RESEARCH INTRODUCTION

Recycling Safe and Healthy Water

Recycling is an indispensable technology for long stays in space

The International Space Station (ISS) now being constructed in orbit some 400 km above the surface of our planet is manned at all times by a human crew. Almost all of the materials crucial for human life in the ISS-water, air, food, and so on-must be transported from the earth. There is always a risk that resources will run short. Events on the ground might prevent the launch of spacecraft with fresh supplies, for example, or high transportation costs could discourage space agencies from sending supplies often. Changes in the future might also hinder the transport of new resources.

As space development advances, the bases for space activity will spread further afield, with the construction of a lunar base and further exploration of Mars. It will therefore be essential to develop technologies to completely recycle the wastes human being excrete (exhalations, domestic wastewater, excreta, etc.) into the resources humans require (breathable air, drinkable water, nutrients, etc.) (Fig.1).

A:Cosmic water

B:Water purifier using a reverse-osmosis membrane (manufactured by New Medican Tech Corporation)

Fig.2 Water Purifier created by Technology Transfer

Safe and delicious drinking water even in space

"Cosmic water" (Fig.2A) is a unique water produced by a water purifier (Fig.2B) developed by New Medican Tech Corporation using technologies from the Japan Aerospace Exploration Agency (JAXA).

A reverse-osmosis membrane (Fig.3), a membrane for the desalination of seawater, is used as a filter to purify water. The 0.1-nanometer(*1) pore size of the reverse-osmosis membrane (far smaller than the smallest virus living under water) ensures the high purity of the water filtered through. It also presents difficulty, however, as a high pressure is required to force the water molecules through the infinitesimal pores. JAXA promoted a joint study to solve this problem and established a technology to pass water molecules through the pores preferentially. With help from this technology, we succeeded in filtering water at lower pressures with smaller filtering devices.

Unsolved problems remained, however. Though the water was

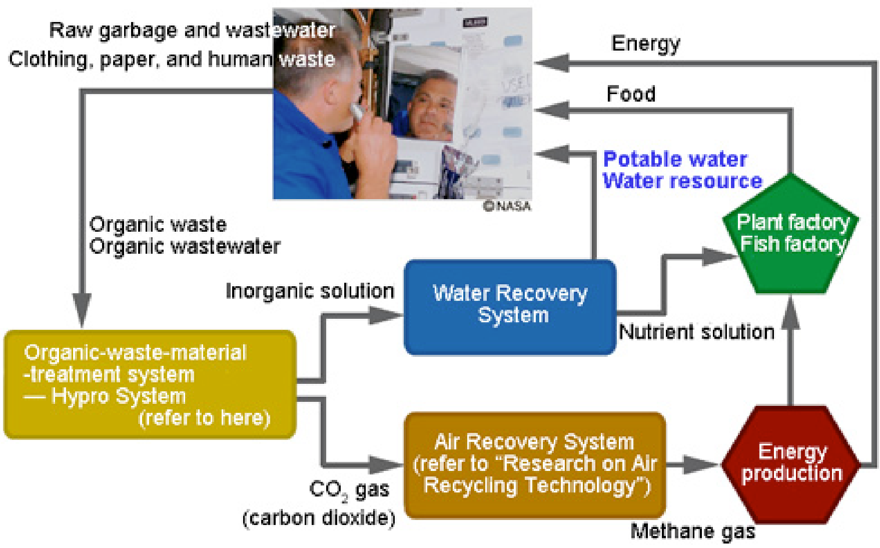
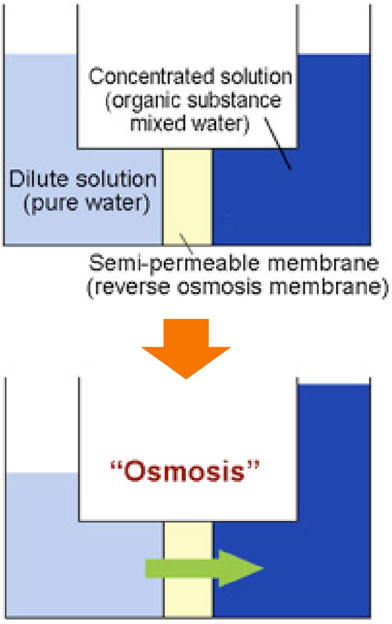
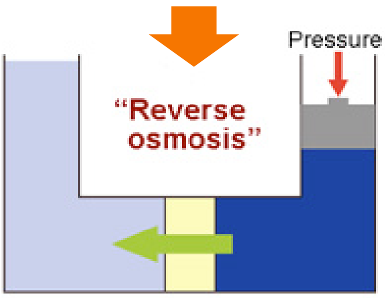


