

Benchmarking of H₂ selective membranes

J. Boon **(ECN)**

J.A.Z. Pieterse **(ECN)**

J.W. Dijkstra **(ECN)**

M. van Sint Annaland **(TU/e)**

September 2013

ECN-L--13-065



Benchmarking of H₂ selective membranes

Jurriaan Boon, J.A.Z. Pieterse,
J.W. Dijkstra, M. van Sint Annaland

5th World Hydrogen Technologies Convention
(WHTC2013), Shanghai, China
27 September, 2013

‘Whoever wishes to foresee the
future must consult the past’

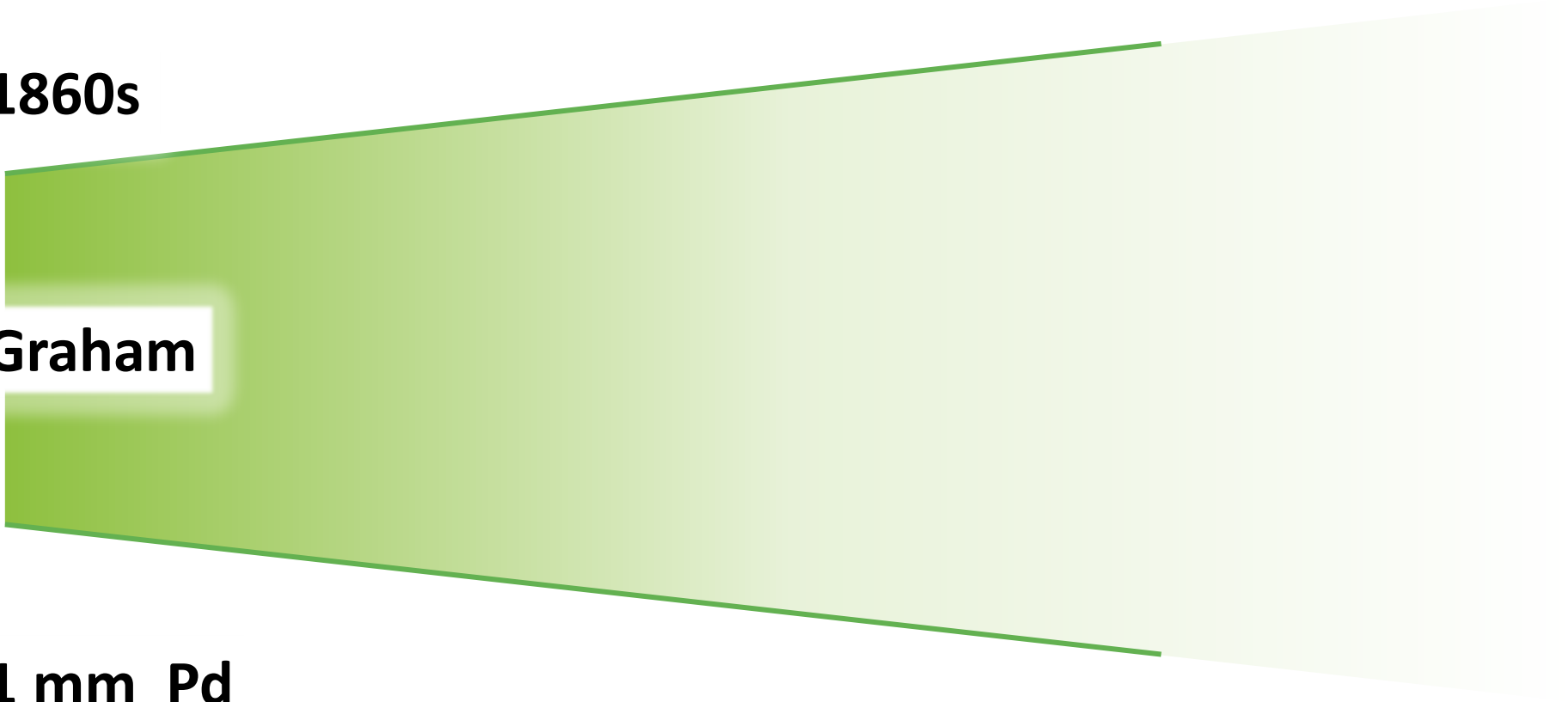
Niccolò Machiavelli, 1513

H₂ selective membranes

1860s

Graham

1 mm Pd



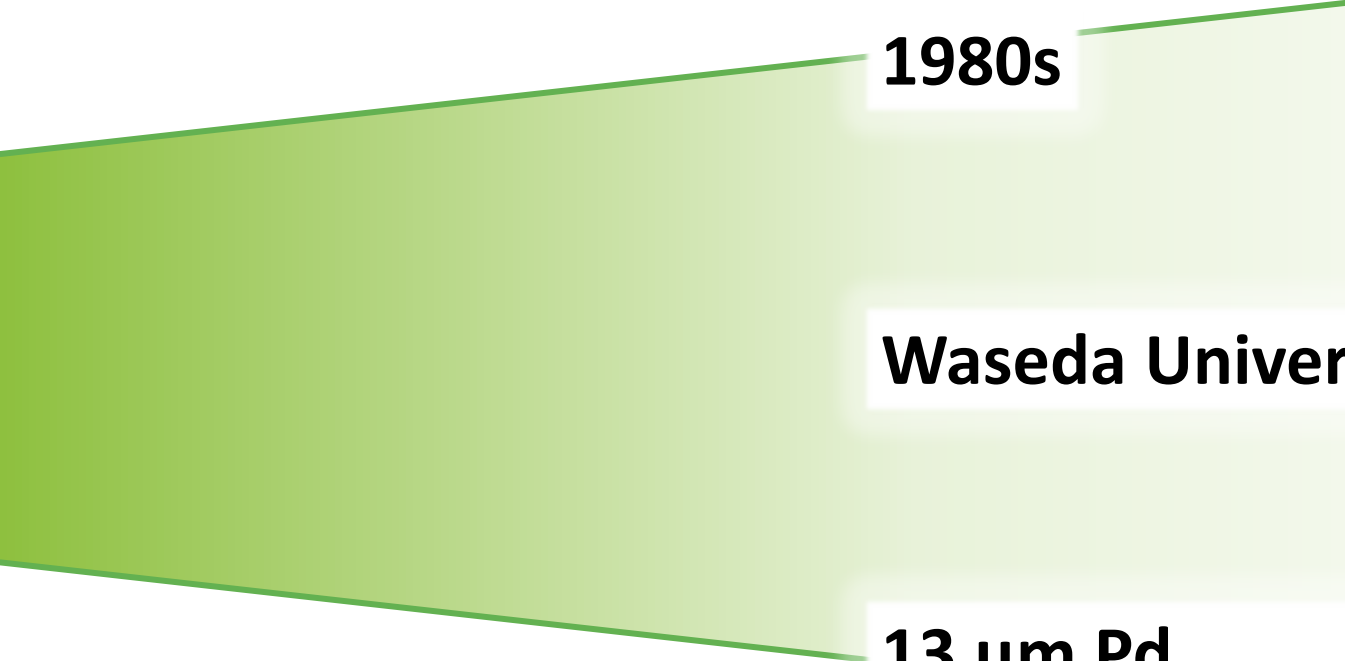
H₂ selective membranes

1950s

**Johnson Matthey
Research Laboratories**

**0.25 mm
Pd tube**

