Carbon membranes for ammonia decomposition in membrane reactors

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Introduction

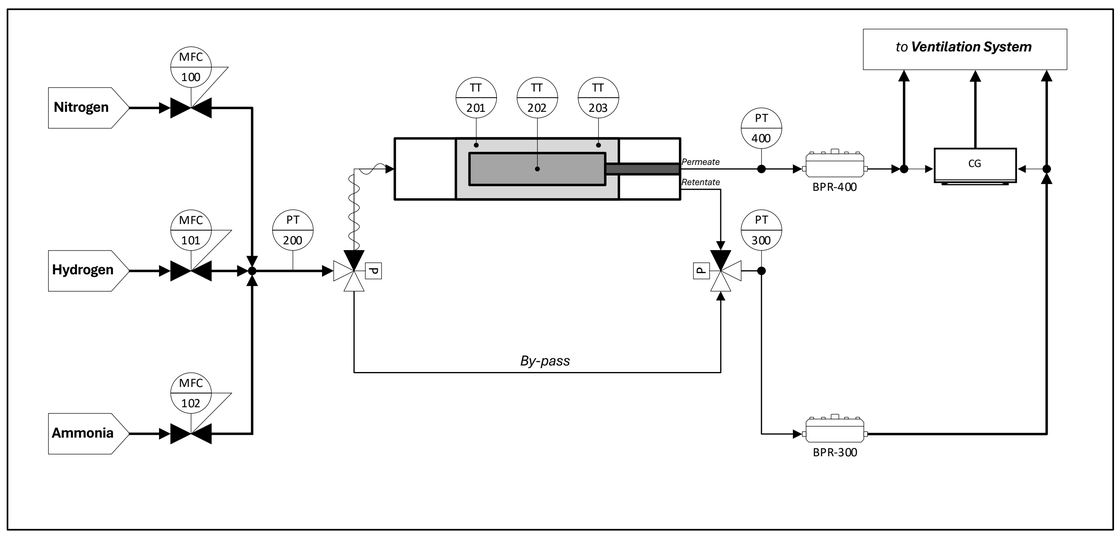
Hydrogen (H_2) is a clean energy carrier with the potential to replace fossil fuels and support decarbonization. However, while renewable routes for H_2 production are available, challenges in H_2 storage and distribution must still be addressed. Green ammonia (NH_3) can serve as sustainable H_2 carrier, allowing on-site production and easier storage. This study investigates the integration of carbon membranes with a commercial Ru-based catalyst for ammonia decomposition, aiming to produce ultrapure H_2 suitable for proton exchange membrane fuel cells.

Membrane fabrication

The membrane employed in this work was prepared as follow:

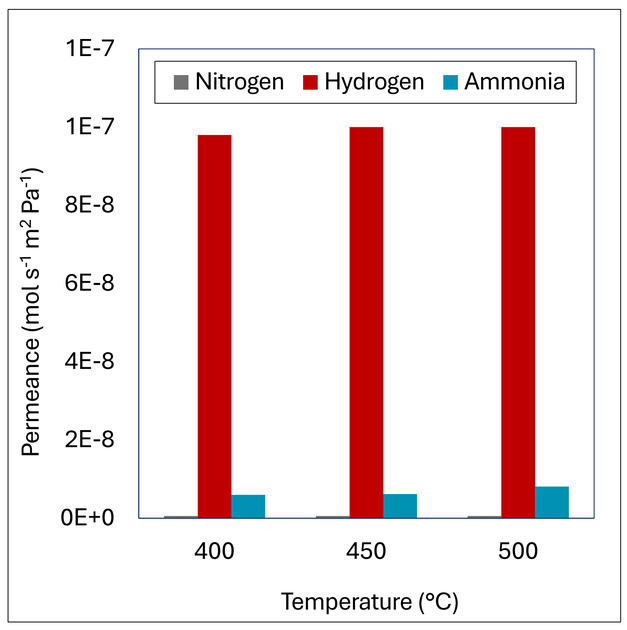
- Ceramic support preparation (I.D. 7 mm, O.D. 10 mm);
- Polymeric precursor synthesis (C_6H_6O/CH_2O = 0.8, time 8 h);
- Dipping solution preparation;
- Dip coating (Speed up/down 10 mm · s^{-1}, waiting time 20 s)
- Rotary drying and polymerization (80ºC, 24 h);
- Carbonization (N_2, 2ºC · min^{-1}, 800ºC, 4 h).