Fig.1 Block diagram of Resource Recycle in Space



"Osmosis" is a balancing between a dilute solution and concentrated solution separated by a semi-permeable membrane. The water on the dilute-solution side passes through the membrane to the concentrated solution side until the concentrations of the two solutions are balanced. The water flow is driven by the pressure difference between the two solutions, or the "osmotic pressure."



If a pressure higher than the osmotic pressure is applied onto the concentrated solution side, the water moves to the dilute solution side in a phenomenon called "reverse osmosis."
Because impurities such as organic substances, etc. cannot pass through the semi-permeable membrane, the water can be purified by reverse osmosis.

Fig.3 Principle behind the Reverse-Osmosis Membrane

highly pure, the taste was disagreeable and continuous consumption of the water over a long period proved to be unhealthy. Finally, by transferring a technology for delicious drinking water, a technology capable of enriching water with natural minerals within a short time, JAXA has developed a device capable of recycling used water into drinking water that is both safe and delicious.

First, the development of water purifier for the ground with technology transferred from JAXA

JAXA is researching and developing a water-recovery system for space use in a joint research project with New Medican Tech Corporation. This system will be capable of treating 200 liters of human urine and domestic wastewater -the amount discharged daily by 6 persons- in only about eight hours. Several issues will have to be solved, however, if this water-recovery system is to be developed for space. One of those issues is the "water quality criteria." As human urine must be recycled in space, it will be necessary to reduce the ammonia and TOC(*2) contained in the urine to below the standard values.

And to reduce the workload required for the replacement of parts, etc., it will also be indispensable to design a reverse-osmosis membrane with longer life. Ultimately JAXA hopes to demonstrate the technologies for the system in Kibo, the Japanese Experiment Module to be commissioned for the ISS.

(*1) 1 nanometer = millionth part of a 1 millimeter.
(*2) TOC : value expressing the ratio of organic substances contained in water.

[Advanced Space Technology Research Group]

Mitsuo Oguchi

RESEARCH INTRODUCTION

Air Can be Safely Recycled, Too

Recycling technologies will be crucial for the construction of the lunar surface base

On September 14, 2007, JAXA launched its lunar exploration satellite, the "Kaguya,(*1)" from the Tanegashima Space Center. Various countries such as the United States, China, and members of the EU are now considering the moon as a way-station for astronauts bound for Mars. To prepare, space agencies from these countries are exploring plans for the construction of a space station on the lunar surface. JAXA also seeks to establish technologies for the construction and use of the lunar surface base (Fig.1). Under its long-term vision, JAXA2025, the agency will be finalizing development plans for the next period of manned space activity by 2015. To establish the technologies for support, JAXA is researching systems indispensable for manned space activities, including the "Water Recycling Technology (refer to here)" and "Air Recycle Technology" mentioned in earlier pages.

