Technical Approaches to Clean-energy Power Systems

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Abstract

NTT is researching environment-friendly clean energy to reduce the environmental load and protect the global environment. This article introduces two key technologies in this field. The first is a nickel metal hydride battery that can be used as an alternative to lead-acid batteries. The second is a micro fuel cell that is expected to provide a clean source of power with no CO_2 emissions for portable information terminals in the ubiquitous network society of tomorrow.

1. Information communication services and clean energy technology

Broadband services, ubiquitous services, and other information communication services are expected to expand greatly in the years to come, providing a true infrastructure for corporate, community, and individual activities. However, sophisticated high-speed services will tend to increase the amount of power consumed by information communication equipment and devices. To protect the global environment, we need to develop information communication facilities and portable information terminals that generate a low load on the environment.

In the event of a power outage or failure in communications equipment, a backup power supply system for communication systems provides electric power from storage batteries to prevent a delay in communications. These storage batteries have traditionally been lead-acid types. At NTT Energy and Environment Systems Laboratories, we are developing technology for nickel metal hydride (NiMH) batteries for application to the high-energy-density and high-reliability backup power supply systems [1] needed for such communication facilities. Compared with conventional lead-acid batteries, NiMH batteries contain no toxic substances and provide a powerful source of clean energy. They also provide a compact and lightweight configuration about one-third the weight and volume of systems using lead-acid batteries. With these features, NiMH batteries need not be limited to the role of backup power supply systems for communications. They can also be applied to uninterruptible, long-term power supply systems for personal computers and servers and to small-scale power supply systems that can be used as lifelines during natural disasters, such as earthquakes and typhoons. Although NTT uses direct-current (DC) power supplies to drive its communications equipment, the specifications for clean power supply systems using the developed NiMH batteries also provide for alternating-current (AC) output to enable their use with general-purpose equipment and devices. Additionally, in conjunction with advances being made in ubiquitous technology to provide safe and reliable communications anytime and anywhere, we are developing micro fuel cells having no CO_2 emissions as energy sources for portable information terminals, whose use is expected to increase dramatically. The development of technologies such as these should significantly reduce the amount of CO_2 discharged into the atmosphere as a result of expanding information communication services and provide a safe and reliable energy environment.

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2. Clean power supply systems

2.1 Overview

External views of three types of power supply systems are shown in **Fig. 1**. Type A is a 1140-Wh power supply system incorporating NiMH batteries. This system has AC100V/50W output with an operation time of more than 20 hours. With a total weight of about 40 kg, it is light enough to be loaded onto an ordinary two-wheeled motor vehicle (whose maximum load by law is 60 kg), which can provide valuable mobility for relief efforts during a natural disaster. The type-A power supply system can therefore be transported quickly as a portable and temporary power supply system to a site needing assistance. The type-B power supply system has a capacity of 4.6 kWh. It can be used as a medium-scale power supply system or as a power supply system for environmental monitoring and telemetry using sensors. Type C is a 9-kWh power supply system that can be used as a backup power supply system for small-scale network systems.

The configuration of a clean power supply system may also be customized according to customer needs and circumstances. For example, a primary inverter power supply can be configured to guarantee high power quality in an uninterruptible power supply system, and a primary commercial power supply system with a crossover switch can be configured for a high-efficiency, low-cost power supply system.

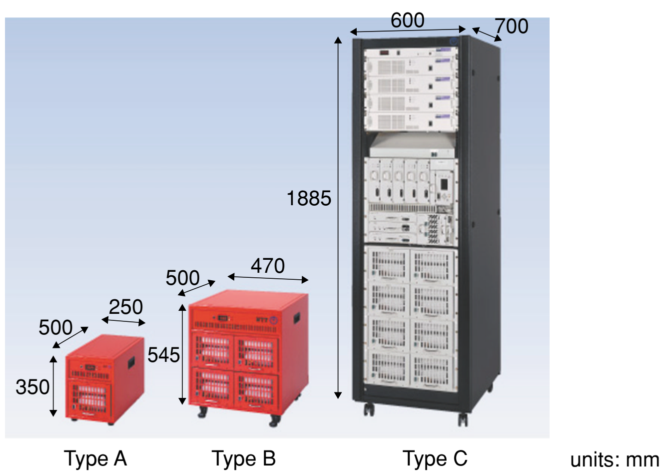


Fig. 1. Clean power supply systems.