H₂ selective membranes



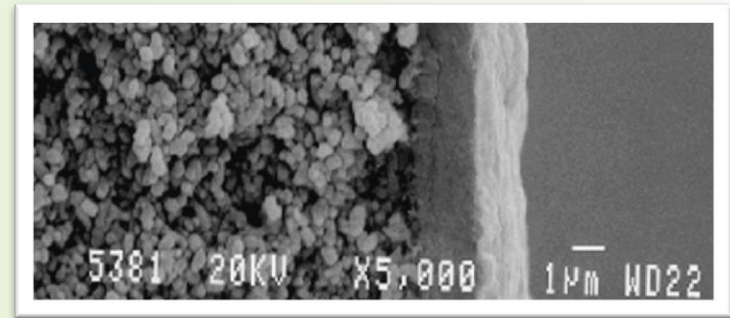
1980s

Waseda University

**13 μm Pd
porous glass tube**

H₂ selective membranes

2000s



**µm-size Pd
porous support**

H₂ selective membranes

2010s

第五届世界氢能技术大会



Benchmarking performance:
a crucial step for the further
development of the technology.

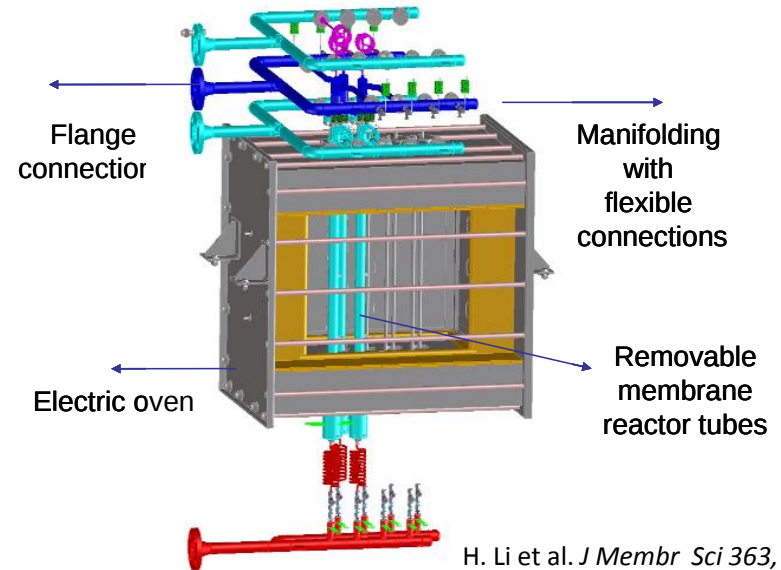
Experimental programme

- H₂ from reformat
 - NGCC with CO₂ capture
400°C 30 / 20 bar ~ 50% H₂ in H₂O, CO₂, CO, ...
 - H₂ production with CO₂ capture
430°C 30 / 5 bar ~ 50% H₂ in H₂O, CO₂, CO, ...
- Obtained membranes from 5 commercial vendors worldwide
- Experiments with tubular Pd-based membranes
300-600 cm², up to 1500 hours on stream