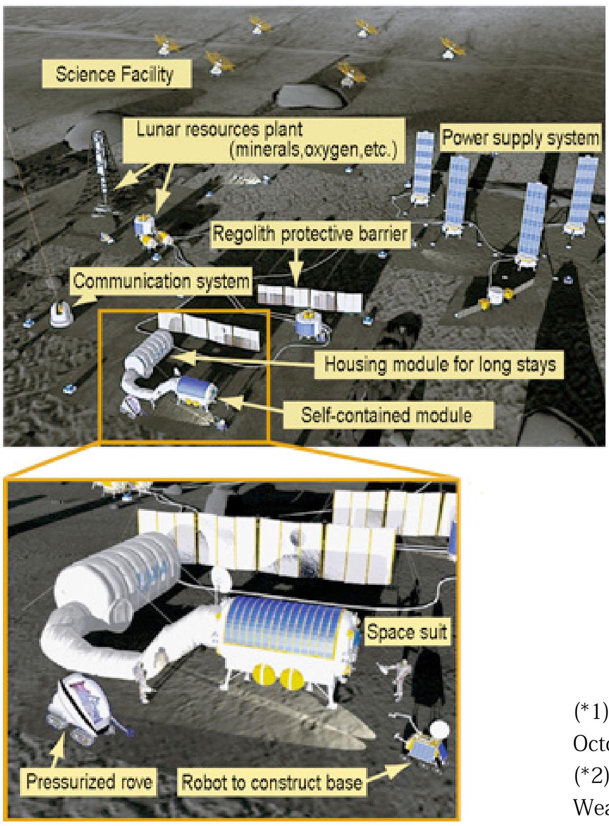


Fig.1 Lunar Surface Base (Prog. Chart)

Towards the recycling of air

An average human consumes about 585 liters of oxygen and exhales about 509 liters of carbon dioxide every day. In the manned spacecraft operated by NASA, the carbon dioxide exhaled from astronauts is treated with a chemical absorption agent. The system requires about 1.5 tons of absorption agent to support eight persons living in space for a six month stay. As the supply of oxygen is indispensable, the astronauts must launch with about 3 tons of material, including the absorption agent. To eliminate this burden, a technology is now being developed to "recycle air."

We need three types of equipment to recycle air: carbon dioxide removal equipment to separate carbon dioxide from the exhaled air, carbon dioxide reduction equipment to produce water from the separated carbon dioxide and added hydrogen, and water electrolysis equipment (Fig.2). JAXA is researching this equipment to find ways to improve its efficiency.

The research so far completed has culminated in systems useful for water electrolysis and the handling of fluid in microgravity. JAXA has already won several prizes for these achievements.(*2)

Towards demonstration in space

To confirm that the equipment functions normally even in the zero gravity (microgravity) space, we are systematizing, downsizing, and reducing the energy consumption of the equipment in pursuit of embarkation on a small satellite.

Harmful trace gases such as metabolic gases from humans and evolved gases from devices are generated during space activity. The removal of these harmful substances is crucial to the supply of safe air. For this purpose, we are also researching an air-cleaning technology using photocatalyst (refer to page 5).

(*1) Kaguya reached its lunar orbit and became a satellite of the moon on October 4.

(*2) Fiscal 2004 : JAXA won the Technical Service Award from the Suga Weathering Technology Foundation.
Fiscal 2005: JAXA won the 3rd Price to Encourage Scientific Development from the Japan Society of Microgravity Applications.

