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Fuel Cell Type Power Generation Using Hydrothermal Fluid from Deep-Sea Hydrothermal Vents —Possibilities for Autonomous Long-Term Electrical Power Supply in the Deep Ocean—

1. Overview

A collaborative group of Masahiro Yamamoto, a researcher for the Japan Agency for Marine-Earth Science and Technology (JAMSTEC: Asahiko Taira, President) Submarine Resources Research Project, and Ryuhei Nakamura, a team leader at the RIKEN Center for Sustainable Resource Science, and others has been carrying out on-site electrochemical measurements of hydrothermal fluid and the surrounding seawater in deep-sea floor hydrothermal vents created artificially (artificial hydrothermal vents[*1]) in the Okinawa trough. Based on these results, they have succeeded in generating power on the deep-sea floor by installing a fuel cell (hereinafter, hydrothermal fluid–seawater fuel cell[*2]), which can use hydrothermal fluid and seawater as fuel, in an artificial hydrothermal vent.

Many (reductive) substances that easily release electrons, such as hydrogen sulfide, are found in hydrothermal fluid vented from the seafloor, and on the other hand, many (oxidative) substances that easily receive electrons, such as oxygen, are found in the surrounding seawater. We focused on the existence of this difference (redox gradient) in the ability of the hydrothermal fluid and seawater to receive electrons, and tested methods for extracting electrical power from this. Specifically, the fuel cell was constructed by the simple method of installing an electrode in each of the hydrothermal vent and the surrounding seawater, and electric power was generated. Since there is an inexhaustible supply of the hydrothermal fluid and seawater that form the fuel, this method is suitable for stably supplying electricity over a long period of time. Up to now, there has been research on using temperature differences and steam for generating electric power in areas of seafloor hydrothermal activity, but this method can generate electricity with a simpler device than those. Furthermore, the materials used in this method resist corrosion and can be considered for long-term use. Moving forward, plans are for a course of long-term tests to confirm this method. It is expected to be important technology for supplying electric power to the increasingly active research and development sites in areas of deep-sea hydrothermal activity.

These research results were published in the online edition of the German chemical journal *Angewandte Chemie International Edition* on September 3 (Japan Time). In addition, a patent application is being submitted based on these results.

Title: Electricity generation and illumination via an environmental fuel cell in deep-sea hydrothermal vents

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*1 Artificial hydrothermal vent: a hydrothermal vent created artificially by drilling down to a hydrothermal pool under the seafloor using seafloor excavation. Naturally occurring hydrothermal vents are cracks that spew out fluid heated geothermally, and since the water pressure in the deep ocean is high and the boiling point of water increases, the hydrothermal fluid reaches 300°C or greater. Vigorous biological activity is frequently seen around natural hydrothermal vents. Microorganisms that extract energy from the chemical reactions of various chemical substances dissolved in the hydrothermal fluid being vented with compounds in the surrounding seawater and synthesize organic compounds support the base of the food chain; above them giant tubeworms, bivalves, shrimp and others can be observed. Artificial hydrothermal vents release hydrothermal fluid with the same components as natural hydrothermal vents. Artificial hydrothermal vent is very useful for observation and experiment of the hydrothermal fluid because it gives us advantages over natural vent about accessibility of vehicles and stability of the vent position

*2 hydrothermal fluid–seawater fuel cell: a fuel cell that uses hydrothermal fluid and seawater for fuel. Terminology coined by the authors. A fuel cell is a power generating device that can continuously extract electrical power as long as the supply of fuel is replenished. There are always two types of fuel, a negative electrode agent (fuel that passes electrons to a negative electrode) and a positive electrode agent (fuel that receives electrons from a positive electrode). In hydrothermal fluid–seawater fuel cells, hydrothermal fluid is the negative electrode agent, and seawater is the positive electrode agent. The hydrothermal fluid-seawater fuel cell form a very simple structure in which some kind of electrically driven device is connected by wires across two electrodes, i. e. anode (hydrothermal side electrode) and cathode (seawater side electrode).