Experimental programme



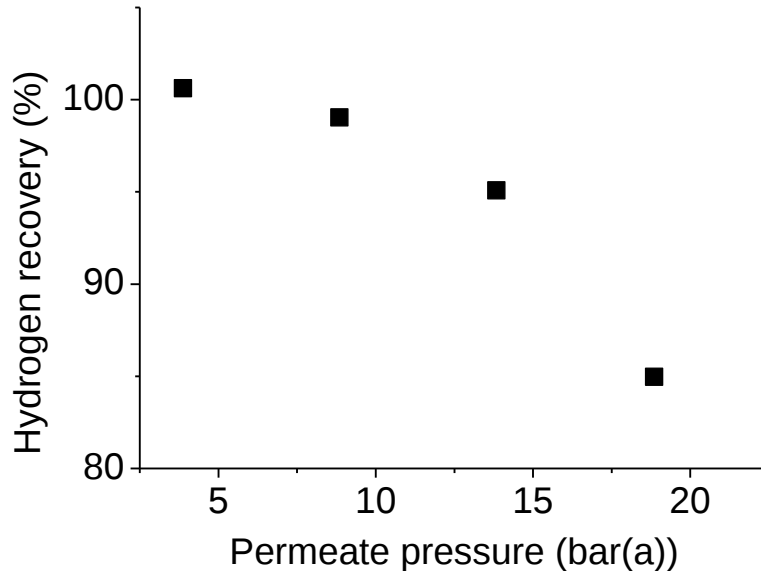
MEMCAP Process Development Unit



H. Li et al. *J Membr Sci* 363, 1-2:
204-211, 2010.

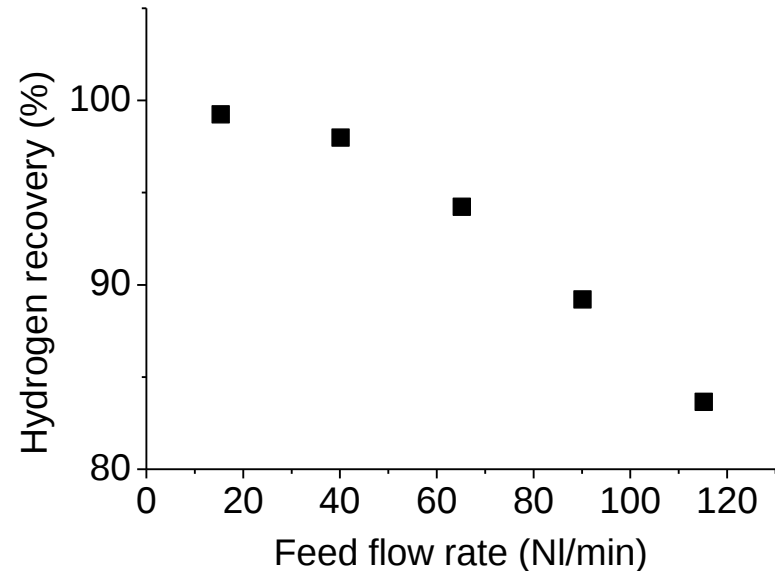
Experimental results

CASE: NGCC with CO₂ capture
400°C 30 / 3-20 bar



- Recovery > 95% for permeate pressure < 15 bar(a)