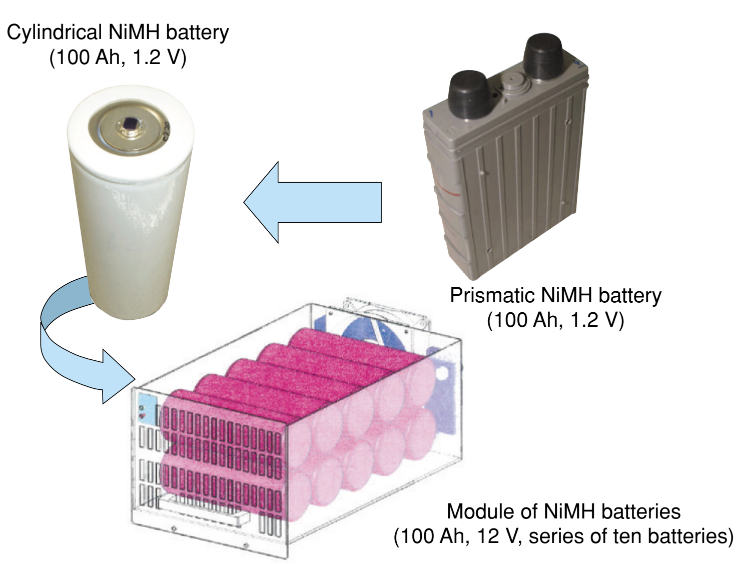


Fig. 2. Redesign of battery.

2.2 Technical features

The NiMH batteries we developed for clean power supply systems represent an advance over conventional prismatic NiMH batteries used in electric automobiles and other applications. Changes include the type of electrode materials used and the concentration of electrolyte solution, resulting in a wider operating temperature range and less self discharging. Moreover, the battery life is expected to be more than twice that of lead-acid batteries. When the temperature of a conventional NiMH battery exceeds 40°C, only water electrolysis can proceed, which prevents a charging state from being achieved. In contrast, our new batteries can be charged at temperatures up to 55°C due to a new additive in the positive electrode and an optimized electrolyte-solution composition [2]. These batteries can therefore achieve the desired performance even when used outdoors in the middle of summer. As shown in **Fig. 2**, these new NiMH batteries are cylindrical, which is very advantageous for mass production and provides a cost saving of about 30% compared with prismatic batteries.

NiMH batteries for use in clean power supply systems are normally packaged in a battery module consisting of ten batteries connected in series. This module incorporates a temperature-control fan enabling the heat generated by each module to be controlled independently. It also includes a connector on the side of its cabinet for making system connections. With this structure, batteries can be replaced by simply removing a NiMH-battery module from a system rack and inserting a new module, eliminating the bothersome wiring work required in the past. Battery exchange can therefore be done in a safe and speedy manner and a power supply system with a capacity corresponding to an integral number of modules can be easily configured. For example, the type-A, -B, and -C power supply systems shown in Fig. 1 incorporate one, four, and eight NiMH-battery modules, respectively. The capacity of a clean power supply system is proportional to the number of modules. These new NiMH batteries enable the development of maintenance-free, transportable power supply systems that can be used outdoors even in the middle of summer. They will lead to quiet and clean power supplies free of the exhaust, noise, and vibration associated with conventional power generators and engines. NiMH batteries of this type are expected to provide robust power supplies during natural disasters.

3. Micro fuel cells as ubiquitous power supplies

3.1 Overview

Cellular phones, notebook computers, and personal digital assistants (PDAs) are becoming increasingly multi-functional as the march toward the ubiquitous network society continues. As a result, the power consumed by these devices is increasing steadily and the amount of CO_2 discharged is expected to increase as well. At the same time, the energy density of lithium-ion batteries is approaching its theoretical limit and the problem of insufficient power capacity in portable information terminals—whose use is expected to increase in the years to come—is becoming serious. This has focused much attention on the development of clean and small fuel cells that have an energy density greater than that of lithium-ion batteries.