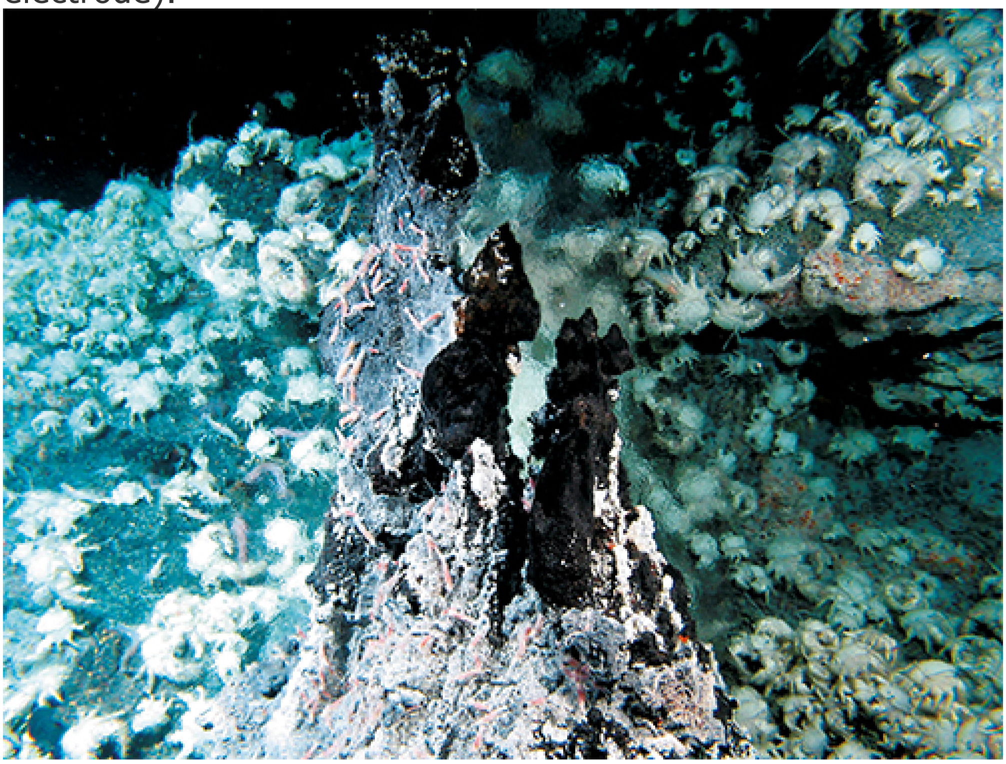

Figure 1. Photograph of deep-sea hydrothermal vent
This is a deep-sea hydrothermal vent in the Iheya-North hydrothermal field of the Okinawa trough. A structure called a chimney, which is seen in the middle of the photograph, is formed by hydrothermal fluid components being deposited. In most cases, the main components are sulfide minerals. A shimmer that indicates the hydrothermal vent can be observed around the tip of the chimney. Polychaete worms, shrimp and other animals living in the surroundings.

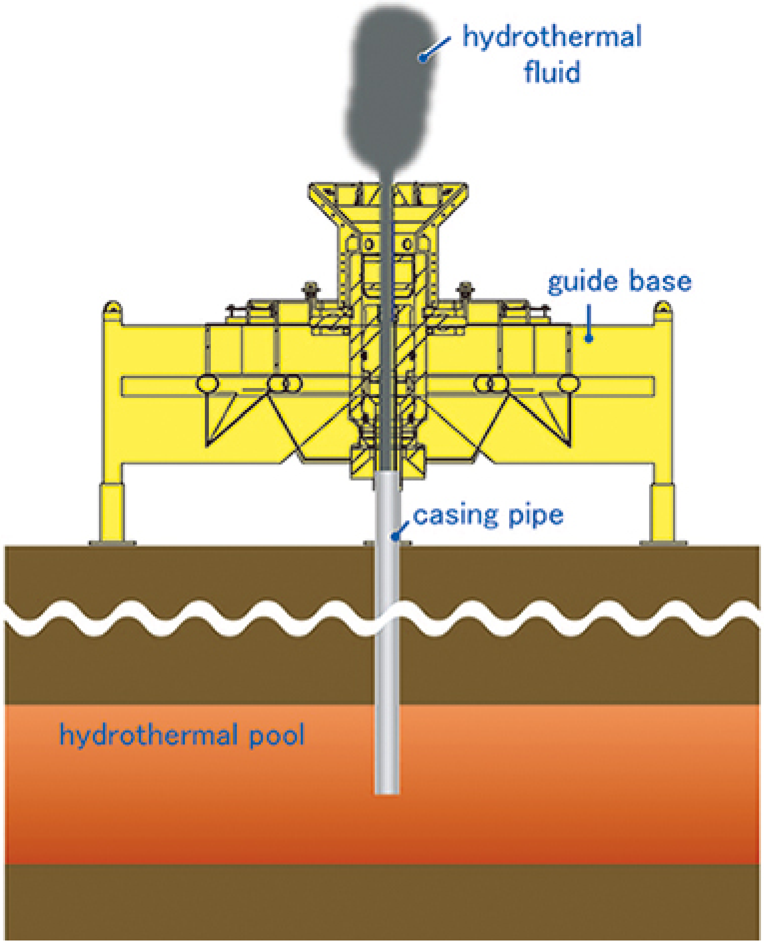

Figure 2. Artificial hydrothermal vent
Hydrothermal vent created artificially by deep-sea excavation. A hole is drilled to a hydrothermal pool under the seafloor, and a pathway for the hydrothermal fluid to the surface of the seafloor is created using stainless steel casing pipe. Since the hydrothermal fluid always vents from the middle of a stable platform, which is called a guide base, approaching the vent with remotely operated vehicles (ROV) and observing the hydrothermal fluid are easier than approaching natural hydrothermal vents.