CASE: H₂ production with CO₂ capture
430°C 30 / 5 bar

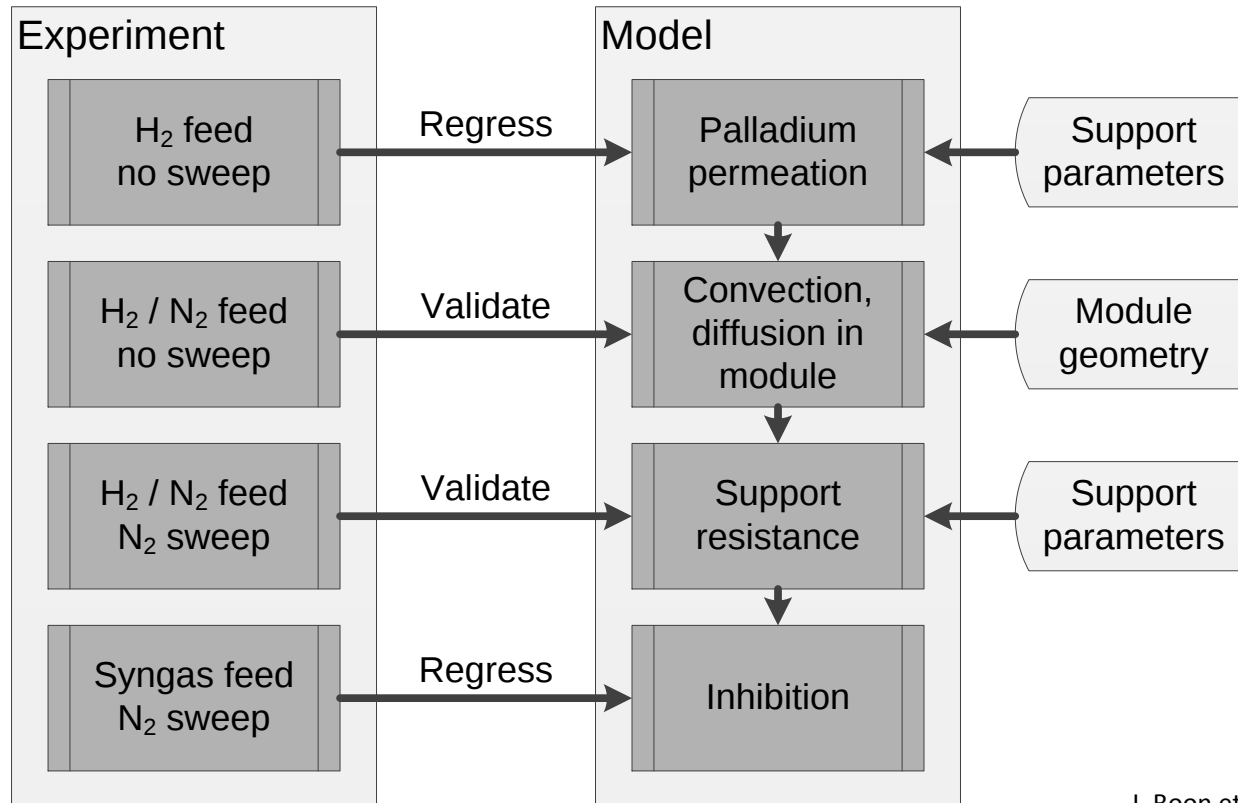


- Recovery > 95% for feed flow < 50 NI/min

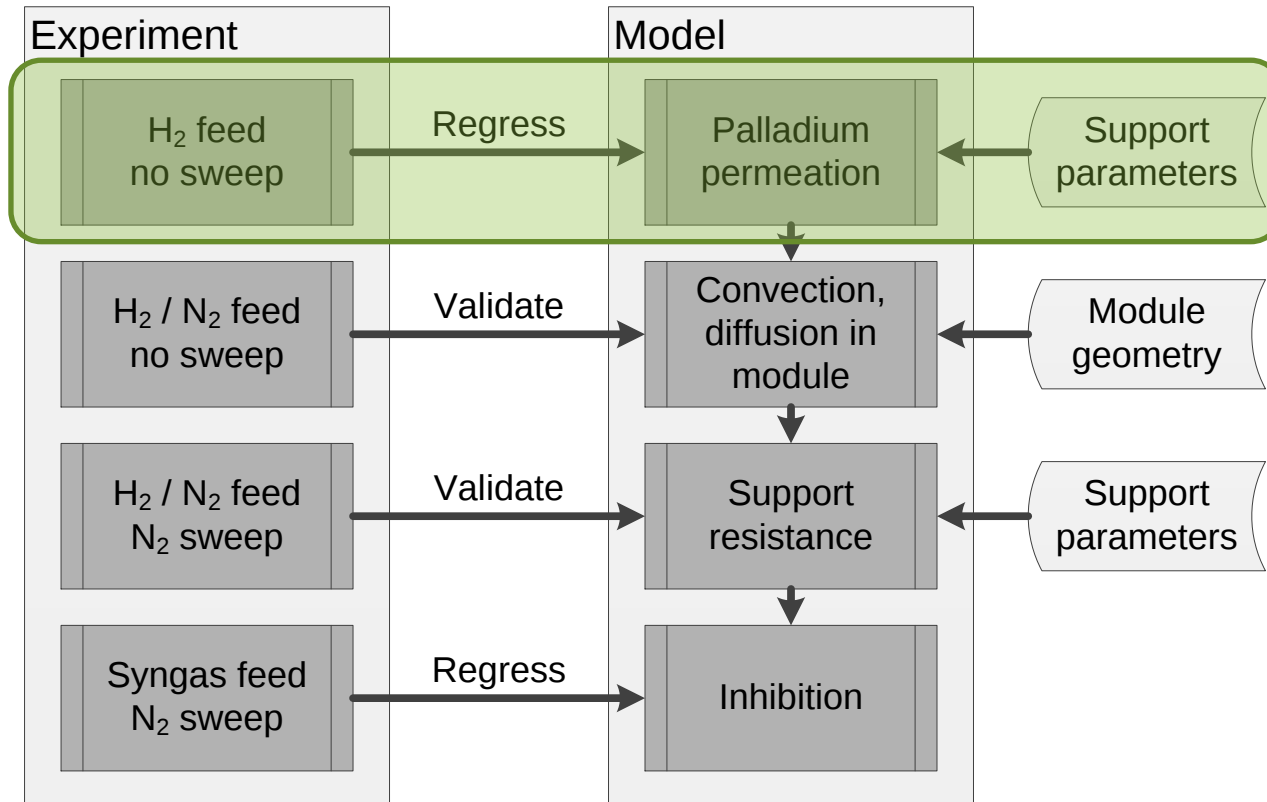
Experimental results

- How to compare results at different sizes, different modules?

