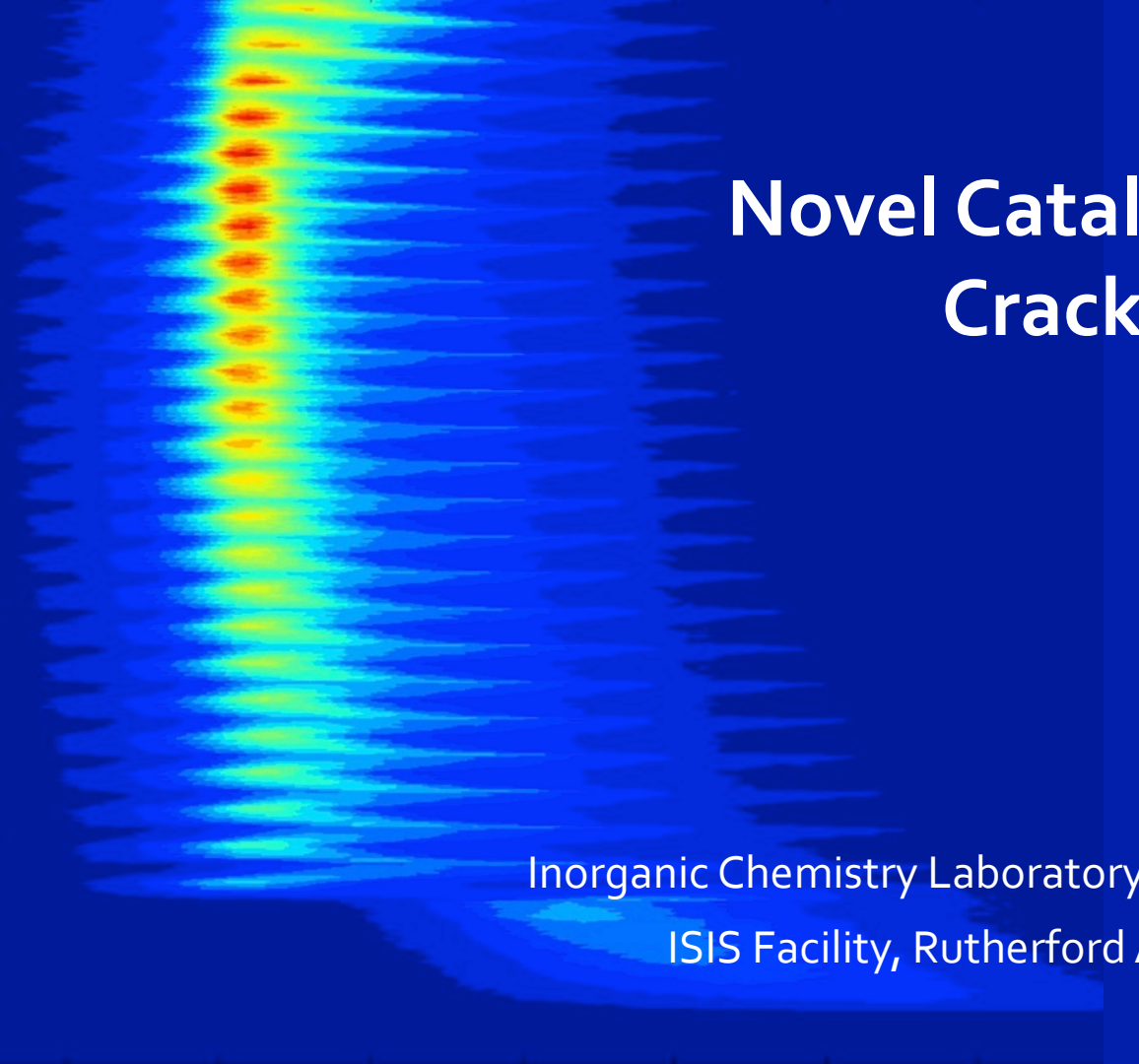

Novel Catalysts for Ammonia Cracking and Synthesis

