Plasma membrane packed bed reactor for hydrogen production from ammonia

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1. Introduction

Ammonia is a promising zero-carbon energy source because of its easy liquefaction, high energy density, and well-established transportation and storage systems. Ammonia production emit CO_2, but the generated CO_2 can be reduced from 65% to 99%, a process referred to as "blue ammonia." To achieve carbon neutrality by 2050, Japan has begun using "blue ammonia" as a fuel for power generation and ship engines. In the industrial field, there is a need for technology to produce hydrogen from ammonia. However, ammonia cracking catalysts cannot convert ammonia into pure hydrogen for fuel cells.

The plasma membrane packed bed reactor (PMR) has been developed to efficiently separate hydrogen and to completely decompose any unreacted ammonia in the catalysis reactor. Details on the research and development of the PMR will be presented.

2. Experimental

Figure 1 shows the detailed configuration of the experimental apparatus for pure hydrogen production[1]. The ammonia cracking catalyst was made by 5%Ru and zeolite particles[2], which was ammonia decomposition of 99.5% at the temperature of 450ºC. The PMR consists of a cylindrical hydrogen separation membrane module coaxially arranged in a quartz tube with an outer diameter of 42 mm, a thickness of 2 mm, and a length of 400 mm. The hydrogen separation membrane is a Pd-40%Cu alloy with a thickness of 20 µm, and the membrane is welded onto a cylindrical metal support, which also serves as a ground electrode. The high-voltage electrode is made of stainless steel (SUS 304), which is 300 mm in length and 0.2 mm in thickness. It is wrapped around the surface of the outer glass tube.

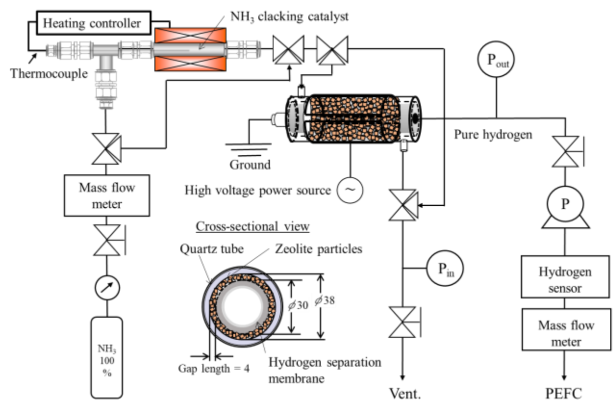

Figure1 Experimental setup for investigating hydrogen separation performance of the PMR.

The gap length is 4 mm. The plasma is generated between the inner surface of the quartz tube and the surface of the hydrogen separation membrane. The gap space is filled with zeolite to generate stable plasma at a pressure of 0.3 MPa. A vacuum pump was placed at the outlet of the hydrogen separation membrane to collect the separated pure hydrogen and measure the flow rate.

3. Results and discussion

Fig. 2 shows the separated hydrogen flow rate with plasma (plots) and without plasma (dot line) at the variation of the reactor surface temperature. Clearly, the system using the PMR have good performance compared with the no plasma system. This is because the PMR generates much H radicals.

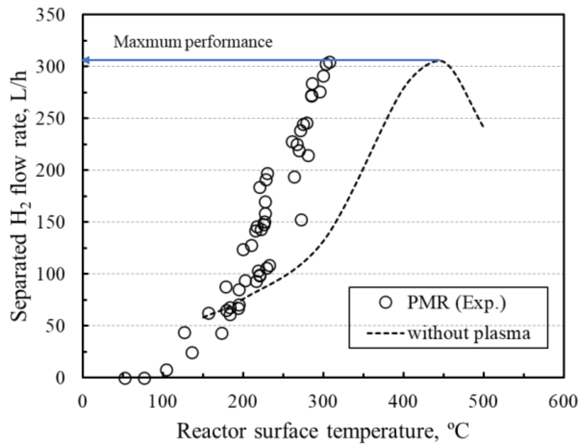

Figure 2 Performance of hydrogen separation with and without plasma (Inlet total pressure: 300 kPaG).

4. Conclusion

The greatest advantage of the PMR is the ability to maximize the performance of the hydrogen separation membrane (Pd-40%Cu) at low pressure and temperature. Another advantage is that unreacted ammonia can be almost all decomposed by the plasma. Maximum H_2 flow rate was 304.2 L/h at 300 kPaG, which was corresponded to the maximum flow rate of the membrane.

References

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[2] Mostafa El-Shafie, S. Kambara, Y. Hayakawa, Catalysis Today, 397–399, pp. 103-112, 2022.