC is based on promising technology which is useable not only for underwater vehicles but also for fully regenerative power generation systems such as those on satellite stations, and lunar bases and whose future development is highly anticipated.

5. Conclusion

The company intends to promote the PEFC fuel cell by making best use of its highly efficient, low temperature power generation, while considering its use in emergencies and on mobile objects, etc.

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Tadashi Gengo

Yoshinori Kobayashi

Yasushi Mori

Hiroshi Hirayama

Toshihiro Tani

Setsuo Ohmoto

Shigeru Tsurumaki