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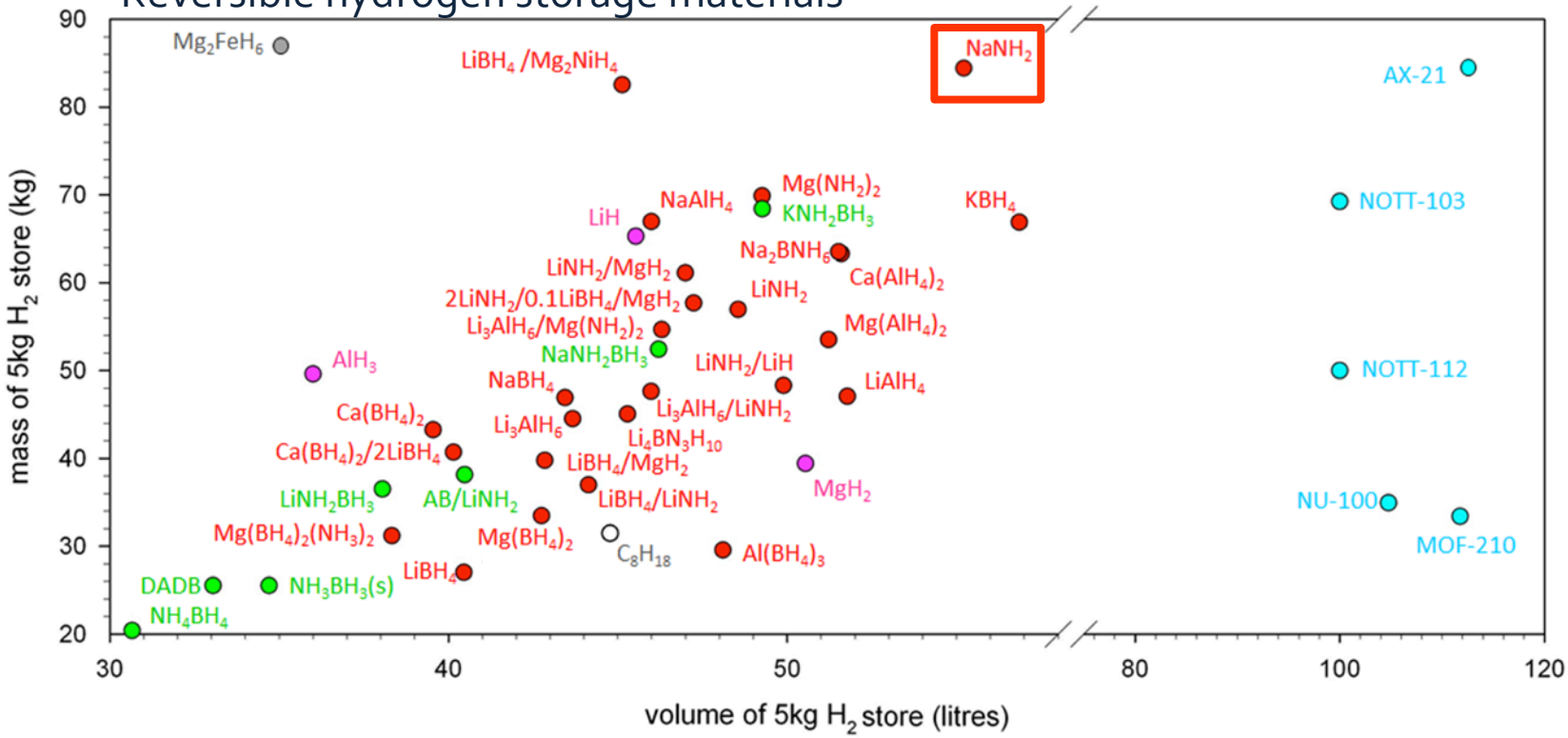
… storing hydrogen is a challenge