Experimental results, Model development



Experimental results, Model development



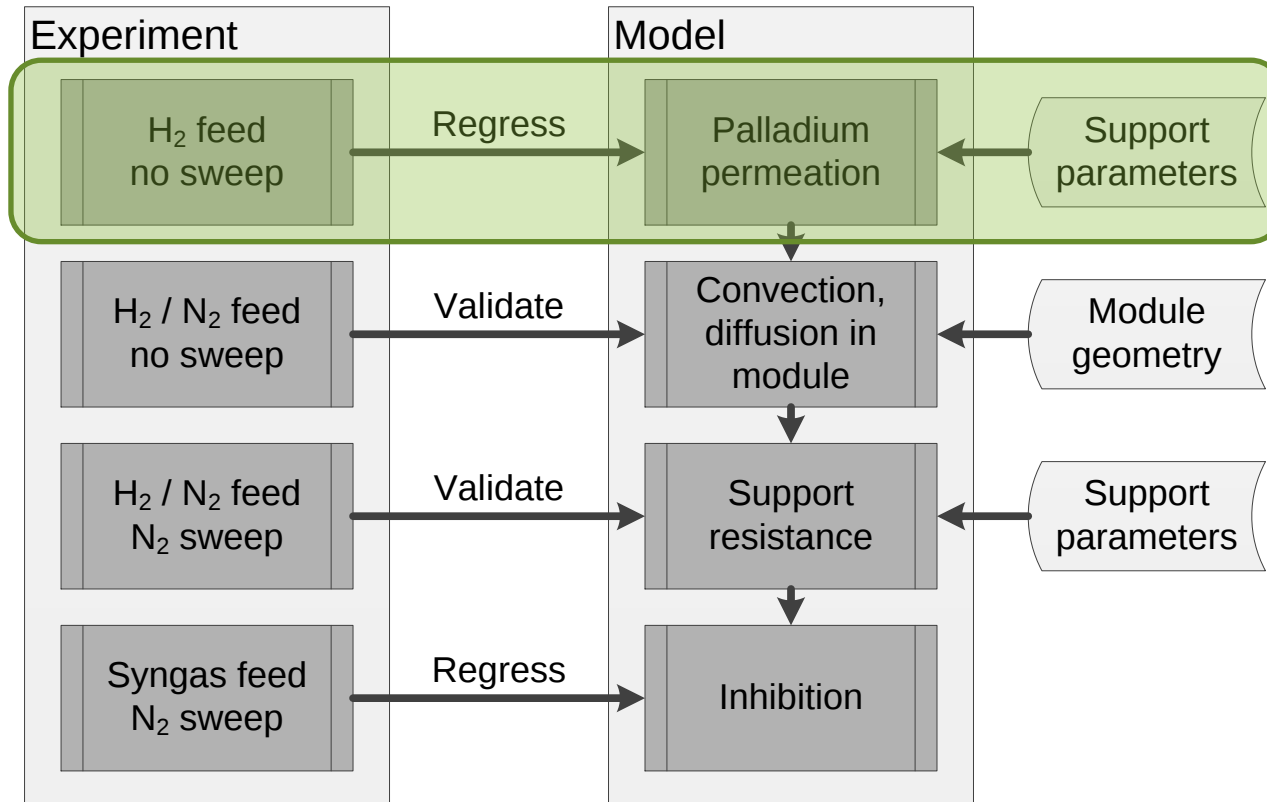
Experimental results, Model development

- Q, n in flux equation ($n = 0.6-0.7$)

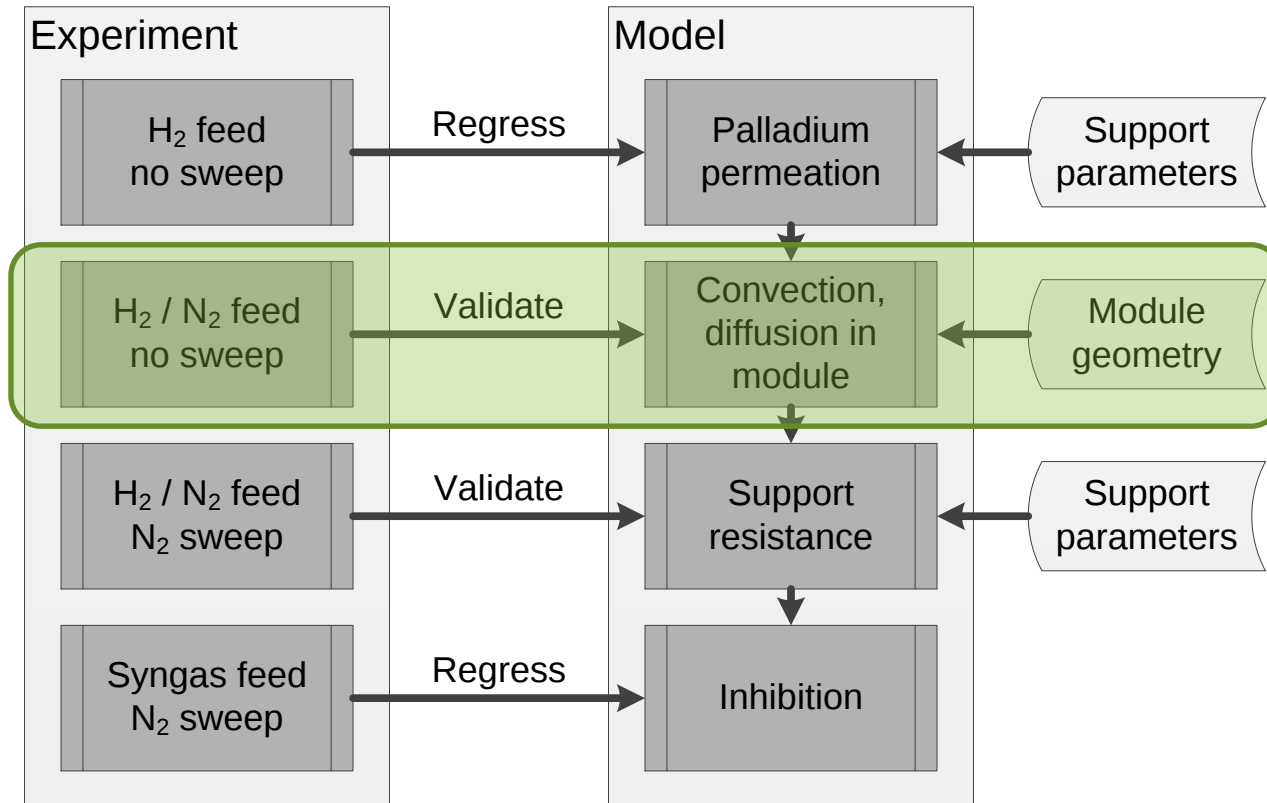
$$J = Q(T)(p_{H_2,ret}^n - p_{H_2,perm}^n)$$