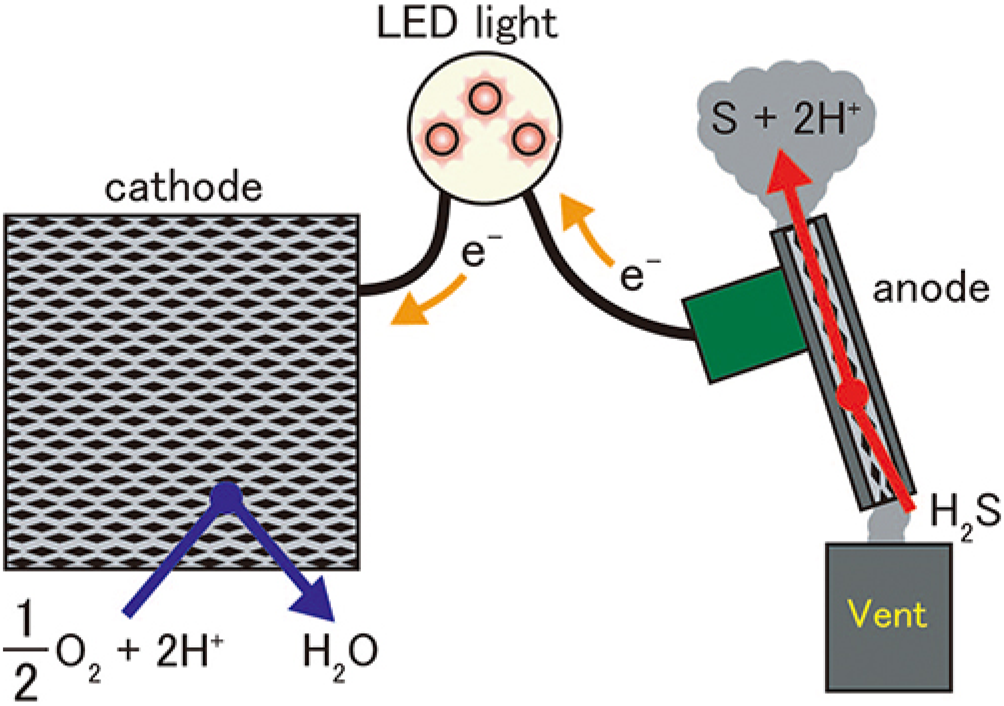

Figure 3. Schematic diagram of hydrothermal water–seawater fuel cell
This is the configuration of the fuel cell used this time. It is a simple configuration in which the anode (hydrothermal fluid side electrode), an LED light and the cathode (seawater side electrode) are connected by wires. The anode is an iridium coated titanium mesh placed inside a titanium pipe with a diameter of 3 cm and a length of 40 cm. The cathode is a 50 cm x 50 cm platinum coated titanium mesh. At the anode, a reaction progresses in which mainly hydrogen sulfide (H_2S) is oxidized and electrons flow into the electrode. At the cathode, a reductive reaction progresses in which oxygen (O_2) receives electrons from the electrode.

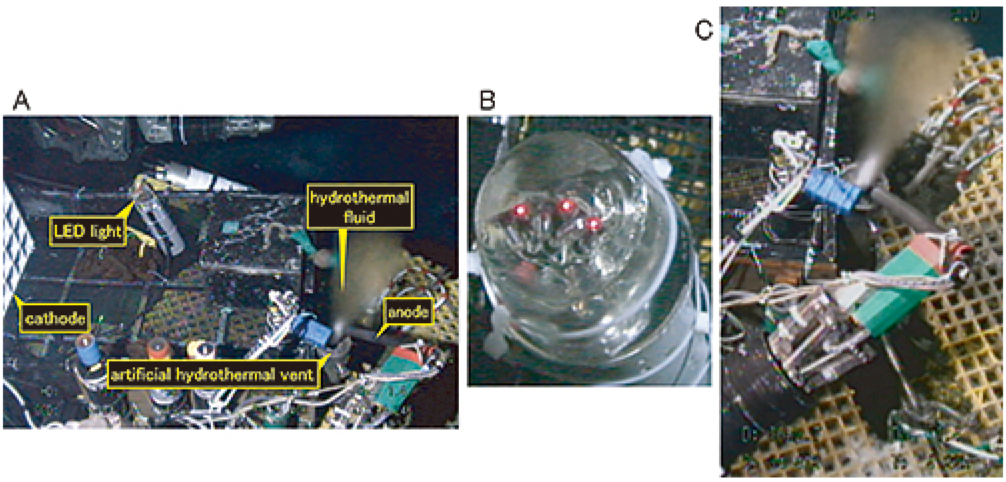

Figure 4. Photographs of hydrothermal fluid–seawater fuel cell
A) Photograph of hydrothermal fluid–seawater fuel cell as a whole. Here, a cathode (seawater side electrode) is cutoff in the photograph (left side of photograph).
B) LED light photographed from the front by another camera. It can be seen that three red LEDs are illuminated.
C) Enlarged photograph of area around anode (hydrothermal fluid side electrode). The artificial hydrothermal vent and the hydrothermal fluid venting from it can be seen on the tip side of the titanium pipe for the electrode. A green receiver is attached on the opposite side of the titanium pipe, and the manipulator of a ROV is grasping that receiver.

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