Reversible hydrogen storage materials



W I F David, Faraday Discuss., 2011, 151, 399–414

NH_3 | high density liquid hydrogen storage

$Na + 1/2\ H_2 \rightarrow NaH$	$\Delta H = -56.3\ kJmol^{-1}$	$>600°C$
$Na + NH_3 \rightarrow NaNH_2 + 1/2\ H_2$	$\Delta H = -77.9\ kJmol^{-1}$	$-33°C$

$$2Na + 2NH_3 \rightarrow 2NaNH_2 + H_2$$

Decomposes to the elements (~400°C) $2NaNH_2 \rightarrow 2Na + N_2 + 2H_2$ 5.4wt%

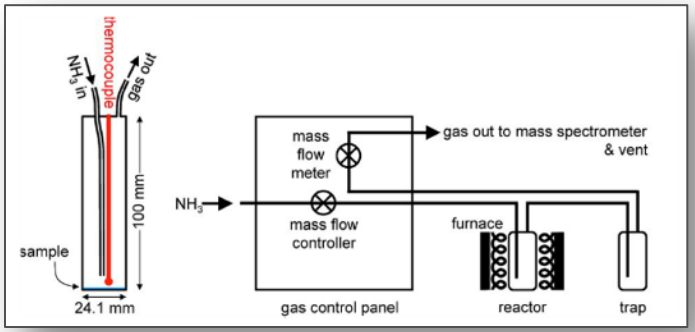
$$2NH_3 + 2Na \rightarrow 2NaNH_2 + H_2 \rightarrow N_2 + 3H_2 + 2Na$$

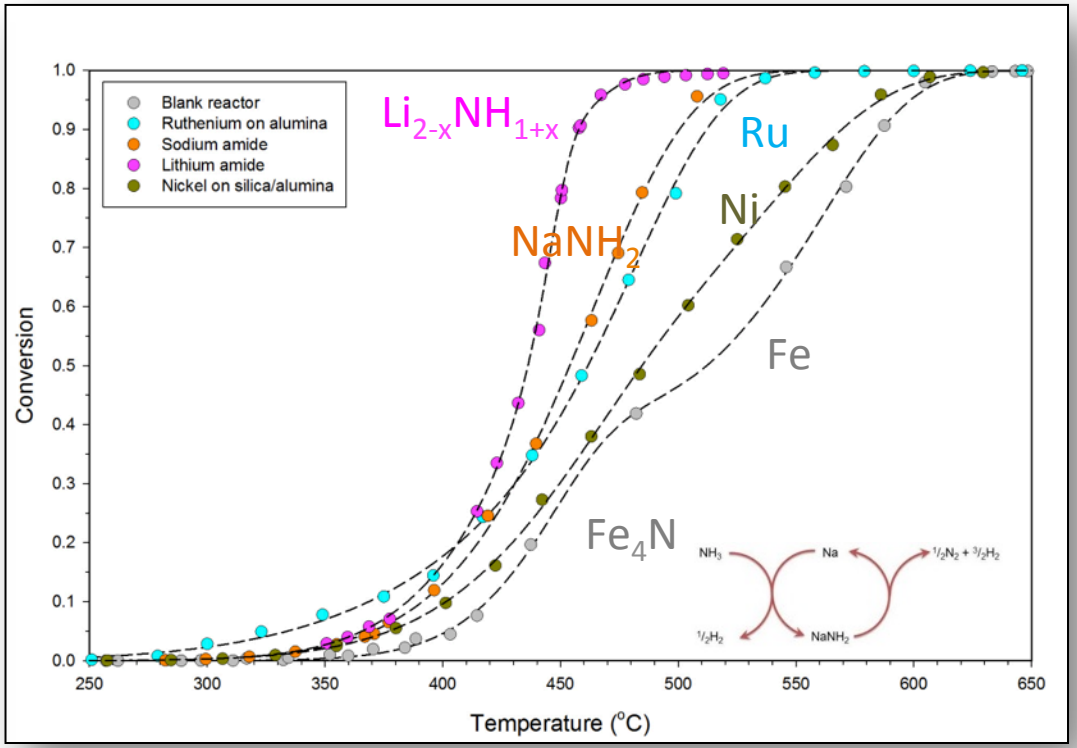
~400°C?

