Delivering clean hydrogen fuel from ammonia using metal membranes

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Renewable Ammonia Export

Power generation: Combustion (internal combustion engine or turbine)
Power generation: Direct conversion (High-temperature fuel cell)
H₂ production: Decomposition and H₂ purification
Hybrid H₂ and power systems

Solar PV
Wind

Electrolysis
Air separation

H₂
N₂

NH₃ synthesis

Transport to Asia
Ammonia decomposition

ISO14687-3 (stationary):
50% non-H₂ species, 100 ppbv NH₃

ISO14687-2 (mobile):
300 ppmv non-H₂ species, 100 ppbv NH₃

100 ppbv NH₃ = 99.99998% conversion

* Use a scrubber or membrane or both
Vanadium-based membranes for H₂ purification

Our design philosophy:
• Minimise materials costs (minimise use of palladium)
• Use scalable manufacturing techniques (metal tube extrusion and electroplating)
• Prioritise purity over flux (to meet ISO14687 for PEM fuel cells)
CSIRO’s membrane technology

10 mm diameter
0.2 mm thick
500 mm long
Self-supporting (no porous support structure which minimises cost)

Catalytic coating

Multi-tube module
Cracking system configuration

NH₃ → catalyst → Cracked NH₃ → membrane → N₂ + NH₃ + H₂

450-500°C

1.5mm diam. granular catalyst: 0.5 wt% Ru layer on Al₂O₃ support

500 mm membrane
Single-tube prototype

NH₃ conversion (150g catalyst loading, 450°C, 5 bar(a) with downstream membrane)

Near-equilibrium NH₃ conversion at 450°C

NH₃ decomposition rate is inhibited by H₂ ($P_{H₂}^{-0.42}$)
Single-tube prototype

$\text{H}_2$ flux and recovery (150g catalyst loading, 450°C, 5 bar(a) with downstream membrane)

$\text{H}_2$ production rate is inversely proportional to $\text{H}_2$ recovery

Can vary yield/flux for specific applications:
- Stand-alone with waste heat
- Stand-alone with self-heating
- Hybrid cracker/combustion
Single-tube prototype

H₂ flux and recovery (5.0 slpm NH₃, 150g catalyst loading at 450°C with membrane)

- Stable performance over 80 hours at 80% total H recovery
- Energy content of retentate ≈ enthalpy requirement for cracking
Single-tube prototype

Mass spectrum of permeate stream with different feed gas compositions

No enrichment of N₂ or NH₃ in H₂ permeate during NH₃ cracking: ISO14687 met
Multi-tube pilot plant

- Membrane area 0.3 m² (19 x 50 cm tubes ≈ 120 slpm ≈ 15 kg/day at 80% yield)
- H₂ to be compressed and dispensed into FCEVs in Australia
Summary

• Australia is at the forefront of renewable ammonia export
• CSIRO’s technology can deliver FCEV-grade $\text{H}_2$ from ammonia
• We’re rapidly scaling this technology towards to 15 kg $\text{H}_2$ per day and beyond, with demonstrations planned in Australia and Asia

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