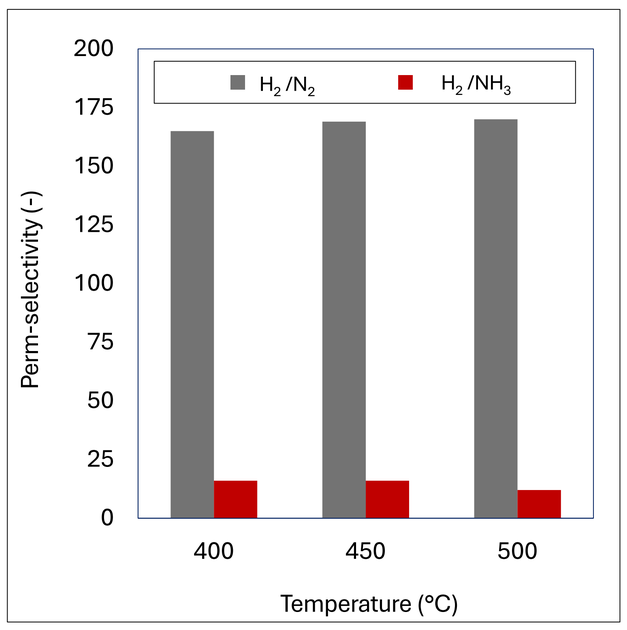
Experimental setup

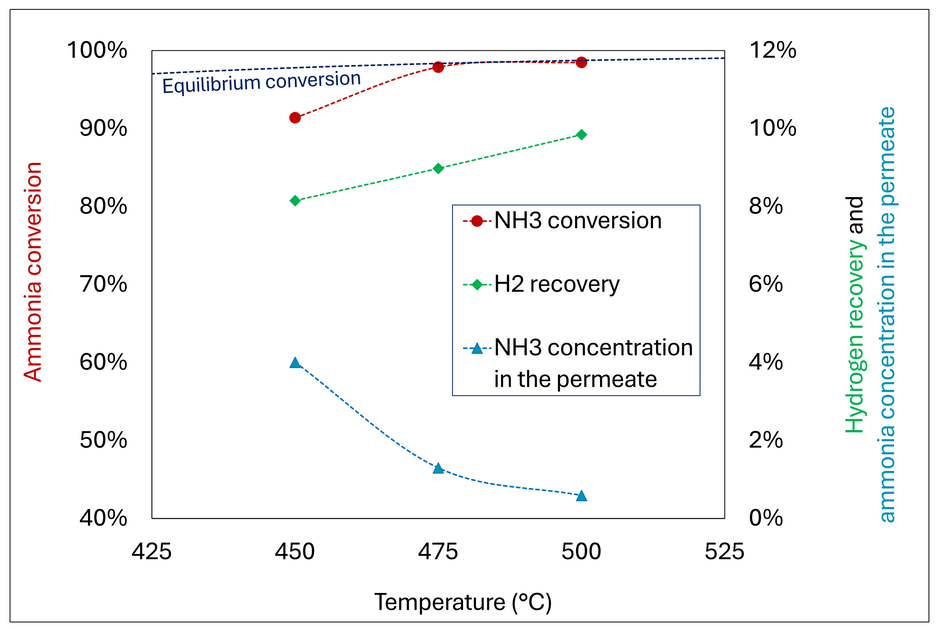


Results

Based on the single gas permeation test, the fabricated carbon membrane exhibited a H_2 permeance approximately 12 times higher than that of NH_3 (500ºC, 1 bar). According to the reaction tests for ammonia decomposition, ammonia conversion exceeded 90% under all operating conditions, approaching thermodynamic equilibrium at temperatures starting from 475ºC. H_2 recovery through the carbon membrane ranged from 8.2% to 9.8% in the temperature range of 450 to 500ºC.







Conclusions and Outlooks

- Carbon membrane for hydrogen separation was prepared without the addition of expensive metals (i.e. Pd, Ag);
- The fabricated membrane was tested in a membrane reactor, coupled with a commercial Ru-based catalyst, achieving more than 98% ammonia conversion and less than 1% of ammonia in the permeate stream (5 bar, 475ºC);
- Ultra-pure hydrogen (NH_3 in the permeate stream below 0.1 ppm) can be obtained in combination with adsorbent materials.

[1] Cechetto V., Anello G., Rahimalimamaghani A., Gallucci F., Carbon Molecular Sieve Membrane Reactors for Ammonia Cracking. Processes. 2024, 12(6), 1168. DOI: 10.3390/pr12061168

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