- Pressure drop in membrane support negligible

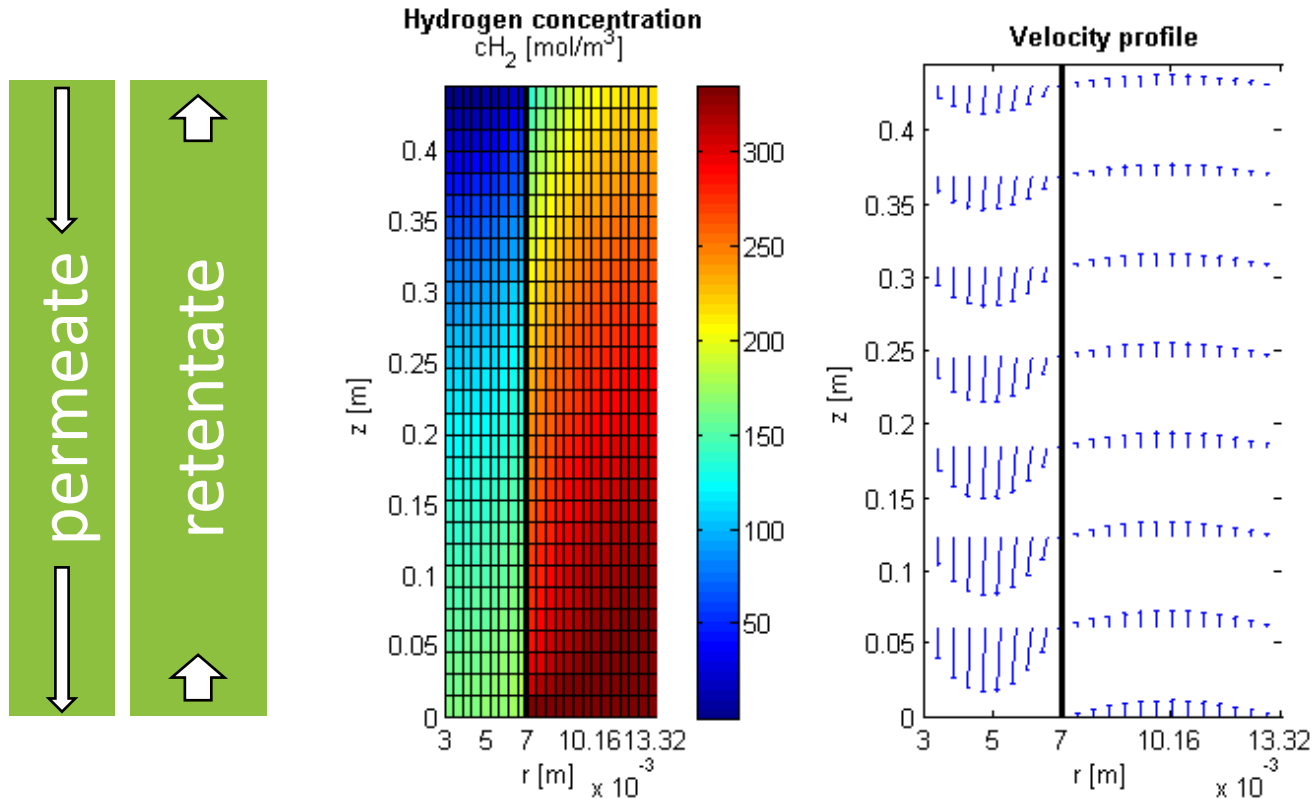
Experimental results, Model development



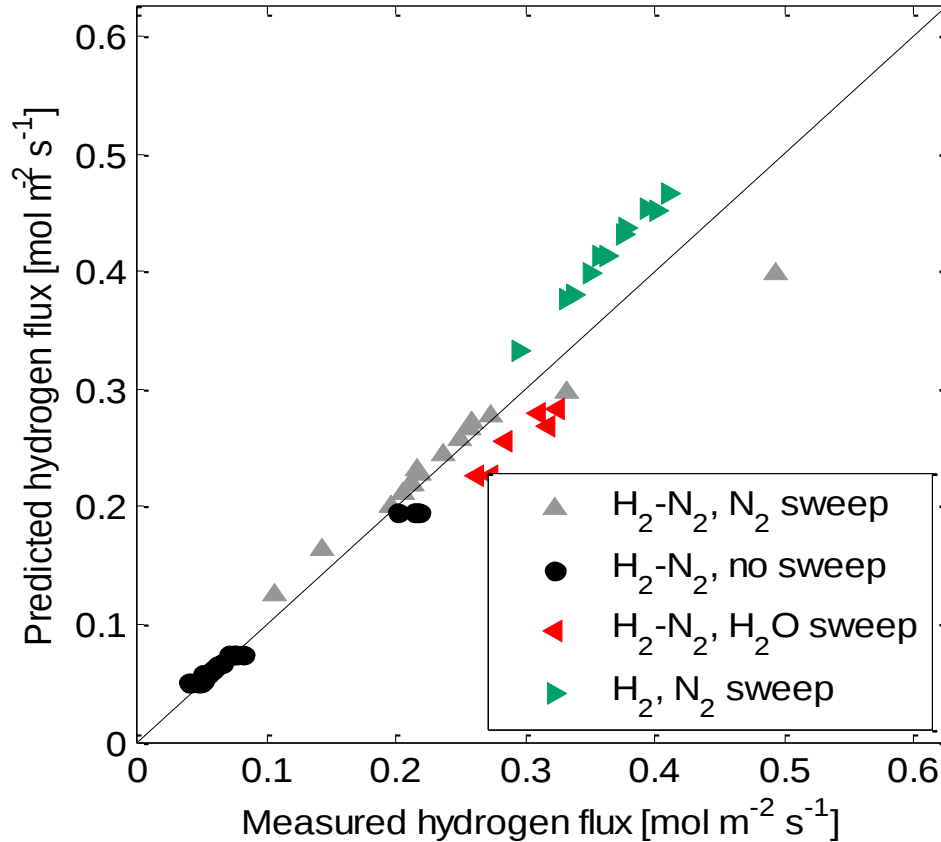
Experimental results, Model development



Experimental results, Model development



Experimental results, Model development



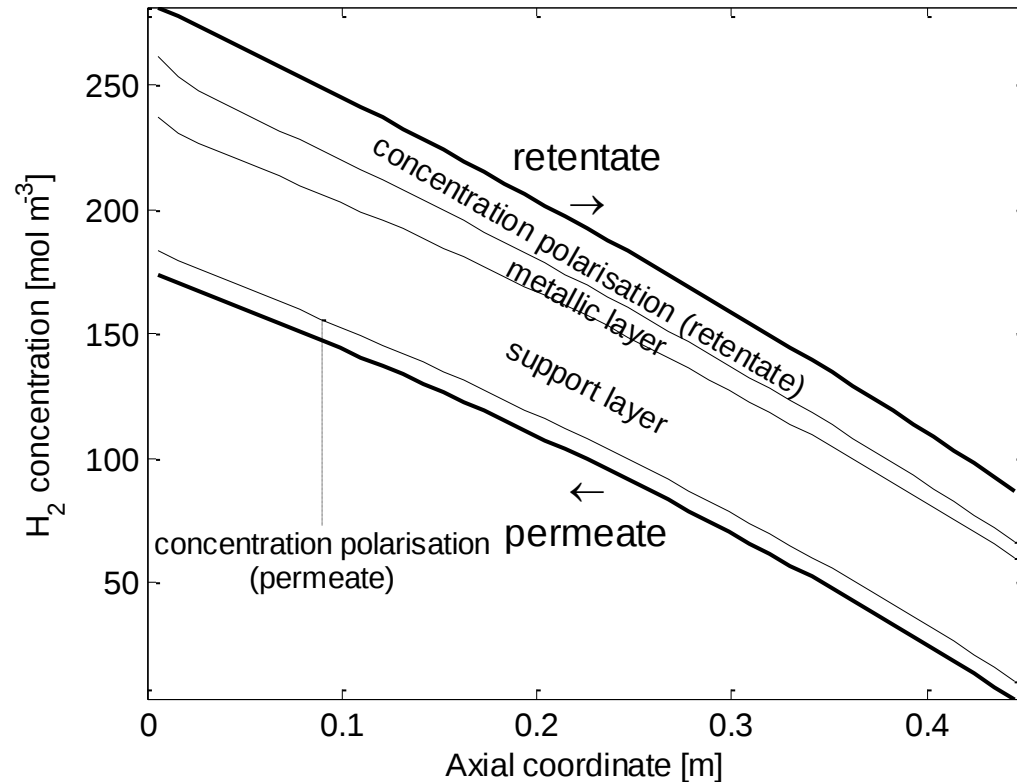