At present, mainstream development efforts are concentrated on direct methanol fuel cells for portable gadgets that use methanol as fuel [3], but this type of fuel cell emits CO_2 when generating power. In addition, achieving a compact configuration is difficult because of the low power-generation density due to the poor reactivity of methanol. In response to this problem, we have developed a polymer electrolyte micro fuel cell that uses hydrogen as fuel, emits no CO_2 when generating power, has a high output power density, and is easily miniaturized.

3.2 Technical features

The operating principle of the polymer electrolyte fuel cell (PEFC) is illustrated in **Fig. 3**. The system feeds hydrogen to the fuel electrode (anode) and oxygen from the air to the air electrode (cathode). On the fuel electrode side, the hydrogen undergoes an oxidizing reaction at the interface between the electrolyte and the electrode (where a platinum electrocatalyst has been coated on carbon particles). This reaction produces protons that move to the air electrode through the polymer electrolyte membrane. At the same time, electrons separated from hydrogen in this reaction also move to the air electrode, but through the fuel electrode and external circuit. On the air electrode side, the protons undergo a reducing reaction with oxygen and electrons. This produces current flow and generates water as a by-product.

The basic structure and appearance of a prototype micro fuel cell is shown in **Fig. 4**. This system uses a hydrogen-absorbing metal alloy to store hydrogen as

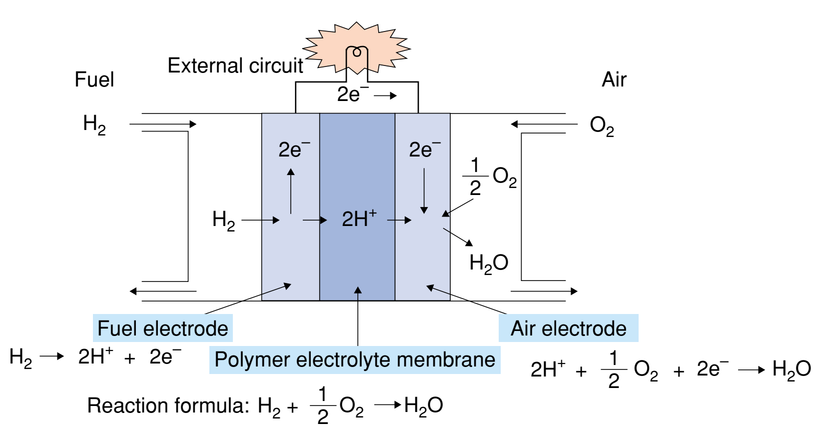
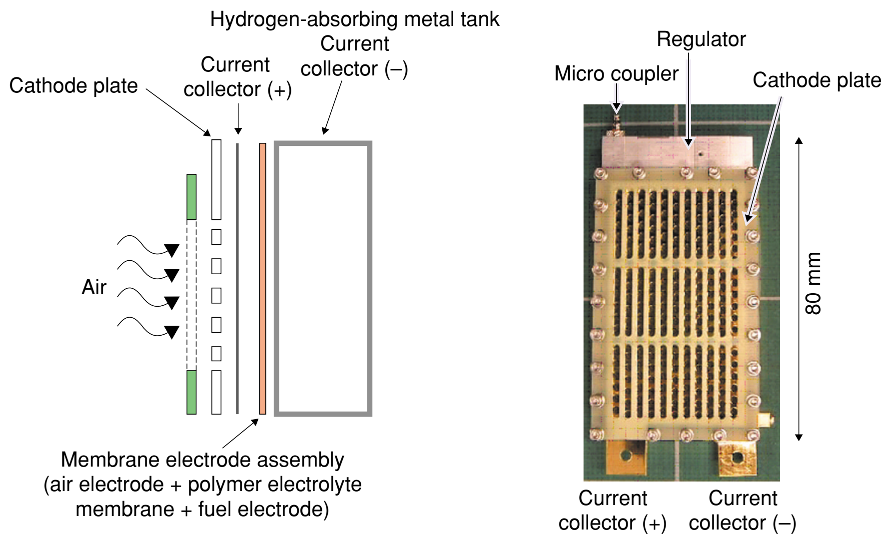


Fig. 3. Operating principle of polymer electrolyte fuel cell.