Under flowing ammonia … $Na/NaNH_2\ (\ell)$

$$2NH_3\ (g) \rightarrow N_2\ (g) + 3H_2\ (g)$$ 17.6wt%

Hydrogen production from ammonia using sodium amide

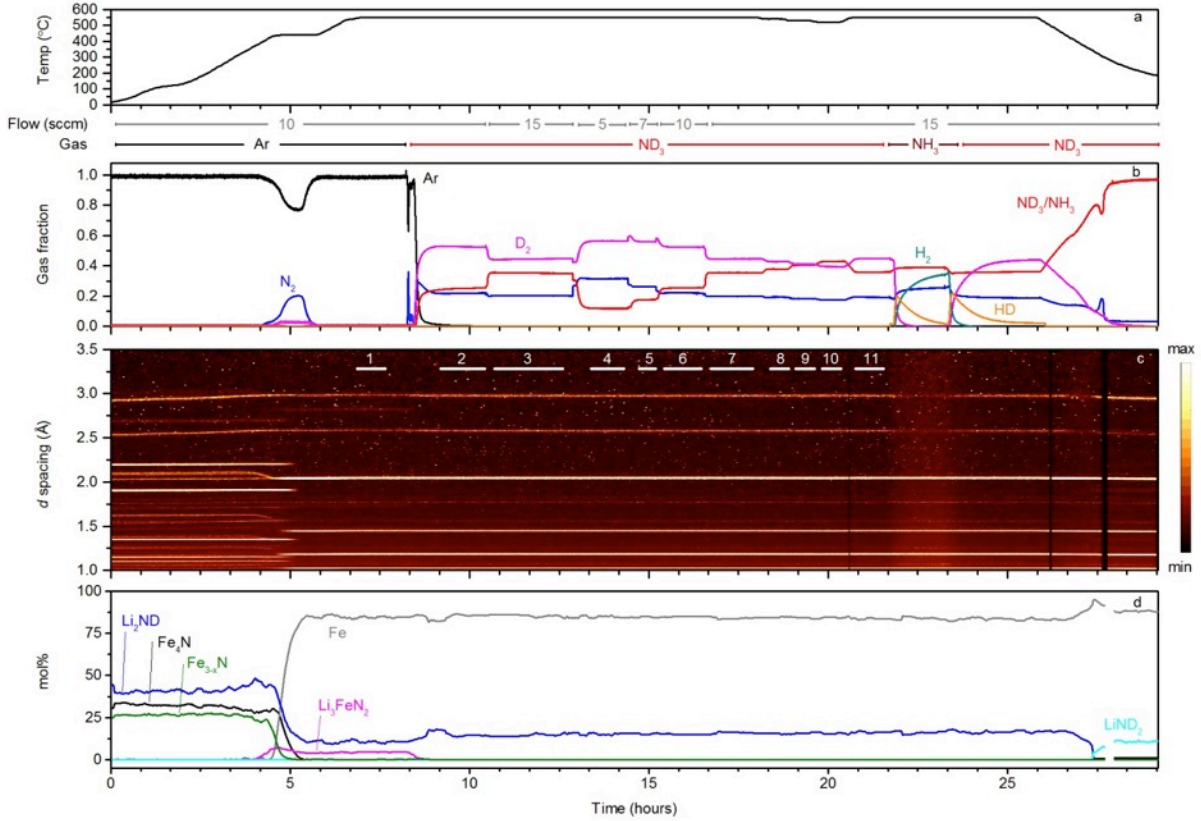


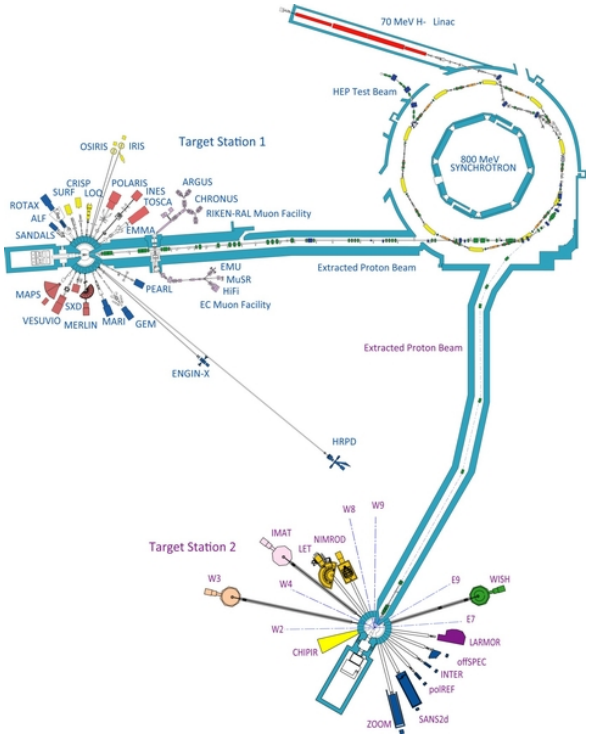