Experimental results, Model development

- Q, n in flux equation

$$J = Q(T)(p_{H_2,ret}^n - p_{H_2,perm}^n)$$

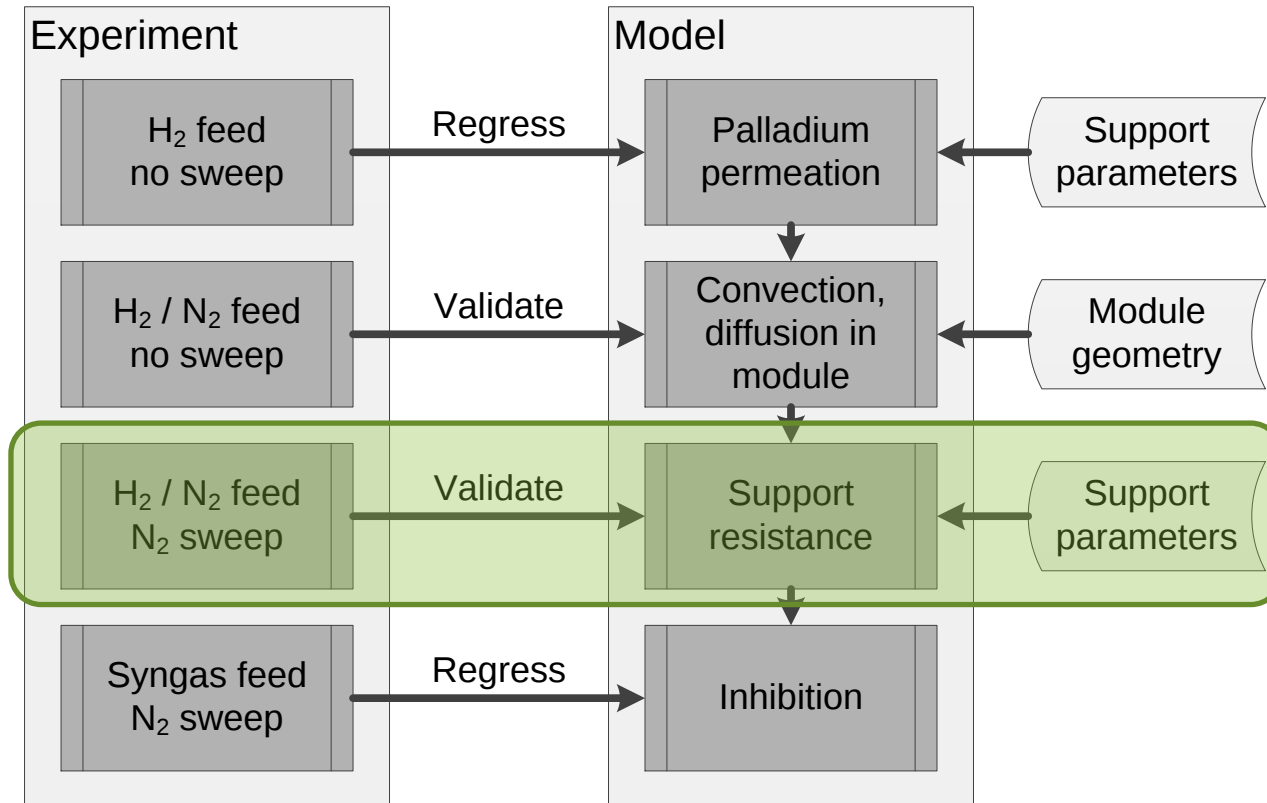
- Pressure drop in membrane support negligible
- Concentration polarisation and support resistance validated
- Diffusional resistance by inert sweep significant