(a) Schematic, cross section view

(b) Photograph, front view

Fig. 4. Structure and features of the micro fuel cell.

fuel [4]. The advantages of storing hydrogen in this way include a large energy density per unit volume, the ability to use hydrogen under typical conditions at normal temperatures and pressures, and a high level of safety.

The two main parts of this micro fuel cell are a power-generation section and a hydrogen-absorbing metal alloy tank for storing hydrogen. The former consists of a membrane electrode assembly (made up of an air electrode, polymer electrolyte membrane, and fuel electrode), a current collector to extract electric power, an air-permeable cathode plate, and a regulator for adjusting hydrogen pressure. Integrating the power-generation section and the hydrogen-absorbing metal alloy tank makes for a compact and light configuration with dimensions of 42 mm × 80 mm × 13 mm and a weight of 99.5 g. A fuel cell of this size can be directly incorporated into a portable device such as a cellular phone.

3.3 Application to FOMA

The performance of this micro fuel cell can be assessed from the relationship between generated current and voltage. **Figure 5** shows the change in voltage and generated power density versus current. A maximum output density of 180 mW/cm^2 was obtained at a generated current density of 0.36 A/cm^2, which represents a maximum output density about three times that of direct methanol fuel cells. Since the obtained power can be changed by altering the area of the power-generation section, this micro fuel cell can be applied to a wide range of portable information terminals, including cellular phones and PDAs.

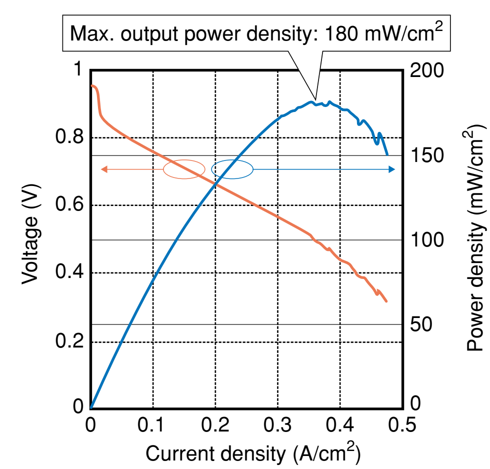


Fig. 5. Performance of the micro fuel cell system.

A photograph of a micro fuel cell system applied to a FOMA* cellular phone is shown in **Fig. 6**. This system consists of the micro fuel cell shown in Fig. 4 and an ultralow-voltage booster circuit [5] developed by NTT Energy and Environment Systems Laboratories. This booster circuit raises the low voltage output of the micro fuel cell (less than 1 V) to the 4 V needed to drive the FOMA phone.

To assess the characteristics of this micro fuel cell

* FOMA: 3G (third-generation) mobile phone service from NTT DoCoMo http://www.nttdocomo.com/corebiz/network/3g/tech.html

Fig. 6. Micro fuel cell system applied to FOMA.

system, we removed the lithium-ion battery from a FOMA phone, connected the phone's power terminal directly to the micro fuel cell system, and tested it. We found that the phone could successfully initiate the videophone, telephone, and i-mode functions of the FOMA system and perform the send and receive operations for those functions. Powering the phone directly by this micro fuel cell provided nine hours of continuous calling.

Various issues still need to be addressed before this micro fuel cell can be deployed, such as the establishment of a hydrogen-fuel supply system and associated regulations. In the meantime, we will continue our efforts to develop clean, powerful, compact, and high-efficiency fuel cells to help reduce CO_2 emissions.

4. Future outlook

With the spread of IP (Internet protocol) networks and ubiquitous services, there is a growing demand for information communication facilities and portable information terminals that operate quickly with more advanced functions, which results in the consumption of even greater amounts of power. We will continue our research and development of clean energy technology with the aim of reducing CO_2 emissions from such equipment. We will also work to enhance and lower the cost of environment-friendly power supply technology as a forerunner to the clean energy society of the future.

References

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