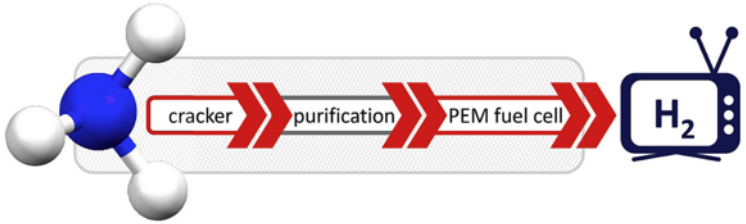
JW Makepeace *et al.*, **Chem. Sci. 2015** 6(7) 3805-3815

WIF David *et al.*, **J. Am. Chem. Soc., 2014,** 136 (38), 13082–13085

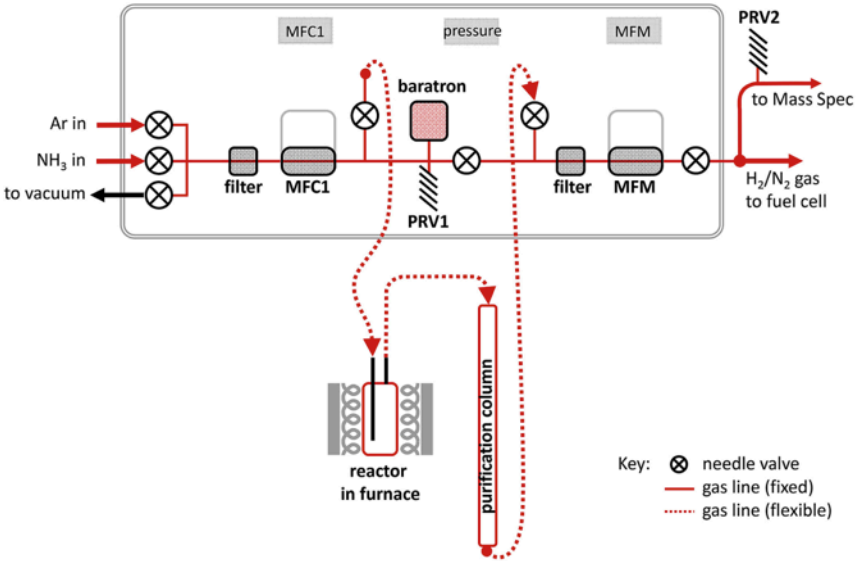
$Li_2NH:Fe_xN$ | in-situ neutron powder diffraction measurements