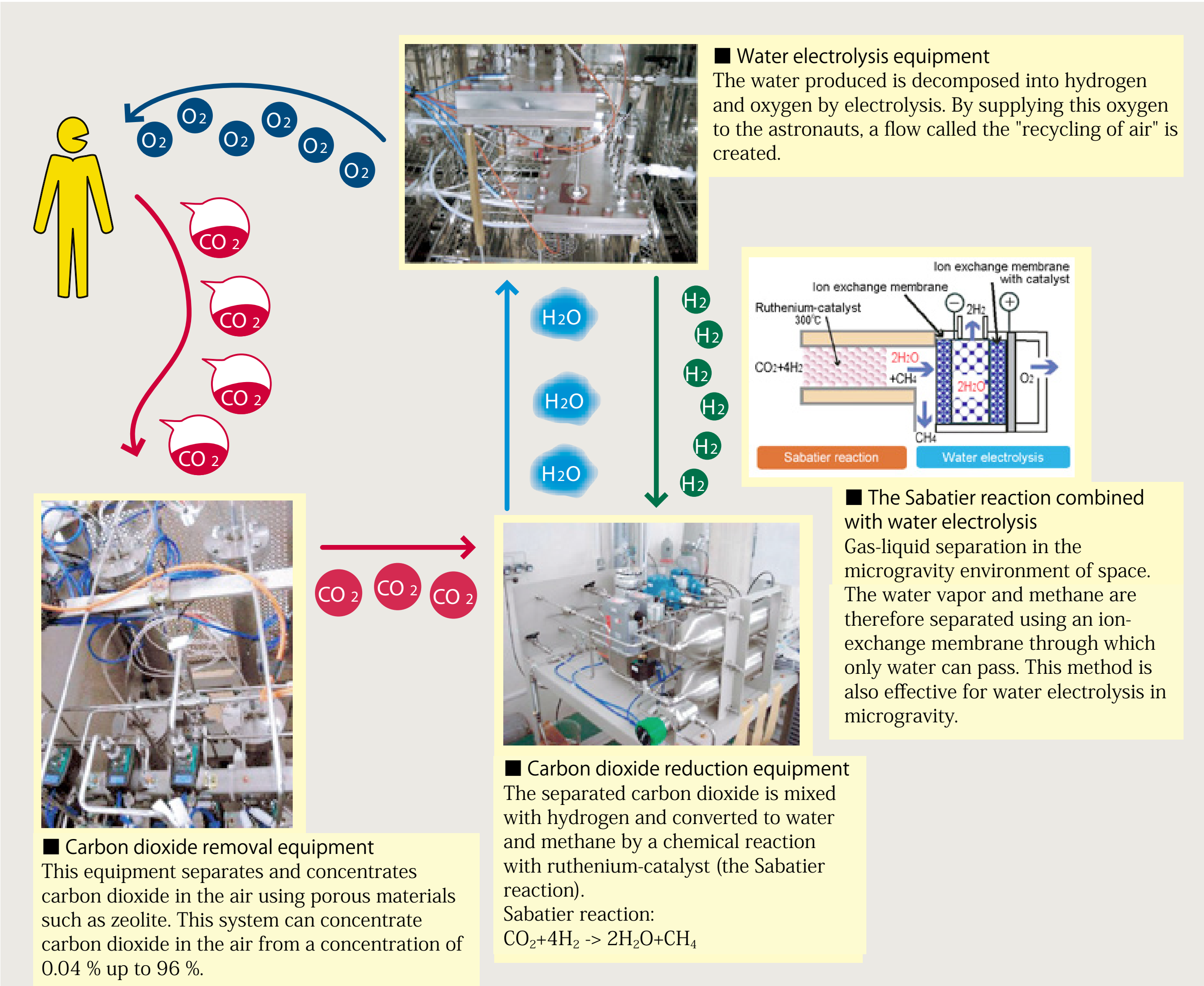
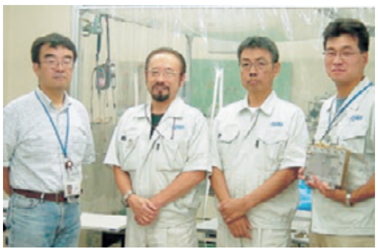


Fig.2 Air Recycling Equipment

[Patent Information]

- Sabatier reaction equipment and water vapor electrolysis equipment that relies on the Sabatier reaction (No. 3639861)
- Water vapor electrolysis equipment (No. 3511608)
- Environment-cleaning recycling-type water electrolysis equipment (No. 3479950)



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(from the left) Mitsuru Onishi, Mitsuo Oguchi, Shoichi Yoshihara and Masato Sakurai

Intermission Break

"Catalysts" and "Photocatalysts"

Water (H_2O) is the product of a chemical reaction between oxygen (O_2) and hydrogen (H_2). This chemical reaction to form water requires a great deal of energy. Even at the high temperature of 200 ℃, oxygen and hydrogen stored in an airtight vessel will form no water. Yet if a small amount of copper (Cu) is added to the container before heating, the chemical reaction to form water will promptly proceed. The Cu lowers the energy required for the reaction (Fig.1). The Cu also remains in its original state, unchanged, during the reaction. A substance that promotes the chemical reaction of other substances without undergoing any change itself is called a "catalyst."

