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Fundamental study of water electrolysis for life support system in space

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ABSTRACT

To establish supporting technologies, JAXA (Japan Aerospace eXploration Agency) is researching systems that will be indispensable for manned space activities beyond low earth orbit, including "Water Recycling Technology" and "Air Recycle Technology". In this paper, SPE (solid polymer electrolyte) water electrolysis is investigated for the recycling technology. Although water is usually supplied into anode side on the earth, cathode feed type and static one is employed under the special environment. The performance of the cathode one could match our target by flushing the gas bubbles sticking on the electrode, while the static one shows the gas-free electrolysis process without any mechanical pumping system. The in situ observation during aqueous water electrolysis shows active bubble motions depending on the solution components. Gas bubbles spontaneously jumps and detach from the electrode in KOH electrolysis, while they easily coalesce and stick in H_2SO_4 one. The transient behavior is strongly controlled by wettability under microgravity where the buoyancy force can be neglected.

1. Introduction

Various space agencies such as JAXA, NASA (National Aeronautics and Space Administration) and ESA (European Space Agency) are currently considering the moon and asteroids as way stations for astronauts bound for Mars. Under JAXA's long-term vision, JAXA2025, we will by 2015 finalize its development plans for the next period of manned space activity. A self-regulated recycling life support system is necessary for the International Space Station (ISS) and the manned space missions for lunar, asteroid or Mars [1,2]. The system must take into consideration of food production and waste disposal including air. The conceptual model applying physicochemical reaction for the materials circulation has been discussed in JAXA.

The air revitalization system is illustrated in Fig. 1. In a spaceship ca. 4000 ppm carbon dioxide is usually created by astronauts' exhalation. It is separated and concentrated to 96% carbon dioxide by the thermal swing of zeolite. Then, it is mixed with hydrogen to produce water and methane by the utilization of ruthenium catalyst at 300 °C (Sabatier reaction) [3,4]. Finally the produced water is electrolyzed to generate hydrogen and oxygen which can be consumed by astronaut breathing again. Although the recycling system seems to be suitable for ISS operation, the gravity effect must be considered in each process, especially for water electrolysis.

The gas evolving electrode under microgravity condition has been examined by spaceship [5,6], parabolic flight [7,8] and drop tower [9–13]. The gas bubbles hardly detach from the electrode surface due to very weak buoyancy force. They shield the active surface area (surface coverage effect) and increase the ohmic resistance between the electrodes (void fraction effect). Moreover, no pumping effect caused by upward moving gas bubbles is expected in microgravity environment, although many important technological improvements have been completed to unconsciously utilize such an effect in the industrial electrolysis process [14]. Thus, the many disadvantage factors should be solved for realizing the smooth electrolysis operation in space.

Kyoto University group has reported that the microscopic convection makes the long-term water electrolysis possible even in drop tower microgravity duration over 8 s. The convection is induced by the interfacial surface tension. For example, the differential concentration [15] and temperature [16–19] around the gas bubble cause the tiny capillary convection. Moreover, the bubble motion accompanied with bubble coalescence is also well known to induce the microscopic convection [20–23]. Therefore, a deeper understanding of the gas evolution in microgravity can help a rational design strategy for the water electrolysis cells in space.

In this paper, water electrolysis in aqueous solutions under microgravity realized by the drop tower is operated and the transient behavior of current density and gas bubble evolution are

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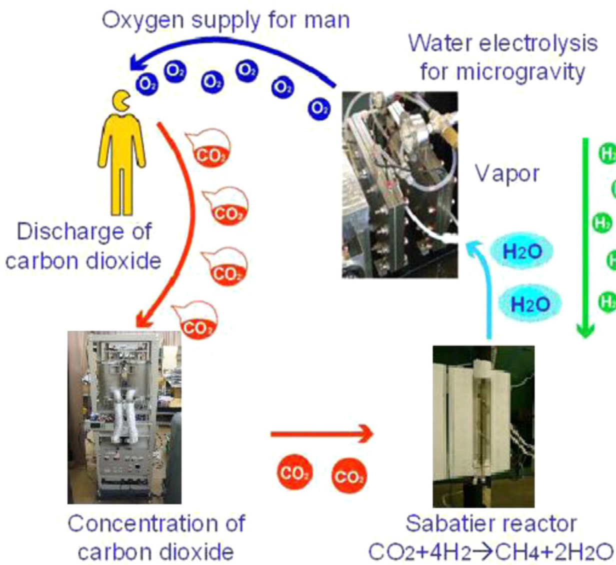

Fig. 1. Conceptual model of air revitalization system in space.