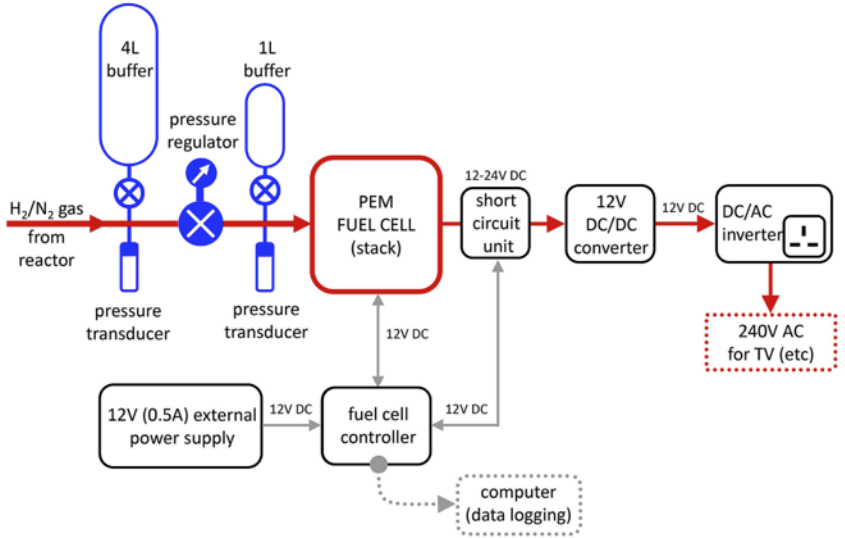






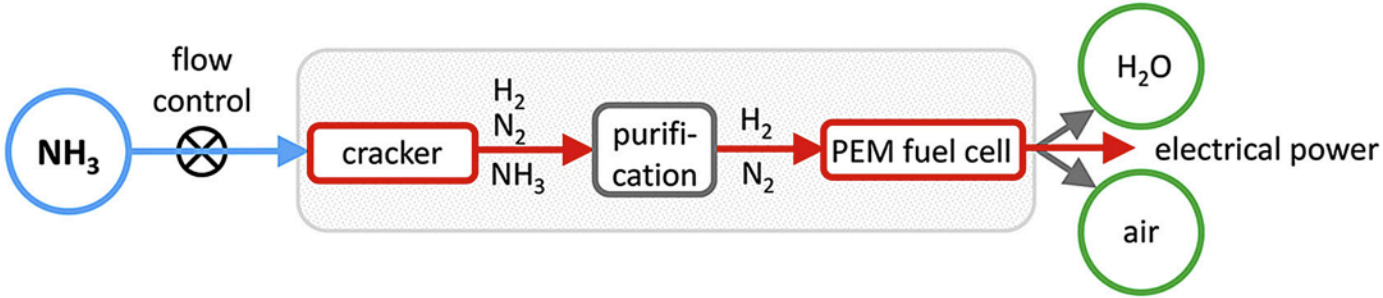
Demonstrating hydrogen production from ammonia using lithium imide - Powering a small proton exchange membrane fuel cell.