Experimental results, Model development



H₂ - inert

Experimental results, Model development



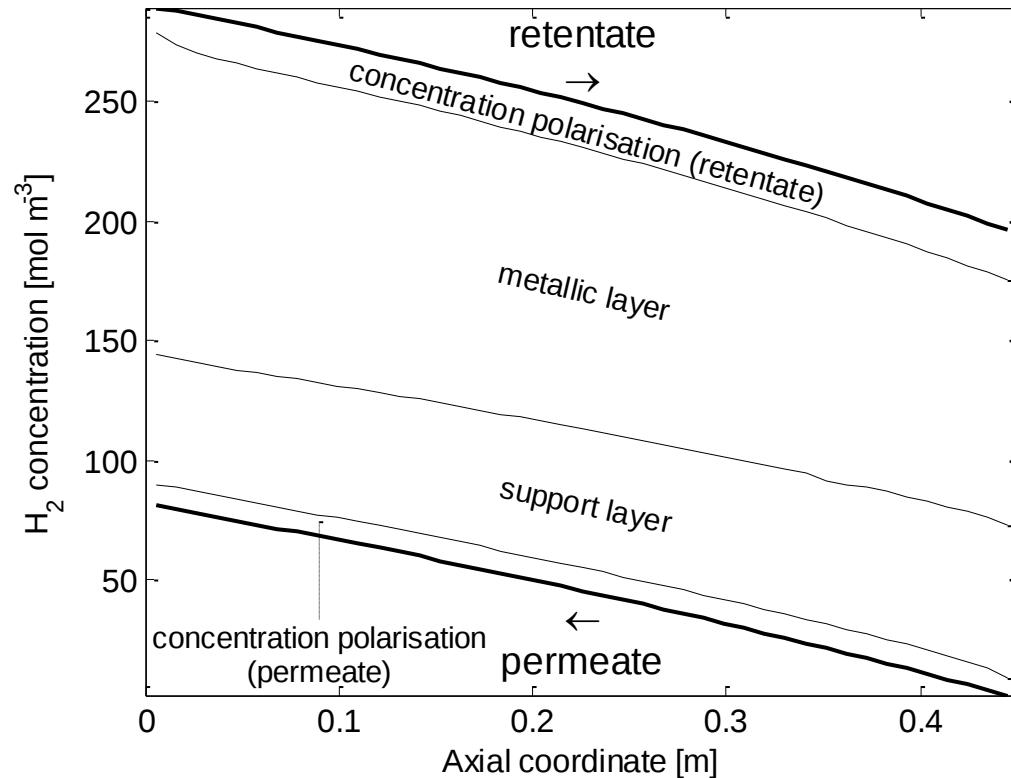
Experimental results, Model development

- Q, n in flux equation

$$J = Q(T)(p_{H_2,ret}^n - p_{H_2,perm}^n)$$

- Pressure drop in membrane support negligible
- Concentration polarisation and support resistance validated
- Diffusional resistance by inert sweep significant
- Inhibition:
Permeance reduction by 20-90%, depending on membrane, conditions

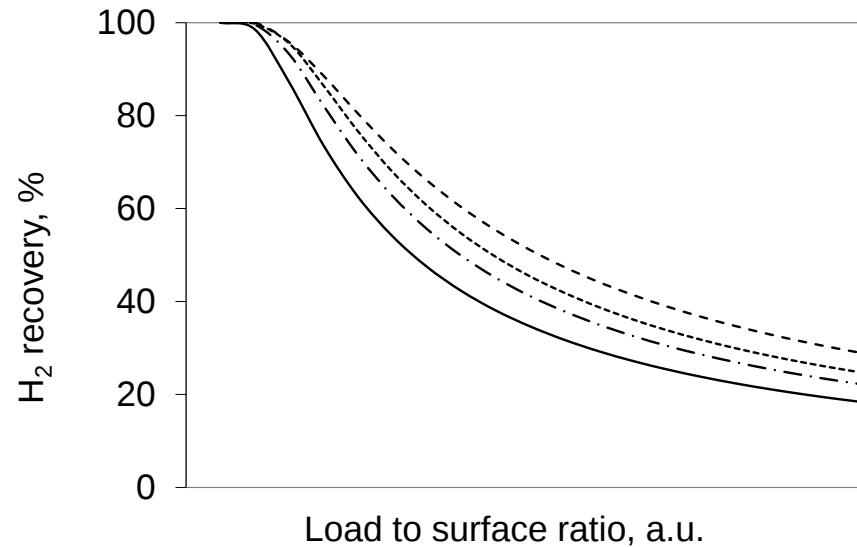
Experimental results, Model development



H_2 - reformate

Model-based comparison

- Comparing intrinsic membrane performance
 - Model without concentration polarisation ignores module effect, allows for comparing intrinsic performance



Benchmarking of H₂ selective membranes

- Pd-based membranes maturing, commercial vendors
- Successful experimental programme
 - Comprising tests in reformat, up to 1500 hours on stream
- Model developed to derive intrinsic membrane performance
 - Significant diffusional resistance in membrane support, when using sweep
 - Metallic layer important resistance, especially with inhibition
- Model allows for comparison of membrane performance without module effect

Thank you for your attention

Acknowledgements

Hans van Wees, Hui Li (ECN)

Peter Veenstra, Arian Nijmeijer (Shell Global Solutions)

This research has been carried out in the context of the CATO-2-program. CATO-2 is the Dutch national research program on CO₂ Capture and Storage technology (CCS). The program is financially supported by the Dutch government (Ministry of Economic Affairs) and the CATO-2 consortium parties.

ECN

Westerduinweg 3
1755 LE Petten
The Netherlands

P.O. Box 1
1755 ZG Petten
The Netherlands

T +31 88 515 49 49
F +31 88 515 44 80

info@ecn.nl
www.ecn.nl



ECN

Westerduinweg 3
1755 LE Petten
The Netherlands

P.O. Box 1
1755 LG Petten
The Netherlands

T +31 88 515 4949
F +31 88 515 8338
info@ecn.nl
www.ecn.nl

