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Hydrogen permeation characteristics of plate-type plasma membrane reactor

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1. Introduction

In recent years, climate change is a problem, and the reduction of greenhouse gases which is one of the causes is demanded. Therefore, hydrogen has been attracting attention as a clean energy in the environment, but there is a problem that hydrogen produces a large energy loss when transporting and storing. In order to solve this problem, our laboratory is conducting research to use ammonia, which is easy to transport and store, as a hydrogen carrier[1)]. We have developed cylindrical plasma membrane reactor (PMR) to produce high purity hydrogen from ammonia. Ammonia is decomposed by atmospheric pressure plasma treatment inside the PMR to generate protons. High purity hydrogen is produced by separating protons using a hydrogen separation membrane incorporated in the PMR. The purity of the obtained hydrogen has reached a level that can be supplied to the fuel cell. However, since the gas flow in the PMR is not uniform, the plasma lighting state is unstable. Therefore, the hydrogen purification flow rate per unit time is very low. In this research, we developed a plate-type plasma membrane reactor with a flow channel to reduce costs for producing high purity hydrogen from ammonia and investigated hydrogen permeation characteristics.

2. Experimental

Figure 1 shows the experimental setup. The experimental apparatus consists of a gas supply system, a high-voltage pulse power supply, the plate-type PMR, a heating device, H_2 separated pump, H_2 sensor, and a soap film flow meter. Figure 2 shows the structure of the plate-type PMR. The plate-type PMR has a layered structure combining several parts. The plate-type PMR is consist of a high voltage electrode (SUS mesh sheet), a dielectric layer (quartz plate), a metal plate with a flow channel (SUS316, width 1 mm, gap length 4.5 mm, full length 1010 mm), a hydrogen separation membrane layer (Pd-Cu 40 % alloy), a ground electrode (SUS316), a support of the hydrogen separation membrane (SUS316), a spacer (SUS316), a plate with separated gas flow channel (SUS316). The sample gas was used 100% H_2. The gas flow rates of the sample gas were adjusted with a mass flow controller and supplied to the plate-type PMR. Atmospheric pressure plasma was generated by dielectric barrier discharge using a pulse power supply. The heating device was used to keep the temperature of the plate-type PMR during the hydrogen permeation test. The pulse repetition rate (R_R) was fixed at 10 kHz. The pressure on the permeable side was fixed at -100 kPa. The applied voltage was adjusted from 0 to 18 kV. The heating temperature was varied from 150 to 300 °C.

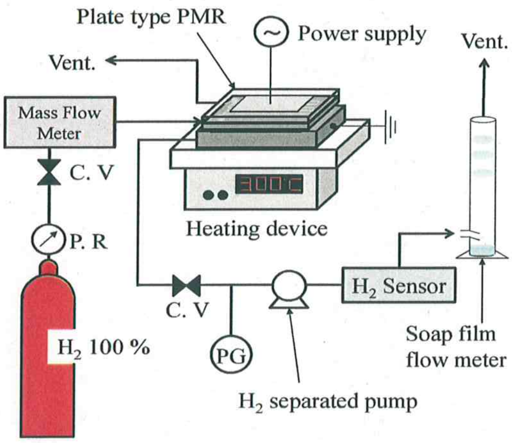

Fig.1 Experimental setup for H_2 permeation

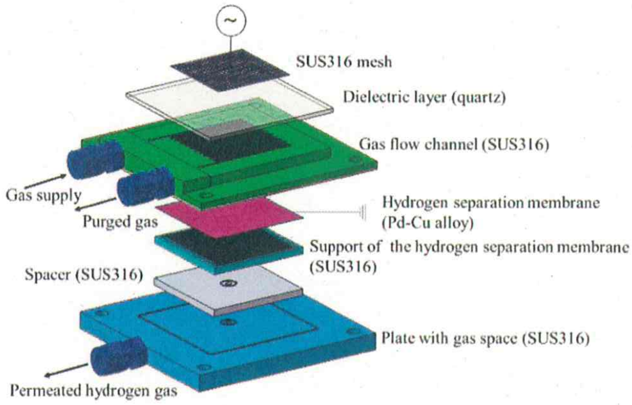

Fig.2 Configuration of the plate-type PMR

3. Results and discussion

Fig. 3 shows the effects of applied voltage on hydrogen permeation. In this experiment, it was revealed that hydrogen permeation is promoted by plasma firing, and the hydrogen permeability increases with the increase of the applied voltage. On the other hand, the hydrogen permeability increased greatly with the increase of the heating temperature. It is considered that the increase of the heating temperature promoted the dissociation of hydrogen molecules into H radicals. Two types of hydrogen separation membranes (thickness of 15 μm or 20 μm) were used in the H_2 permeation experiments to investigate the effect of membrane thickness on hydrogen permeability. The hydrogen permeability increased as the membrane thickness was reduced. It has been reported that the hydrogen permeation flux was inversely proportional to the membrane (2). While it was found that fluctuation of applied voltage greatly contributes to fluctuation of hydrogen permeability when the separation film thickness becomes thin. Maximum hydrogen permeability of 99.3% was obtained under the conditions of a heating temperature of 250 °C, membrane thickness of 15 μm, and an applied voltage of 16 kV.

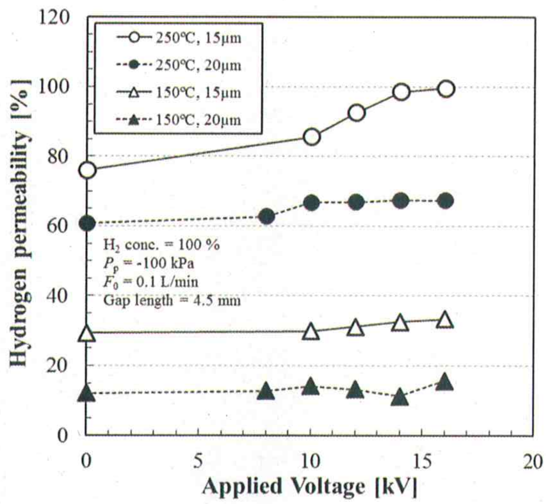

Fig.3 Effects of applied voltage on H_2 permeation

4. References

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