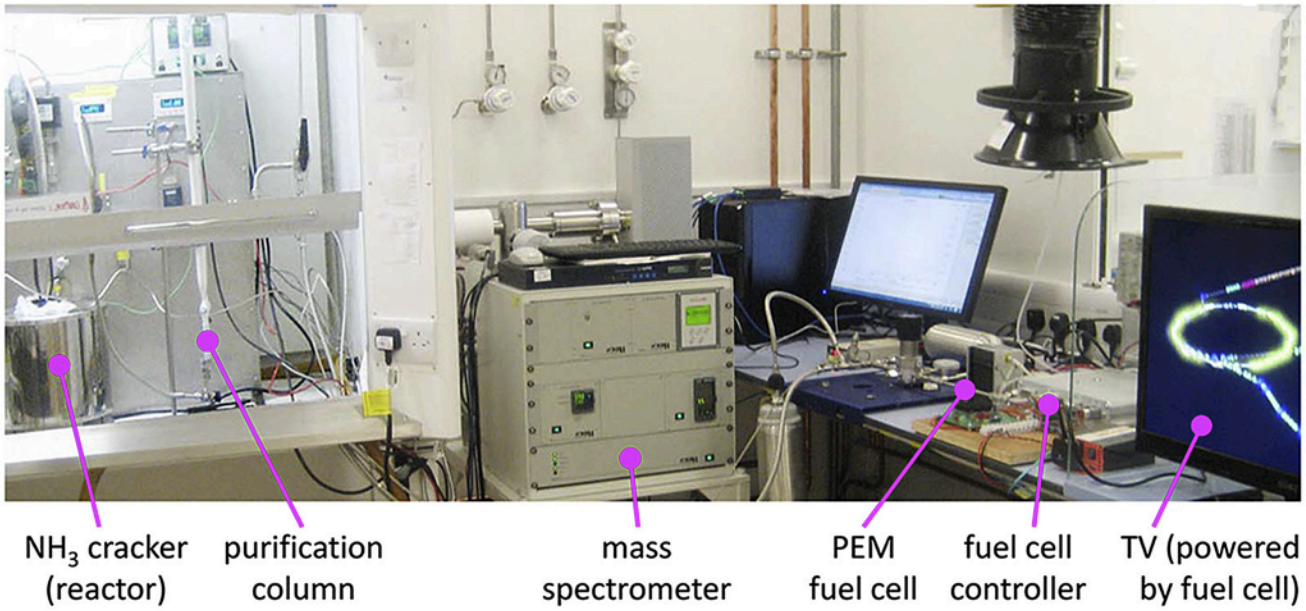




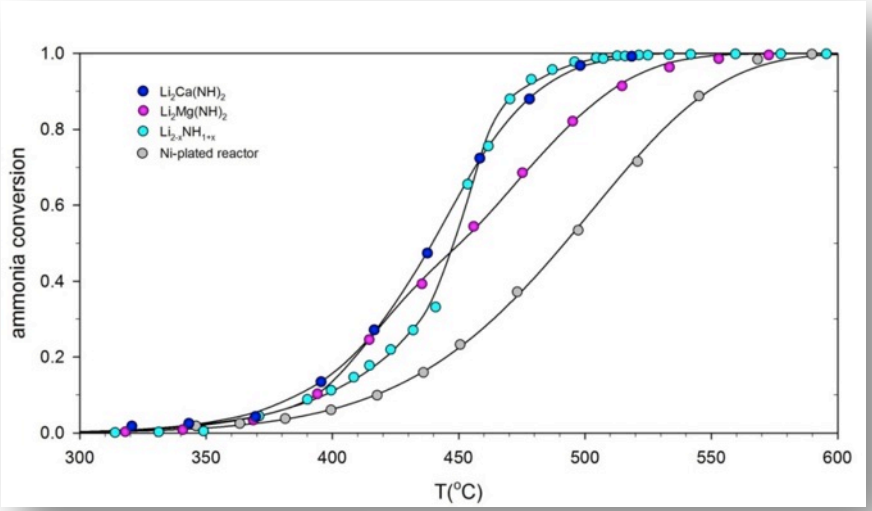
Hunter et al. Journal of Power Sources, Vol. 329, 15.10.2016, p. 138-147

Demonstrating hydrogen production from NH_3 using Li_2NH | Powering a small PEM fuel cell





Scale-up demonstrator



reactor volume | 21cm^3

0.5g $Li_{2-x}NH_{1+x}$

300sccm NH_3

450sccm H_2 | 45W

Next step: 1.0kW(nett) PEM

1.5kW(gross) ≡ 10l/m NH_3(g)

10l NH_3(g) ≡ 0.4mol | 7.5gm | 12.5cm^3 NH_3(l)

NH_3 heat capacity

ΔT ≈ 500K | power required

P ≈ 500 × 42.5 × 0.4 / 60 ≈ 140W ≈ 9%

c.f. ~15% energy loss for 750 H_2 tanks from compression (Eberle et al., *Angew. Chem. Int. Ed.* 2009, 48, 6608 – 6630)