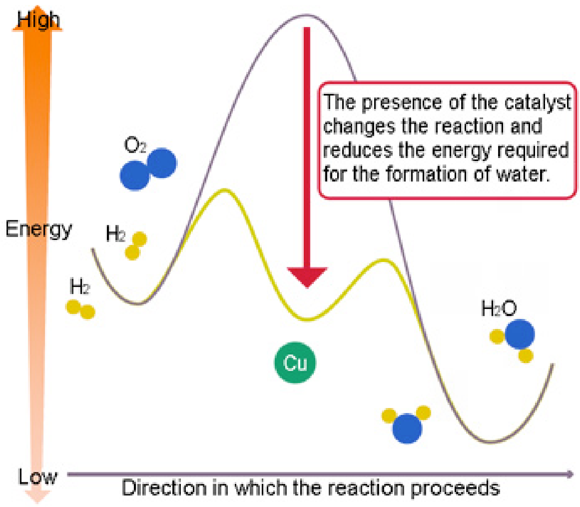


Fig.1 Action of catalysts

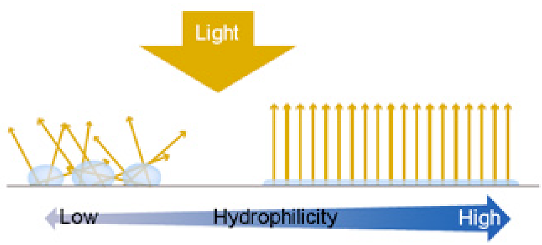
Though they stay unchanged themselves, catalysts are deeply involved in chemical reactions. Because Cu has the power to dissociate O_2 and H_2 into the oxygen atom (O) and hydrogen atom (H), respectively, O_2 in contact with Cu dissociates into O to form copper oxide (CuO). The O atom from CuO reacts with the H atom, which is likewise dissociated as a result of the contact with Cu to form water.

In addition to promoting chemical reactions, a catalyst can also react with a specific substance or form only a specific substance. This property is called "selectivity." An appropriate catalyst will reduce or form a targeted substance selectively. Industries are now exploiting the selectivity of catalysts to remove harmful substances in automobile exhaust emissions, such as nitrogen oxides (NOx) and carbon monoxide (CO). Catalysts also play active roles in various processes we rely on inextricably behind the scenes in daily life, such as the refinement of gasoline and kerosene.

"Photocatalysts" are a class of catalysts that act only in the presence of light. Titanium oxide (TiO) is one of the best known photocatalysts. A salient feature of TiO is strong oxidizability. When light is irradiated onto TiO, a substance called high oxidizing oxygen is formed on the surface of the TiO. The highly oxidizing oxygen has a very high oxidizability and can decompose various organic substances. Theoretically, it decomposes all the organic substances up to carbon dioxide and water. Products using photocatalysts are widely available on the market. Sterilizers for medical use and artificial foliage for air-purification systems are common examples you have probably seen.

Among the various forms of light, TiO reacts with "ultraviolet rays." Sunlight ordinarily consists of only about 3% ultraviolet rays. Because of this, TiO under sunlight is only partially effective for the selective cleaning of components such as water, etc. from vessels. The cleaning of river water with a photocatalyst would be wholly ineffective. Researchers are therefore studying new photocatalysts that work even under visible light.

TiO also has the feature of "ultra hydrophilicity." When steam collects on a mirror, the glass clouds over and the mirror loses its ability to reflect images. The surface moisture (steam) over the glass consists of tiny granules that reflect light diffusely. When the glass of a mirror is coated with TiO, water will adhere to it uniformly. The mirror will once more reflect images, with no diffusion of light (Fig.2). This anti-clouding function of TiO has been developed for products commercially.



When the hydrophilicity is low, the water on the surface of the glass collects into tiny granules and diffusely reflects light. When the hydrophilicity is high, the water adheres uniformly over the surface of the glass and the diffusive effect is suppressed.

Fig.2 Hydrophilicity