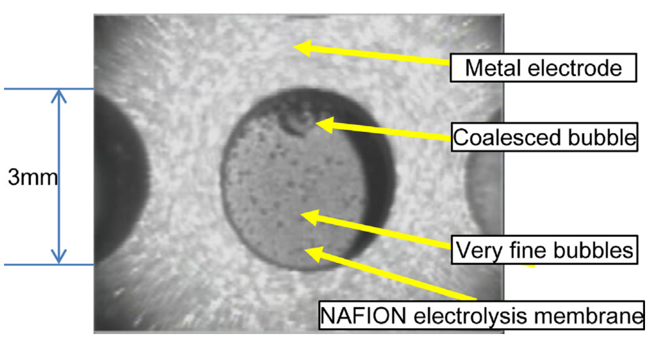

Fig. 2. High-speed camera image of gas evolution generated at PEM assembly.

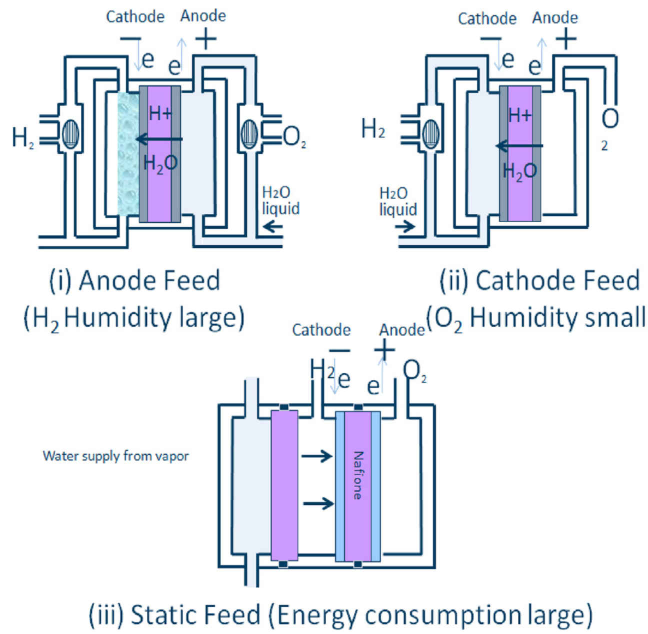

Fig. 3. Schematic overview drawing of SPE water electrolysis system with different types of water supply method.

investigated in order to propose a suitable electrolysis system without a liquid/gas separation problem.

2. Experimental

2.1. Electrolysis in solid polymer electrolyte (SPE)

The cathode feed water electrolysis unit was prepared by Daiki Ataka Engineering Co. Ltd. It was 10 cells stack, and each cell had 64 cm^2 catalyst area. Proton conducting membrane was used as the electrolyte. The water supplied for the electrolysis was 1 L min^{-1},

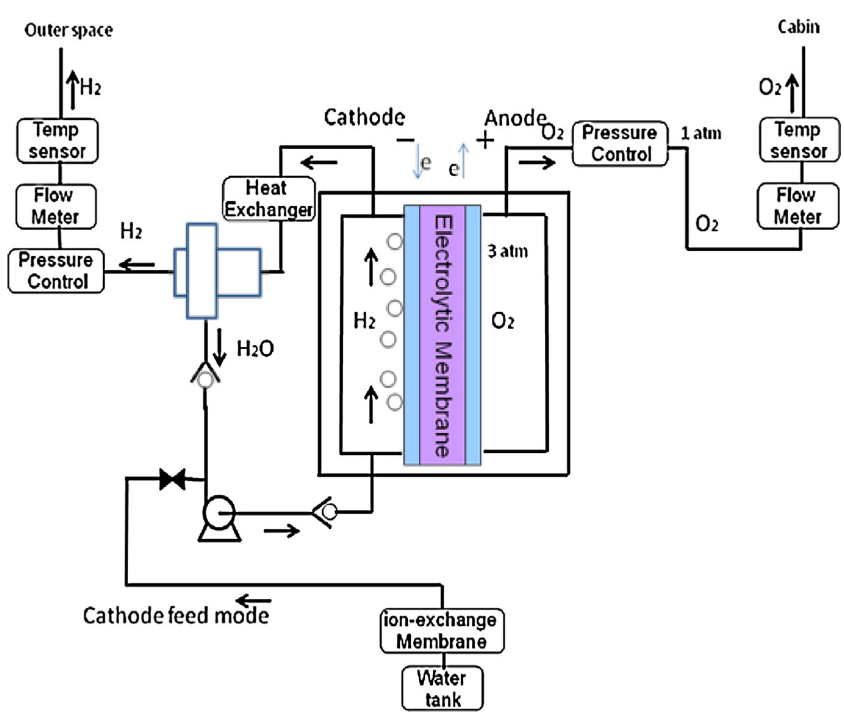

Fig. 4. Flow diagram of cathode feed SPE water electrolysis.