Acknowledgements

- Josh Makepeace

- Martin Jones
- Tom Wood
- Hazel Hunter
- Ron Smith
- Mark Kibble

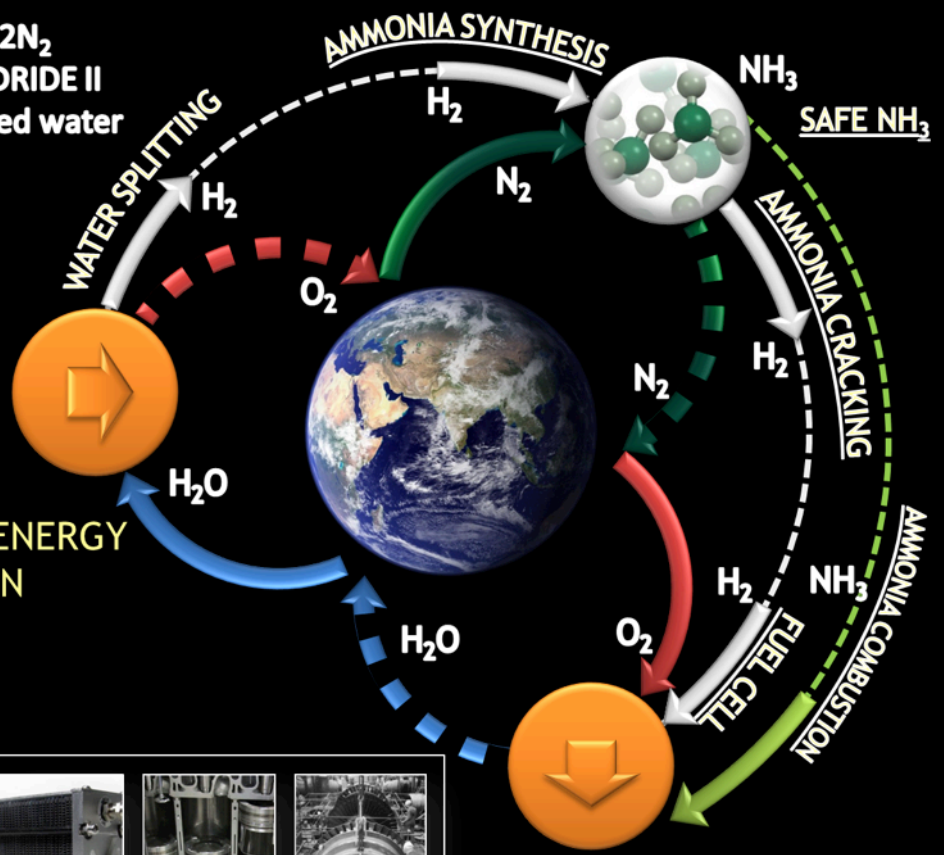
- Claire Murray
- Chiu Tang

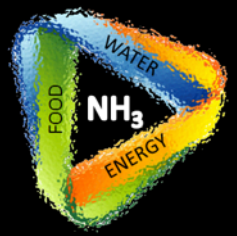
- Christina Dräthen

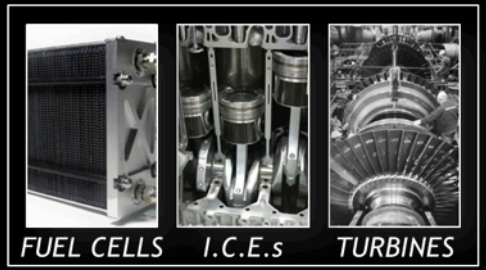
$4NH_3 + 3O_2 \leftrightarrow 6H_20 + 2N_2$

AIR HYDRIDE I ↔ AIR HYDRIDE II

water ↔ energised water







THE WATER : AMMONIA CYCLE